

# 90-летие Валериана Григорьевича Шевченко

## АМС: ПЕРВЫЕ РЕЗУЛЬТАТЫ

Научный семинар НИИЯФ МГУ  
14 июня 2013 года

**ПАМЯТИ ВАЛЕРИАНА ГРИГОРЬЕВИЧА ШЕВЧЕНКО**

**ВКЛАД В.Г. ШЕВЧЕНКО В РАЗВИТИЕ НАШЕЙ  
НАУКИ ПЕРЕОЦЕНИТЬ НЕЛЬЗЯ:**

**ОН ОДНИМ ИЗ ПЕРВЫХ ПОНЯЛ, ЧТО  
СОВРЕМЕННЫЙ ПУТЬ РАЗВИТИЯ  
ЭКСПЕРИМЕНТАЛЬНОЙ ФИЗИКИ ВЫСОКИХ  
ЭНЕРГИЙ В РОССИИ ПРОХОДИТ ЧЕРЕЗ  
СОТРУДНИЧЕСТВО, МЕЖДУНАРОДНОЕ  
СОТРУДНИЧЕСТВО.**

**ОРГАНИЗАЦИИ СОТРУДНИЧЕСТВА ОН И  
ПОСВЯТИЛ СВОЮ ЖИЗНЬ.**

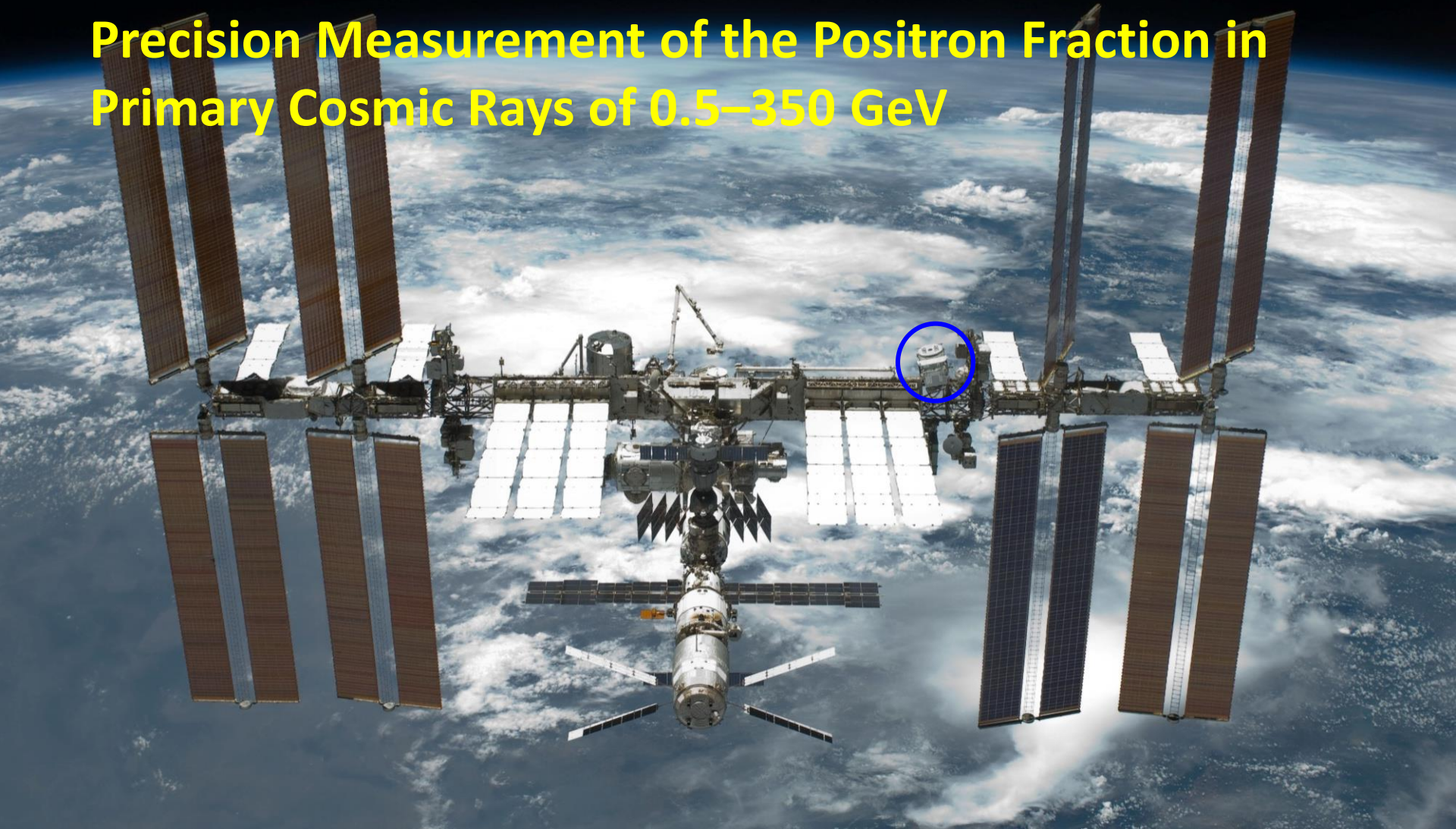
Это не было простым делом: я был рядом с ним и видел сколько нервов стоила эта деятельность, палки в колеса ставили отовсюду. То неожиданно активизировались два полковника КГБ из выездных комиссий, и стоило большого труда не дать этим людям развалить работающие группы физиков, заменяя толковых и самостоятельных на бездарных но послушных, то возникали инструкторы из отдела науки ЦК, ничего не понимающие в науке, но желающие влиять на подбор научных кадров. Огромного напряжения сил Валериана Григорьевича потребовало, например, изготовление и вывоз за границу 300 тонн урановых пластин для адронного калориметра ЛЗ, против были все, и только вмешательство министра Славского позволило решить проблему. Эти примеры можно умножать и умножать. Против были даже некоторые физики, влиятельные физики, которые считали, что сотрудничество ничего нашей науке не дает, что мы должны работать вне мировой науки, в изоляции и т.д. и т.п. Все это приходилось преодолевать Валериану Григорьевичу, **как? ценой своего здоровья.**

Результаты, однако, превзошли ожидания: в конце шестидесятых, когда В.Г.Шевченко пришел в ИТЭФ, только наши теоретики были на мировом уровне, когда через два десятилетия он уходил, мы, экспериментаторы, **получили признание везде, где В.Г. Шевченко был во главе организации сотрудничества: и в ЦЕРНе, и в Дези, и в США. Мы стали неотъемлемой частью мировой науки. В этом главная заслуга В.Г.Шевченко. Он не зря прожил свою жизнь**

РАБОТА , О КОТОРОЙ Я СЕЙЧАС БУДУ РАССКАЗЫВАТЬ, ЯВЛЯЕТСЯ ПРЯМЫМ РЕЗУЛЬТАТОМ ДЕЯТЕЛЬНОСТИ ВАЛЕРИАНА ГРИГОРЬЕВИЧА, ХОТЯ И ВЫПОЛНЕНА ПОСЛЕ ЕГО УХОДА.



**First Result from the Alpha Magnetic Spectrometer  
on the International Space Station:  
Precision Measurement of the Positron Fraction in  
Primary Cosmic Rays of 0.5–350 GeV**





# The Alpha Magnetic Spectrometer Experiment on the International Space Station



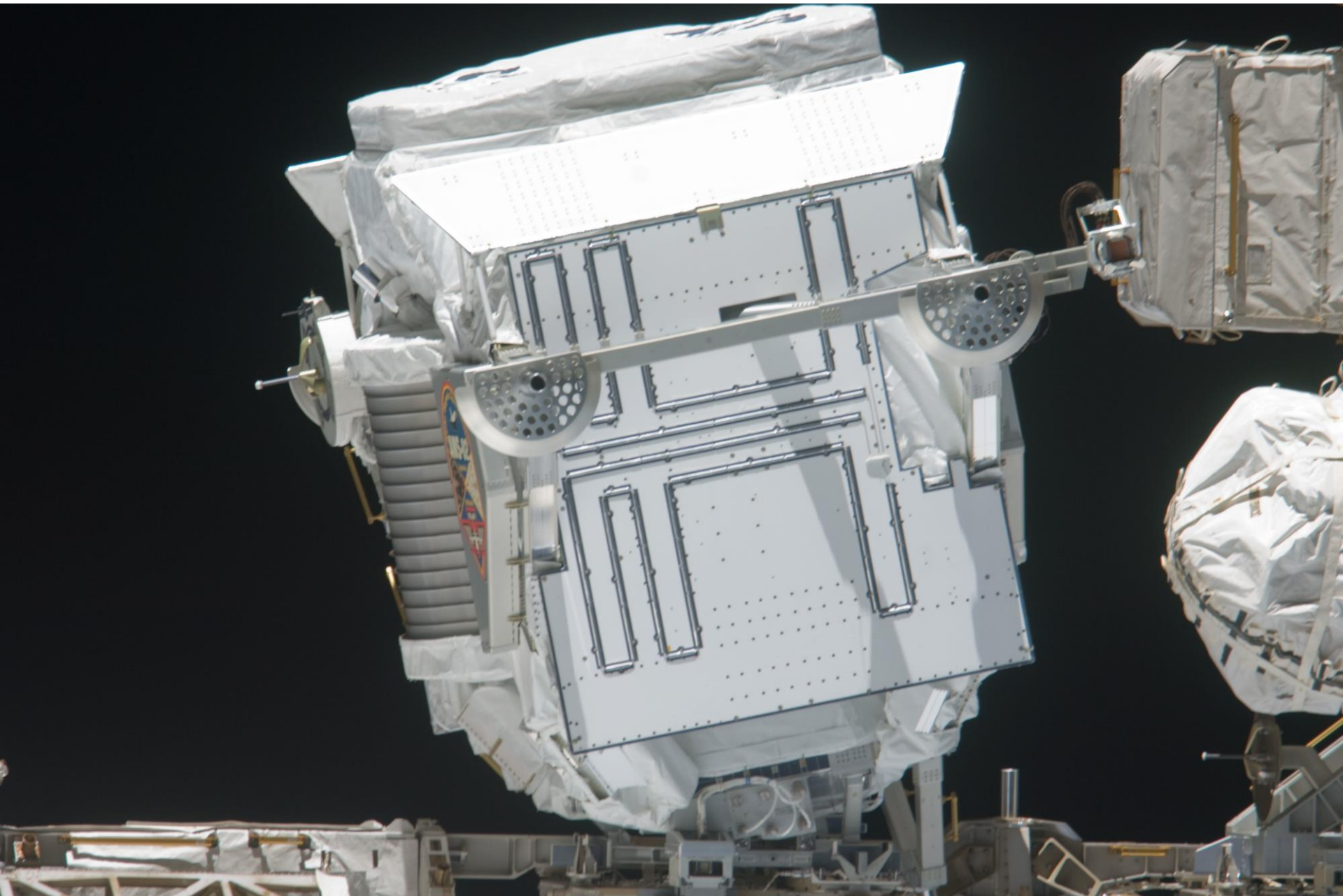
S. Ting



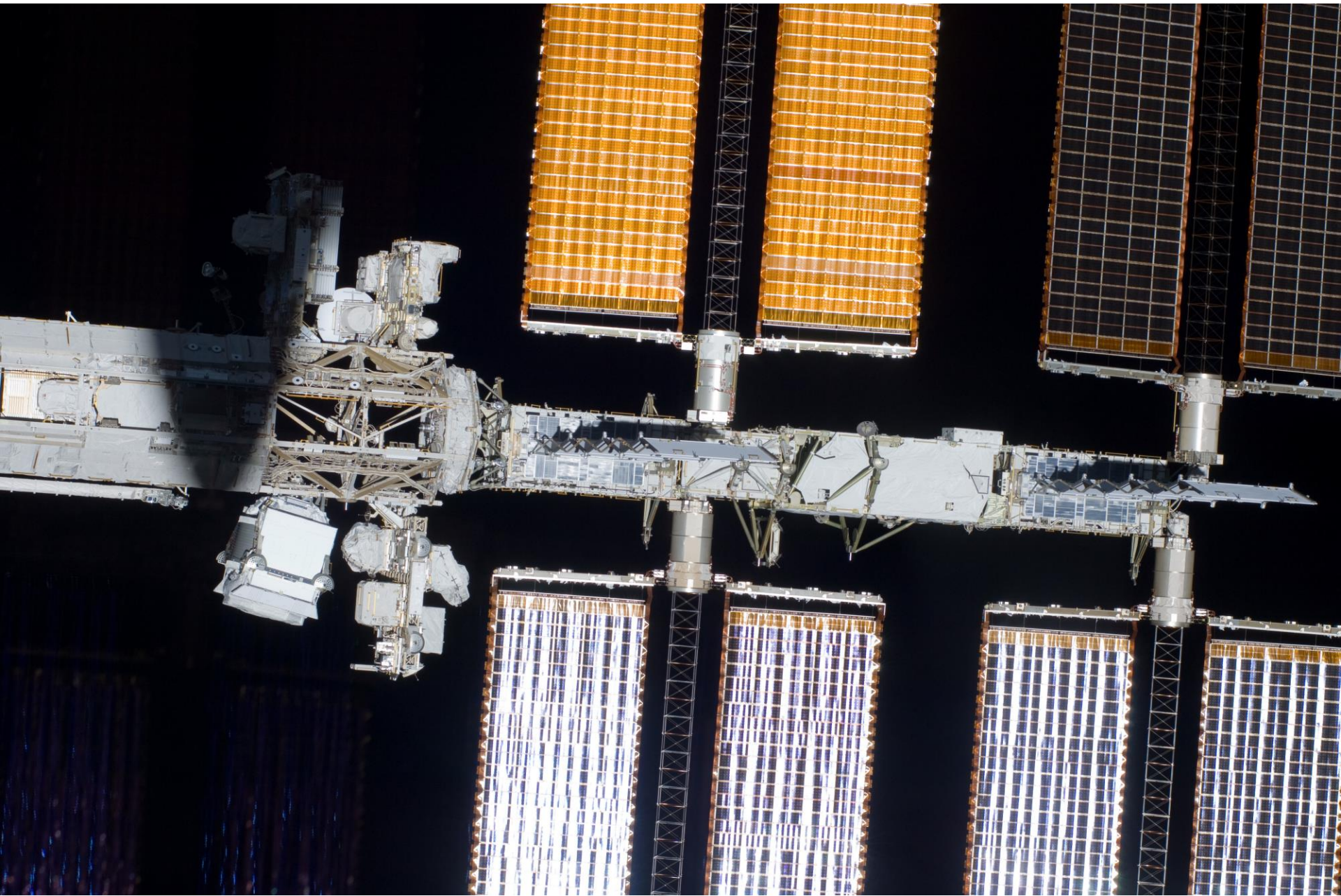
# AMS On-Orbit

Photo - June 29,  
2012 (ISS)



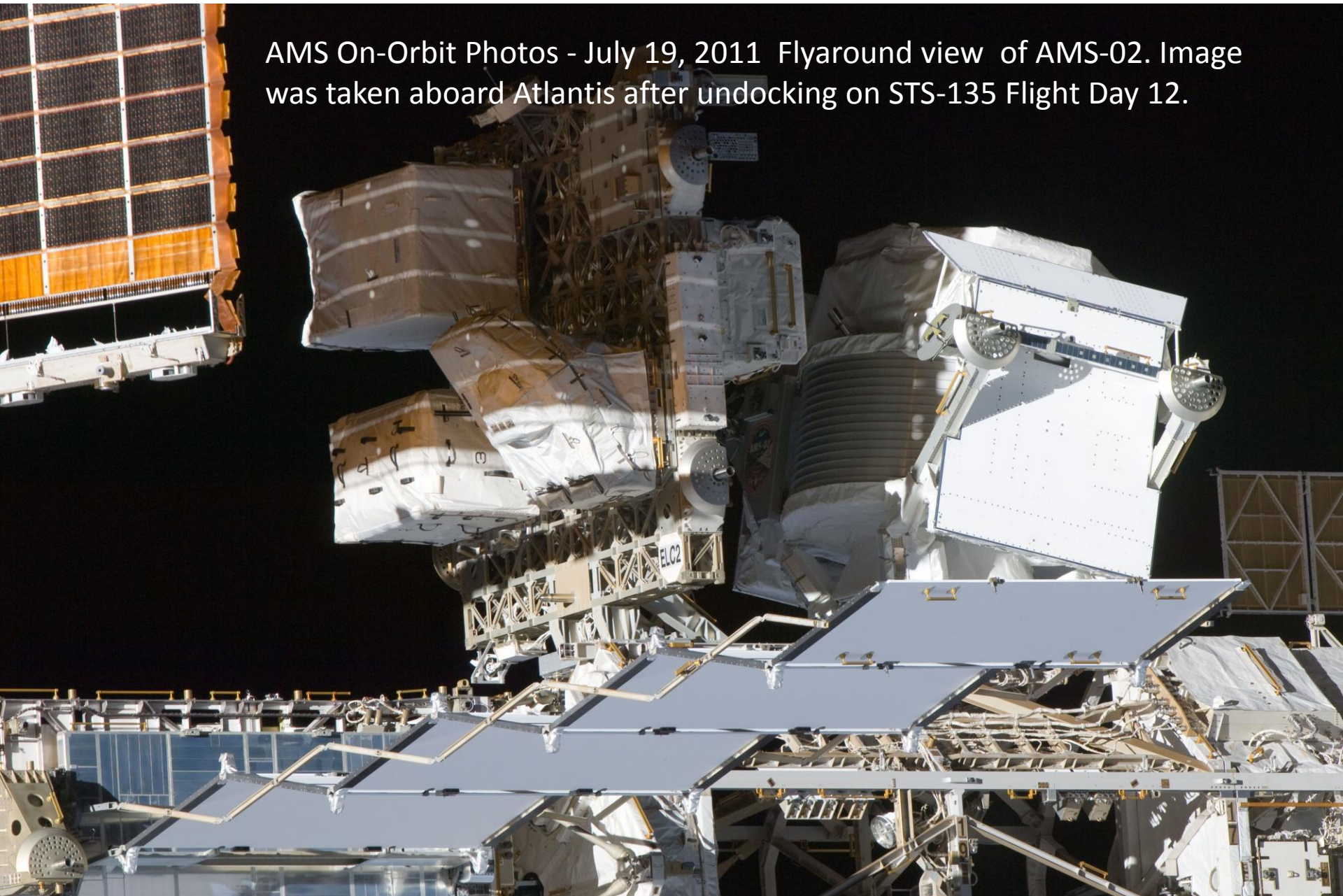








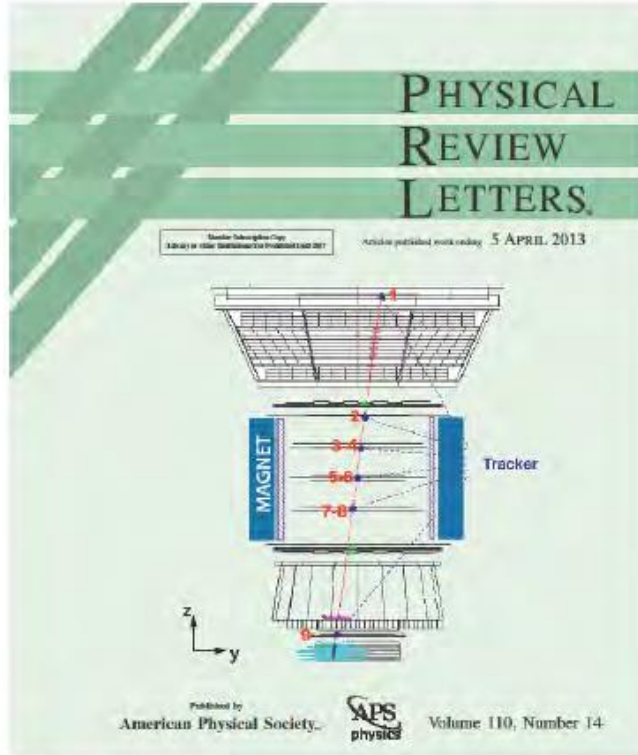
AMS On-Orbit Photos - July 19, 2011 Flyaround view of AMS-02. Image was taken aboard Atlantis after undocking on STS-135 Flight Day 12.







# .....to the cover of PRL



PRL 110, 141102 (2013)

## First Result from the Alpha Magnetic Spectrometer on the International Space Station: Precision Measurement of the Positron Fraction in Primary Cosmic Rays of 0.5–350 GeV

M. Aguilar,<sup>1,2,3,4</sup> G. Alberti,<sup>4,5,6</sup> B. Alpat,<sup>4,7</sup> A. Alvino,<sup>4,8,9</sup> G. Ambrosi,<sup>4,10</sup> K. Andeen,<sup>2,8</sup> H. Anderhub,<sup>2,8</sup> L. Arrada,<sup>11</sup> P. Azzarello,<sup>12,13,14</sup> A. Badierne,<sup>15</sup> F. Barao,<sup>16</sup> B. Baret,<sup>17</sup> A. Barrau,<sup>18</sup> L. Barua,<sup>19</sup> A. Barstow,<sup>20</sup> L. Basso,<sup>21</sup> A. Bash,<sup>22</sup> L. Batalha,<sup>23</sup> J. Basco,<sup>24</sup> R. Battistoni,<sup>25,26,27</sup> J. Baur,<sup>28</sup> K. Becker,<sup>29</sup> U. Beckler,<sup>30</sup> M. Behlmann,<sup>31</sup> B. Betsworth,<sup>32</sup> J. Berlingo,<sup>33</sup> P. Berge,<sup>34</sup> B. Bertucci,<sup>35,36</sup> G. Bigongiari,<sup>37,38</sup> A. Biland,<sup>39</sup> V. Bindi,<sup>40</sup> S. Bizzaglia,<sup>41</sup> G. Boella,<sup>42,43</sup> W. de Boer,<sup>44</sup> K. Bollweg,<sup>45</sup> J. Bolton,<sup>46</sup> B. Borja,<sup>47,48</sup> S. Borsini,<sup>49,50</sup> M. J. Boschim,<sup>51</sup> G. Boucsein,<sup>52</sup> M. Bougaja,<sup>53</sup> P. Brun,<sup>54</sup> M. Buehler,<sup>55</sup> J. Burger,<sup>56</sup> W. Burger,<sup>57</sup> F. Cadoux,<sup>58,59</sup> X. D. Cai,<sup>60</sup> M. Capell,<sup>61</sup> D. Casadei,<sup>62,63</sup> J. Casas,<sup>64</sup> V. Cavaliere,<sup>65</sup> G. Castellani,<sup>66</sup> I. Ceradini,<sup>67</sup> F. Cervelli,<sup>68</sup> M. J. Chae,<sup>69</sup> Y. H. Chang,<sup>70</sup> A. L. Chen,<sup>71</sup> C. R. Chen,<sup>72</sup> H. Chen,<sup>73</sup> G. M. Cheng,<sup>74</sup> H. S. Chen,<sup>75</sup> L. Cheng,<sup>76</sup> N. Chernysheva,<sup>77</sup> A. Chikuzhi,<sup>78</sup> E. Chiumo,<sup>79,80</sup> A. V. Chuvpik,<sup>81</sup> C. H. Chung,<sup>82</sup> C. Ciad<sup>83</sup>, R. Clouven,<sup>84</sup> G. Colgate,<sup>85</sup> Y. Comandari,<sup>86</sup> A. Cossani,<sup>87,88</sup> A. Cumini,<sup>89</sup> C. Corti,<sup>90</sup> M. T. Covault,<sup>91</sup> D. S. Cox,<sup>92</sup> D. Crepeau,<sup>93</sup> Z. Cui,<sup>94</sup> M. Dai,<sup>95</sup> C. Dalgado,<sup>96</sup> S. Della Torre,<sup>97,98</sup> B. Demortier,<sup>99</sup> P. Denton,<sup>100</sup> L. Descombes,<sup>101</sup> S. Di Falco,<sup>102</sup> X. H. Dia,<sup>103</sup> A. Diago,<sup>104</sup> L. Djambazov,<sup>105</sup> C. Diaz,<sup>106</sup> P. von Doetinchem,<sup>107</sup> W. J. Du,<sup>108</sup> J. M. Dubois,<sup>109</sup> R. Duperez,<sup>110</sup> M. Durani,<sup>111,112</sup> D. D'Urso,<sup>113</sup> A. Eggen,<sup>114</sup> A. Elme,<sup>115</sup> J. J. Epling,<sup>116</sup> T. Ennera,<sup>117</sup> J. van Eic,<sup>118</sup> H. Erzer,<sup>119</sup> A. Falvard,<sup>120</sup> E. Fiorini,<sup>121</sup> A. Flacco,<sup>122</sup> E. Finch,<sup>123</sup> P. Fisher,<sup>124</sup> K. Flood,<sup>125</sup> R. Fugita,<sup>126</sup> M. E. Fulton,<sup>127</sup> S. Foppa,<sup>128</sup> N. Fouquet,<sup>129</sup> Y. Galaktionov,<sup>130</sup> M. Galkice,<sup>131</sup> L. Gallio-Manet,<sup>132</sup> G. Gallucci,<sup>133</sup> B. Garcia,<sup>134</sup> J. Garcia,<sup>135</sup> R. Garcia-Lopez,<sup>136</sup> L. Garcia-Talavera,<sup>137</sup> C. Garrido,<sup>138,139</sup> H. Gao,<sup>140</sup> I. Gebauer,<sup>141</sup> S. Gentile,<sup>142,143</sup> M. Gerres,<sup>144</sup> W. Gilman,<sup>145</sup> F. Giacomini,<sup>146</sup> J. Girard,<sup>147</sup> P. Giron,<sup>148</sup> J. Gong,<sup>149</sup> C. Goy-Henningsen,<sup>150</sup> D. Grand,<sup>151</sup> M. Graziani,<sup>152</sup> A. Greife,<sup>153</sup> A. Gross,<sup>154</sup> I. Guenther,<sup>155</sup> C. de la Guina,<sup>156</sup> K. H. Guo,<sup>157</sup> M. Habib,<sup>158</sup> S. Hahn,<sup>159</sup> E. Haisler,<sup>160</sup> Z. H. He,<sup>161</sup> M. Heit,<sup>162</sup> J. Heilig,<sup>163</sup> R. Hernand,<sup>164</sup> H. Hofer,<sup>165</sup> Z. C. Huang,<sup>166</sup> W. Hurgert,<sup>167,168</sup> M. Hugi,<sup>169,170</sup> M. Iacono,<sup>171</sup> A. Jacholkowska,<sup>172</sup> W. Y. Jang,<sup>173</sup> H. Jirchi,<sup>174</sup> M. Jorgensen,<sup>175</sup> L. Jorjnetz,<sup>176</sup> L. Jorgensen,<sup>177</sup> W. Karpinski,<sup>178</sup> G. N. Kim,<sup>179</sup> K. S. Kim,<sup>180</sup> Th. Kim,<sup>181</sup> R. Kosloski,<sup>182</sup> A. Kozlowski,<sup>183</sup> D. Korinna,<sup>184</sup> A. Kozmin,<sup>185</sup> V. Kostin,<sup>186</sup> M. S. Krafczyk,<sup>187</sup> E. Laati,<sup>188,189</sup> G. Laurent,<sup>190</sup> C. Lauritzen,<sup>191</sup> A. Lebedev,<sup>192</sup> M. W. Lee,<sup>193</sup> S. C. Lee,<sup>194</sup> C. Leifert,<sup>195</sup> H. Leon Vargas,<sup>196</sup> V. Lepore,<sup>197</sup> J. Q. Li,<sup>198</sup> Q. Li,<sup>199</sup> T. X. Li,<sup>200</sup> W. Li,<sup>201</sup> Z. H. Li,<sup>202</sup> P. Ligon,<sup>203</sup> C. H. Lin,<sup>204</sup> D. Liu,<sup>205</sup> H. Liu,<sup>206</sup> T. Lomtadze,<sup>207</sup> Y. S. Lu,<sup>208</sup> S. Lushchik,<sup>209</sup> K. L. Lohmeyer,<sup>210</sup> J. Z. Luo,<sup>211</sup> W. Lustermann,<sup>212</sup> S. Lv,<sup>213</sup> J. Maier,<sup>214</sup> R. Majka,<sup>215</sup> A. Malinin,<sup>216</sup> C. Manti,<sup>217</sup> J. Marin,<sup>218</sup> T. Martin,<sup>219</sup> G. Martinez,<sup>220</sup> F. Masuocchi,<sup>221</sup> N. Masi,<sup>222</sup> D. Maurin,<sup>223</sup> A. McInerney,<sup>224</sup> P. McInerney,<sup>225</sup> A. Menchaca-Rocha,<sup>226</sup> Q. Meng,<sup>227</sup> M. Messichelli,<sup>228</sup> J. Merou,<sup>229</sup> M. Millinger,<sup>230</sup> D. C. Mo,<sup>231</sup> M. Molina,<sup>232</sup> P. Mor,<sup>233</sup> A. Mujumdar,<sup>234</sup> S. Nandori,<sup>235</sup> P. Nemech,<sup>236</sup> J. Q. Ni,<sup>237</sup> N. Nikolic,<sup>238</sup> E. Nozaki,<sup>239</sup> P. Nunes,<sup>240</sup> A. Obermaier,<sup>241</sup> S. Oh,<sup>242</sup> A. Olive,<sup>243,244</sup> F. Palmonari,<sup>245</sup> C. Palomares,<sup>246</sup> M. Paticcia,<sup>247</sup> A. Papi,<sup>248</sup> W. H. Park,<sup>249</sup> M. Pauluzzi,<sup>250,251</sup> F. Pauss,<sup>252</sup> A. Pavni,<sup>253</sup> E. Pedreschi,<sup>254</sup> S. Perrotti,<sup>255,256</sup> R. Perreia,<sup>257</sup> E. Perini,<sup>258</sup> G. Pevsna,<sup>259</sup> G. Pirelli,<sup>260</sup> F. Pilo,<sup>261</sup> A. Pilo,<sup>262,263</sup> C. Pizzoferrato,<sup>264</sup> V. Plyuskin,<sup>265</sup> J. Pochon,<sup>266</sup> M. Pohl,<sup>267</sup> W. Poireau,<sup>268</sup> S. Preter,<sup>269</sup> J. Prune,<sup>270</sup> A. Pyras,<sup>271</sup> L. Quadran,<sup>272</sup> X. N. Qe,<sup>273</sup> P. G. Ramonou,<sup>274</sup> D. Rapan,<sup>275</sup> Z. L. Han,<sup>276</sup> J. S. Rico,<sup>277</sup> E. Ribonon,<sup>278</sup> I. Rodriguez,<sup>279</sup> U. Roeder,<sup>280</sup> S. Rosier-Lees,<sup>281</sup> L. Rossi,<sup>282,283</sup> D. Rozza,<sup>284</sup> A. Sabella,<sup>285</sup> R. Sagdeev,<sup>286</sup> J. Sandweiss,<sup>287</sup> B. Santos,<sup>288</sup> P. Sauerer,<sup>289</sup> M. Sarchioni,<sup>290</sup> S. Schael,<sup>291</sup> D. Scherdel,<sup>292</sup> M. Schwaner,<sup>293</sup> G. Schwaner,<sup>294</sup> A. Schulz von Dratzig,<sup>295</sup> G. Scuderi,<sup>296</sup> E. S. Seo,<sup>297</sup> B. S. Shiu,<sup>298</sup> J. Y. Shi,<sup>299</sup> Y. M. Shi,<sup>300</sup> T. Siedenburg,<sup>301</sup> R. Siedling,<sup>302</sup> D. Sot,<sup>303</sup> F. Spada,<sup>304</sup> F. Spinella,<sup>305</sup> M. Steuer,<sup>306</sup> K. Stiffl,<sup>307</sup> W. Sun,<sup>308</sup> W. H. Sun,<sup>309</sup> S. H. Sun,<sup>310</sup> M. Taccioni,<sup>311</sup> C. P. Tang,<sup>312</sup> X. W. Tang,<sup>313</sup> Z. C. Tang,<sup>314</sup> L. Tao,<sup>315</sup> J. Tascion-Viel,<sup>316</sup> Samuel C. C. Tang,<sup>317</sup> S. M. Tang,<sup>318</sup> C. Tian,<sup>319</sup> N. Tsumasaka,<sup>320</sup> E. Taval,<sup>321</sup> J. Teresi,<sup>322</sup> E. R. Tziou,<sup>323</sup> J. C. Tziou,<sup>324</sup> J. Ubrich,<sup>325</sup> T. Urban,<sup>326</sup> V. Vagstad,<sup>327</sup> E. Valente,<sup>328</sup> C. Vannit,<sup>329</sup> E. Vahanian,<sup>330</sup> M. Vargas Trevino,<sup>331</sup> S. Vaynshteyn,<sup>332</sup> M. Yacobi,<sup>333</sup> M. Nagata,<sup>334</sup> B. Verlat,<sup>335</sup> C. Vescovi,<sup>336</sup> J. P. Valle,<sup>337</sup> G. Vignani,<sup>338</sup> G. Volpi,<sup>339</sup> D. Wang,<sup>340</sup> N. H. Wang,<sup>341</sup> Q. L. Wang,<sup>342</sup> R. S. Wang,<sup>343</sup> K. Wang,<sup>344</sup> Z. X. Wang,<sup>345</sup> W. Waldfahr,<sup>346</sup> Z. L. Wang,<sup>347</sup> M. Willebrord,<sup>348</sup> M. Wlochow,<sup>349</sup> H. Wu,<sup>350</sup> K. Y. Wu,<sup>351</sup> Z. S. Wu,<sup>352</sup> W. J. Xia,<sup>353</sup> S. Xie,<sup>354</sup> R. Q. Xiong,<sup>355</sup> G. M. Xin,<sup>356</sup> S. S. Xu,<sup>357</sup> W. Xu,<sup>358</sup> Q. Yan,<sup>359</sup> J. Yang,<sup>360</sup> M. Yang,<sup>361</sup> Q. H. Yi,<sup>362</sup> H. Yi,<sup>363</sup> J. Yi,<sup>364</sup> Z. Q. Yu,<sup>365</sup> S. Zou,<sup>366</sup> J. G. Zhang,<sup>367</sup> Z. Zhang,<sup>368</sup> M. M. Zhang,<sup>369</sup> Z. M. Zhang,<sup>370</sup> H. L. Zhang,<sup>371</sup> V. Zhukov,<sup>372</sup> A. Zichichi,<sup>373</sup> P. Zuccon,<sup>374</sup> and C. Zurbach.<sup>375</sup>

(AMS Collaboration)

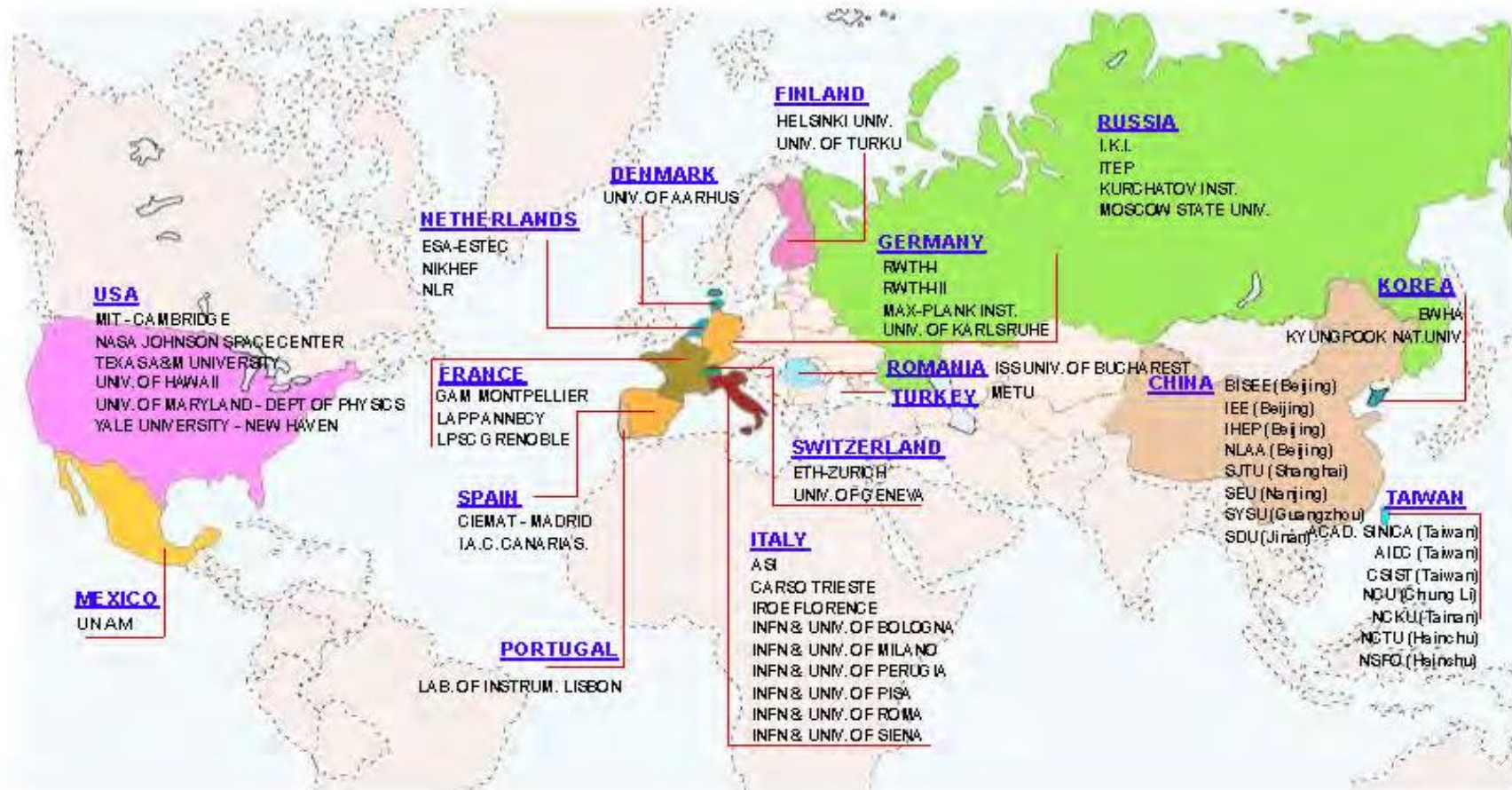


Viewpoint: Positrons Galore



# МЕЖДУНАРОДНОЕ СОТРУДНИЧЕСТВО АМС

## AMS international collaboration



# AMS: A TeV precision, multipurpose spectrometer

TRD  
Identify  $e^+$ ,  $e^-$

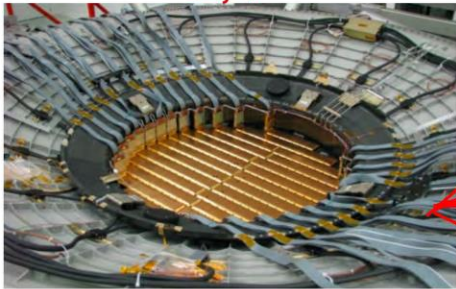


Particles and nuclei are defined by their charge ( $Z$ ) and energy ( $E \sim P$ )

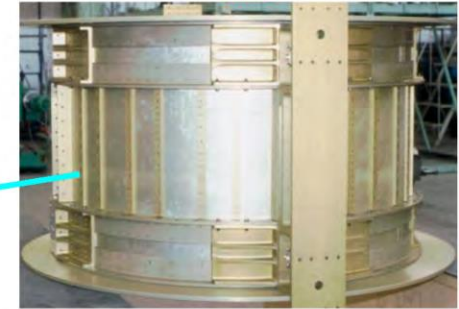
TOF  
 $Z, E$



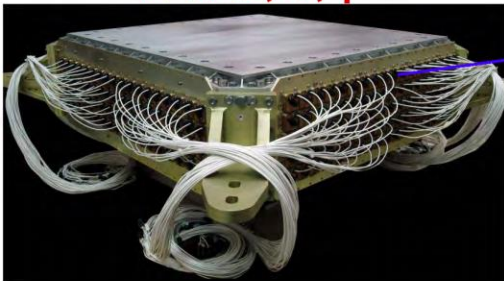
Silicon Tracker  
 $Z, P$



Magnet  
 $\pm Z$

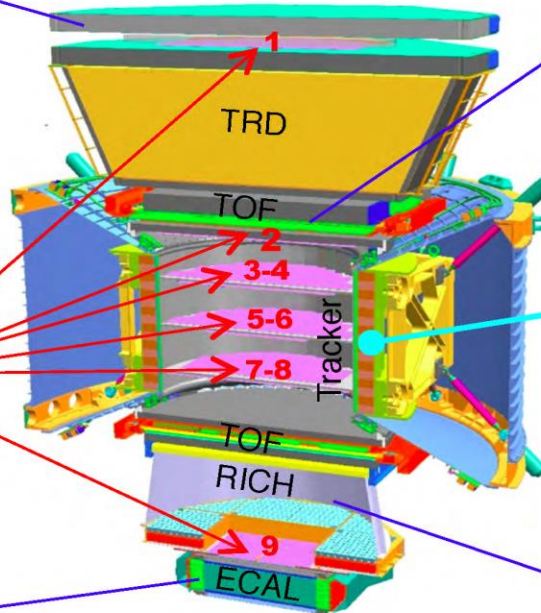


ECAL  
 $E$  of  $e^+$ ,  $e^-$ ,  $\gamma$



$Z, P$  are measured independently by the Tracker, RICH, TOF and ECAL

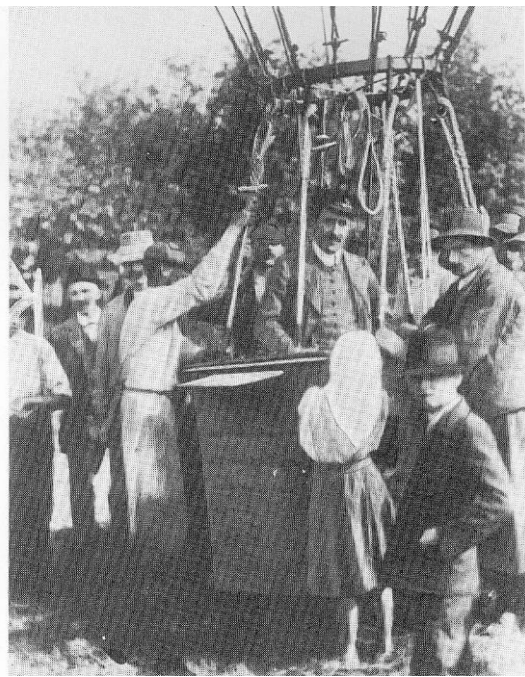
RICH  
 $Z, E$



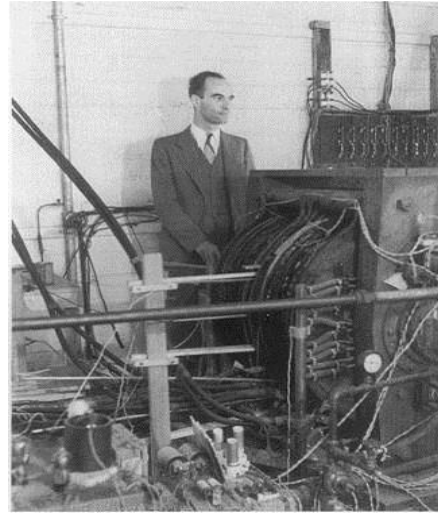


# Science of AMS

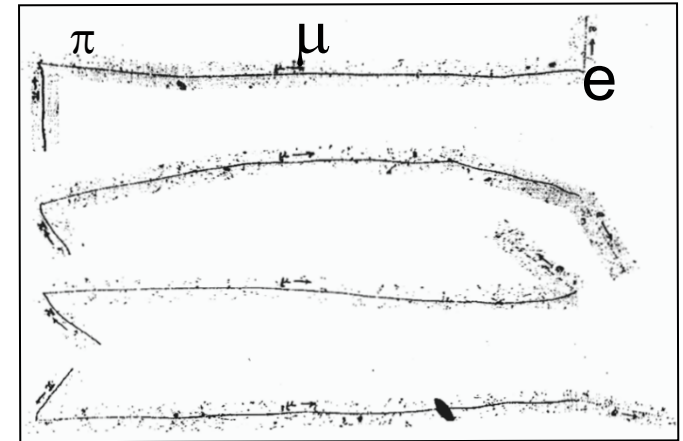
## Fundamental Discoveries from Charged Cosmic Rays



1912: Discovery of Cosmic Rays



1932: Discovery of positron



1947: Discovery of pions

### Discoveries of

1936: Muon ( $\mu$ )

1949: Kaon (K)

1949: Lambda ( $\Lambda$ )

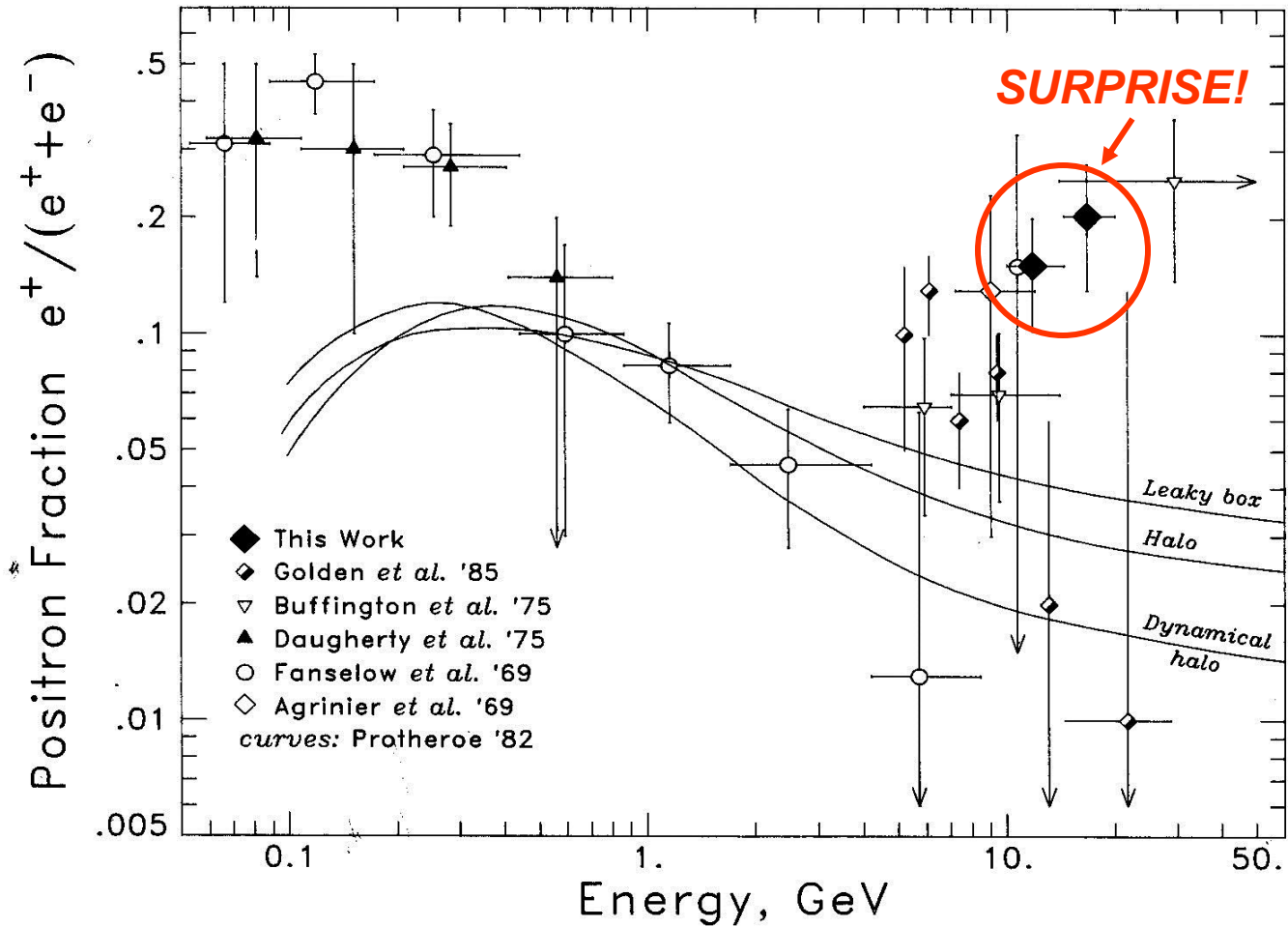
1952: Xi ( $\Xi$ )

1953: Sigma ( $\Sigma$ )



**As accelerators have become exceedingly costly, the ISS is a valuable alternative to study fundamental physics.**

# 10-20 GeV COSMIC-RAY POSITRONS



**POSITRON-FRACTION**  
Müller & Tang,  
1987

*With Earth's  
Magnetic Field  
As Charge  
Analyzer*

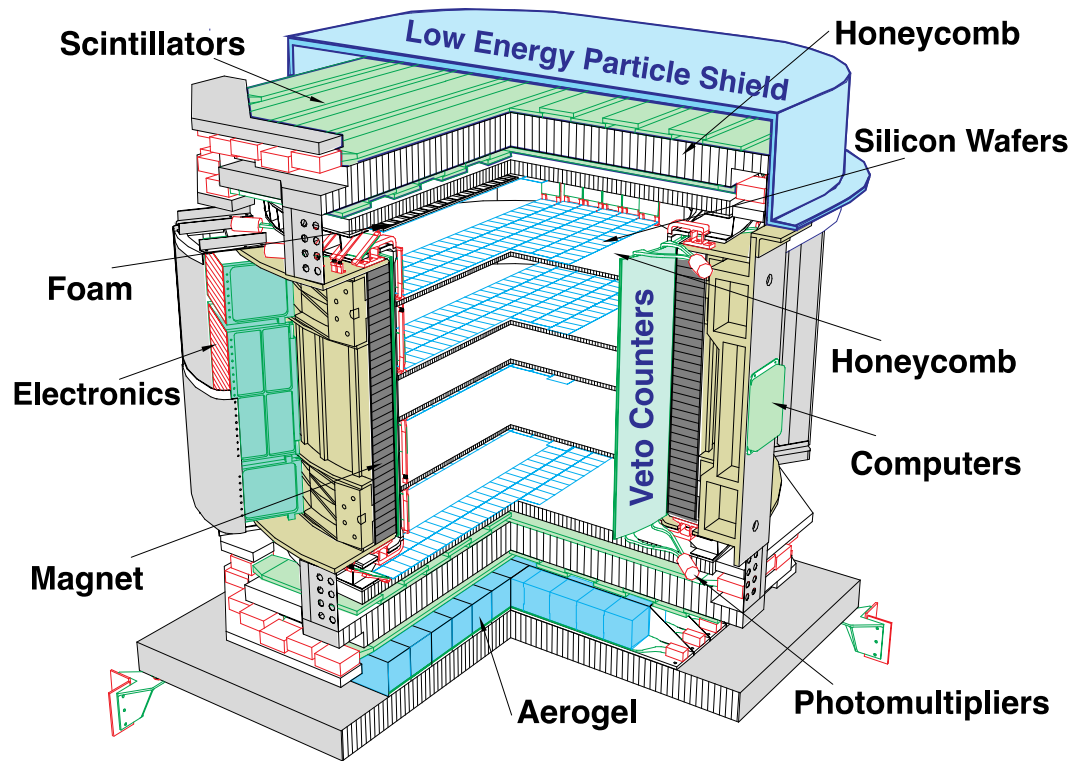


5m x 4m x 3m  
7.5 tons



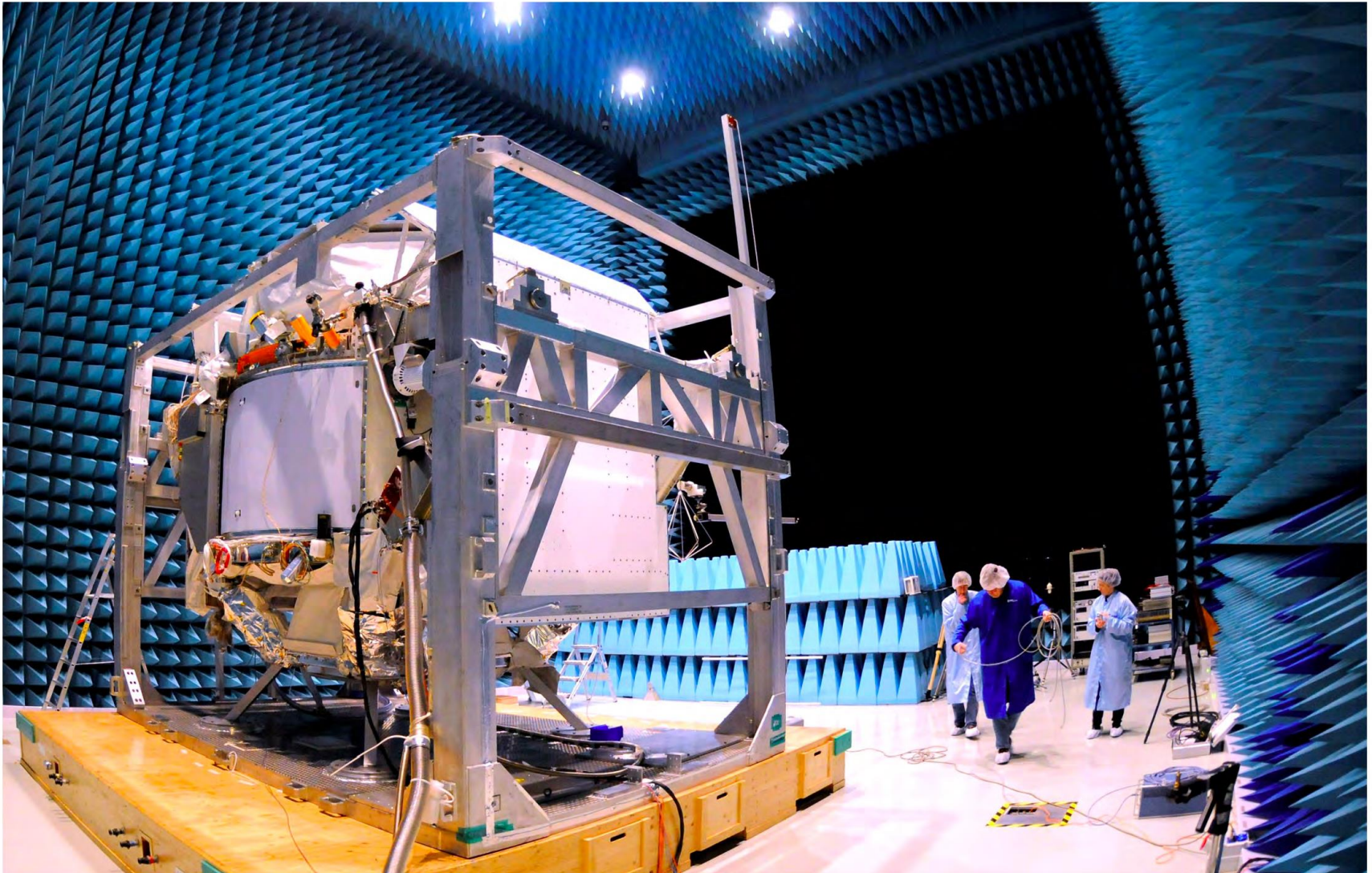
**1998 год AMS-1 :**

10ти-дневный технический полет, который показал, что , во-первых,, техника ускорительной физики высоких энергий вполне хорошо работает в условиях космического полета, и во вторых, рассеял сомнения NASA в отношении сугубо земных, не имеющих космического опыта физиков.





# AMS in the ESA Electromagnetic Interference (EMI) Chamber, March 2010, Noordwijk, the Netherlands

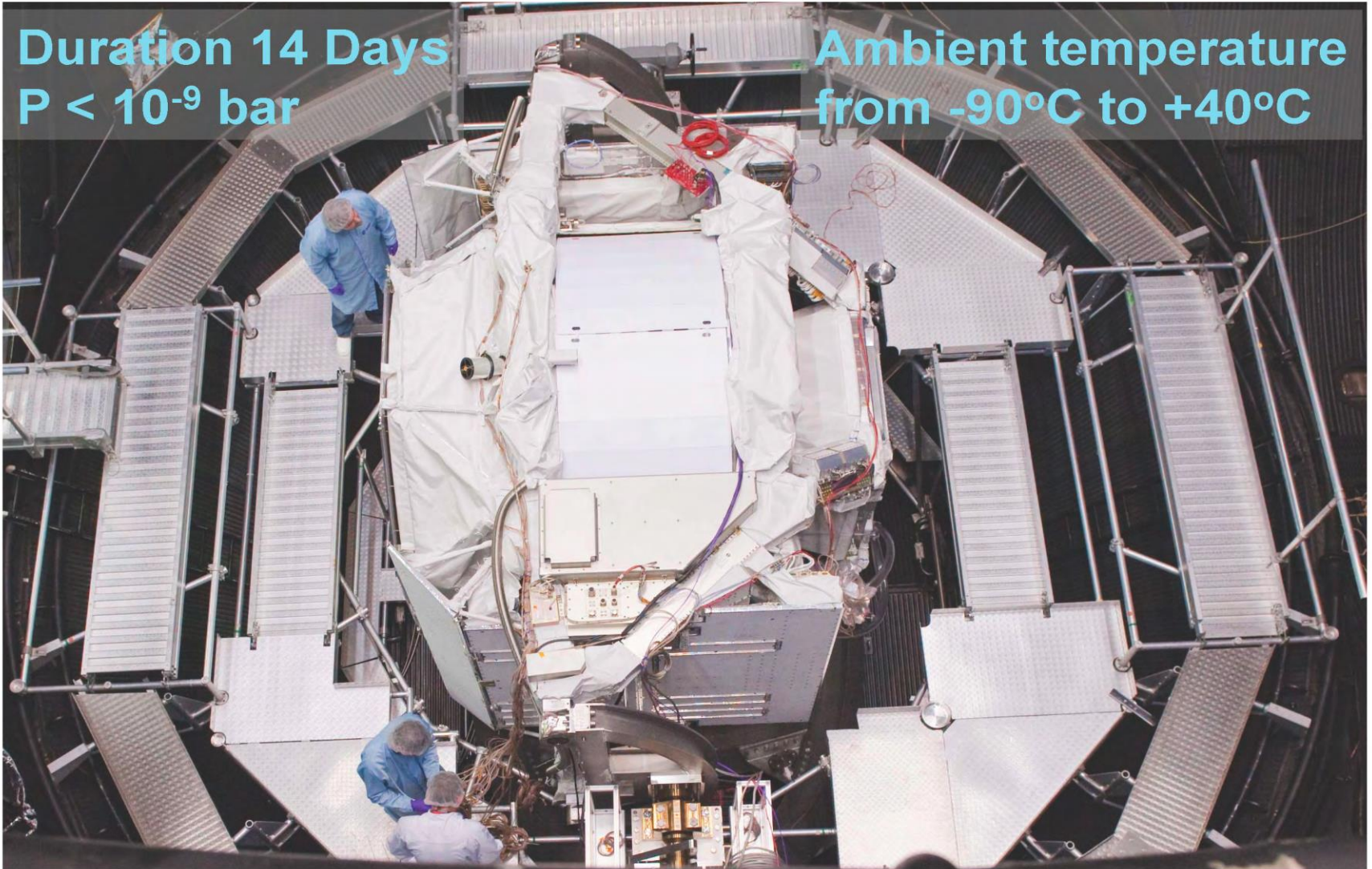




## AMS in the ESA Thermal Vacuum Chamber, April 2010

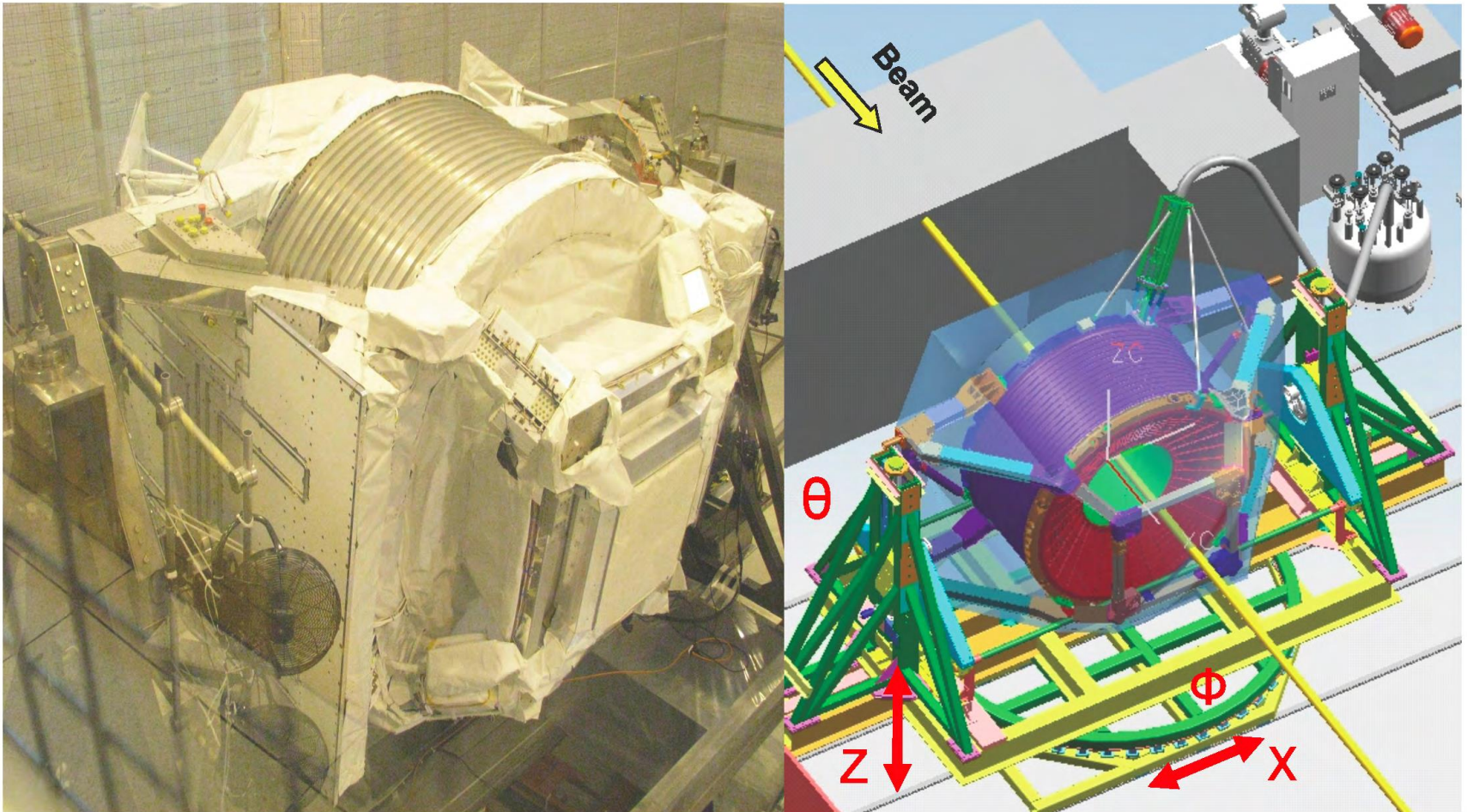
Duration 14 Days  
 $P < 10^{-9}$  bar

Ambient temperature  
from  $-90^{\circ}\text{C}$  to  $+40^{\circ}\text{C}$





# Intensive Tests at CERN



Strong support from CERN (R. Heuer, A. Siemko, S. Meyers, C. Garguilo)

**Фактически сделано два варианта  
детектора:**

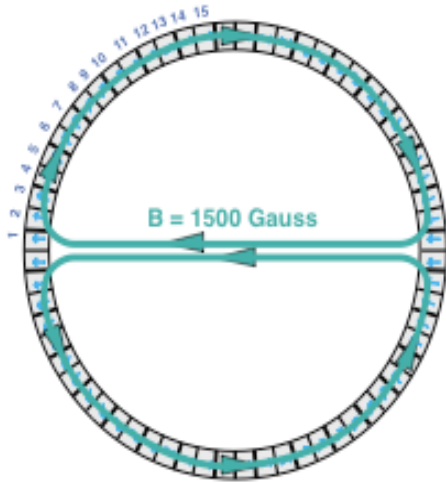
**со сверхпроводящим магнитом и  
с постоянным магнитом.**

There has never been a precision magnetic Spectrometer in space due to the extremely difficult technical challenges

**STEP ONE: AMS-01**

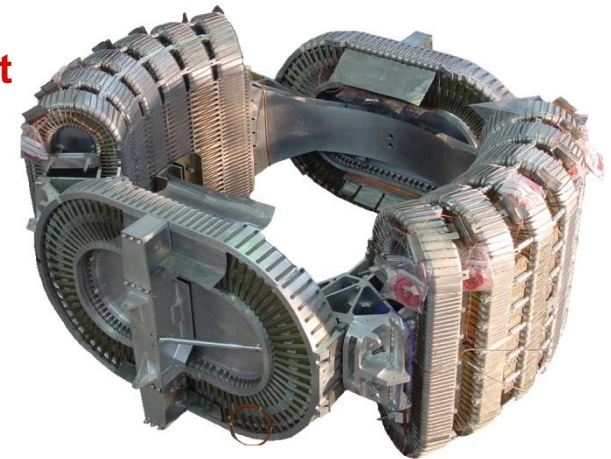
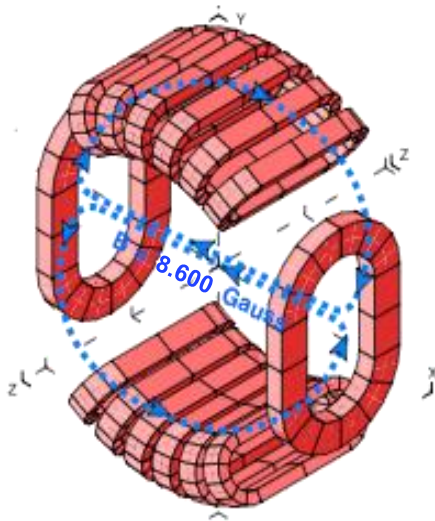
A Permanent Magnet to fly on the Shuttle

- 1- Minimum torque from Earth's magnetic field
- 2- Minimum field leakage



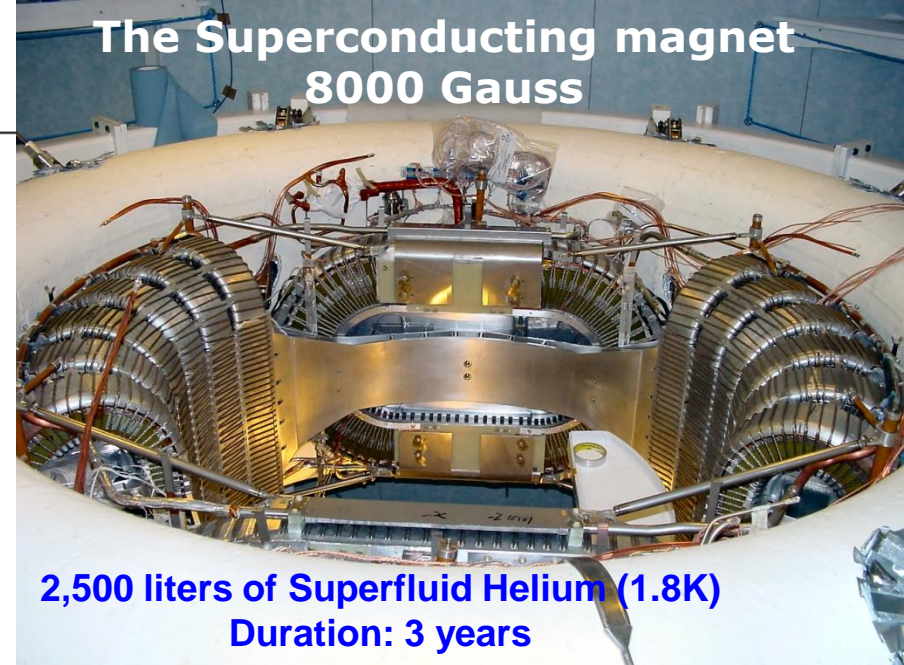
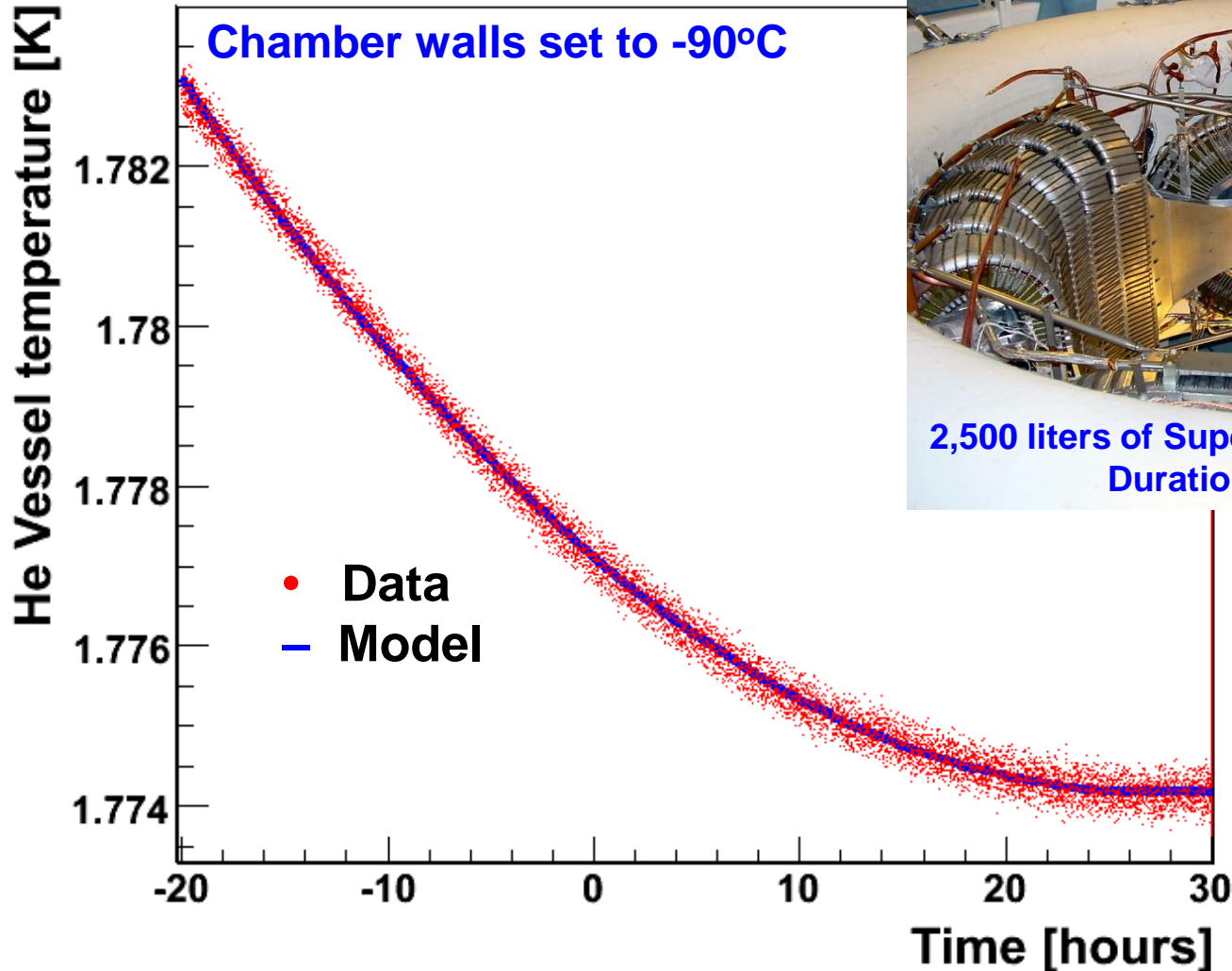
**STEP TWO: AMS-02**

A Superconducting Magnet with the same field arrangement





# Stabilization of the He Vessel



*Stability criteria:*  
 $dT/dt < 0.0001\text{K/h}$

Expected life time of the AMS Cryostat on ISS:  
 $28 \pm 6$  months

IMPLEMENTING ARRANGEMENT  
BETWEEN  
THE DEPARTMENT OF ENERGY  
AND  
THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
REGARDING THE  
ALPHA MAGNETIC SPECTROMETER IN SPACE PROGRAM

...  
I. PROGRAM DESCRIPTION

The AMS is a state-of-the-art particle physics detector containing a large permanent magnet that will be designed constructed and tested by an international team organized under DOE sponsorship and that will use the unique environment of space to advance knowledge of the universe and lead potentially to a clearer understanding of the origin of the universe. Specifically, the science objectives of the AMS are to search for cosmic sources of anti-matter (i.e., anti-helium or heavier elements) and dark matter.

... On the second flight, NASA will launch the AMS on the Shuttle and transfer and install it onto the International Space Station (ISS). The AMS then will be operated as an externally attached payload on the ISS for a nominal three-year period, after which NASA will detach the AMS from the ISS, transfer it to a Space Shuttle, and return it to Earth. ...

By *Harold G. Ables* By *Martha Krebs*  
Associate Administrator Director  
for Life and Microgravity  
Sciences and Applications Office of Energy Research  
National Aeronautics and Department of Energy  
Space Administration

Date: *20 Sept 95* Date: *Sept 20, 1995*

**2010 год**

**Продление  
работы МКС  
до 2020 – 2028  
года**

Michael Braukus  
Headquarters, Washington  
202-358-1979  
[michael.j.braukus@nasa.gov](mailto:michael.j.braukus@nasa.gov)

March 11, 2010

RELEASE : 10-063

## **Heads of Agency International Space Station Joint Statement**

**TOKYO --** The heads of the International Space Station (ISS) agencies from Canada, Europe, Japan, Russia, and the United States met in Tokyo, Japan, on March 11, 2010, to review ISS cooperation.

The heads of agency reaffirmed the importance of full exploitation of the station's scientific, engineering, utilization, and education potential. They noted that there are no identified technical constraints **to continuing ISS operations beyond the current planning horizon of 2015 to at least 2020, and that the partnership is currently working to certify on-orbit elements through 2028.** The heads of agency expressed their strong mutual interest in continuing operations and utilization for as long as the benefits of ISS exploitation are demonstrated

**Сверхпроводящий магнит был идеальным решением, когда эксплуатация МКС была ограничена тремя годами, как первоначально планировалось для АМС.**

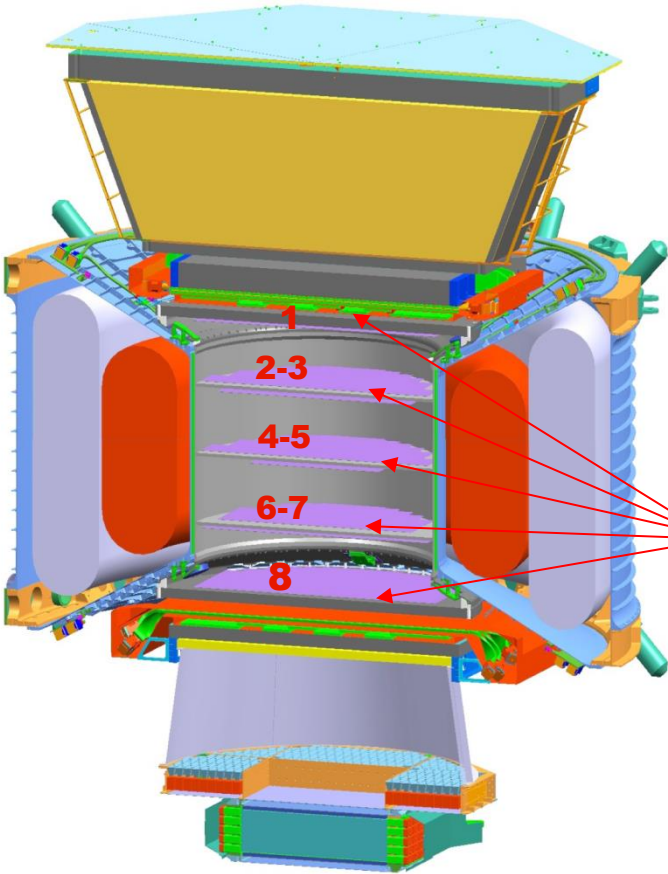
**Период эксплуатации станции продлен до 2020 (2028) года. Программа челноков завершена, и это полностью исключило возможность возврата АМС на землю или повторной заливки гелия.**

**Сверхпроводящий магнит очевидно не является больше идеальным выбором, поскольку постоянный магнит дает возможность 18-ти летней эксплуатации детектора АМС обеспечивая гораздо большую чувствительность для поиска и обнаружения новых явлений.**

# AMS-02

(3 yrs)

with Superconducting Magnet  
8 layers of Silicon

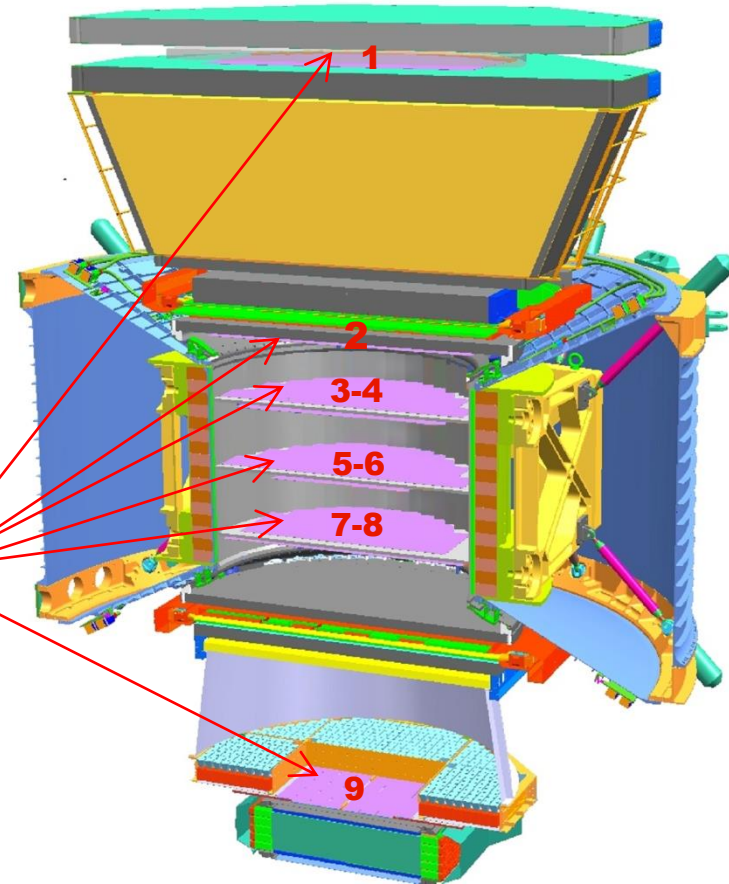


## Silicon layers



# AMS-02

with Permanent Magnet  
9 layers of Silicon

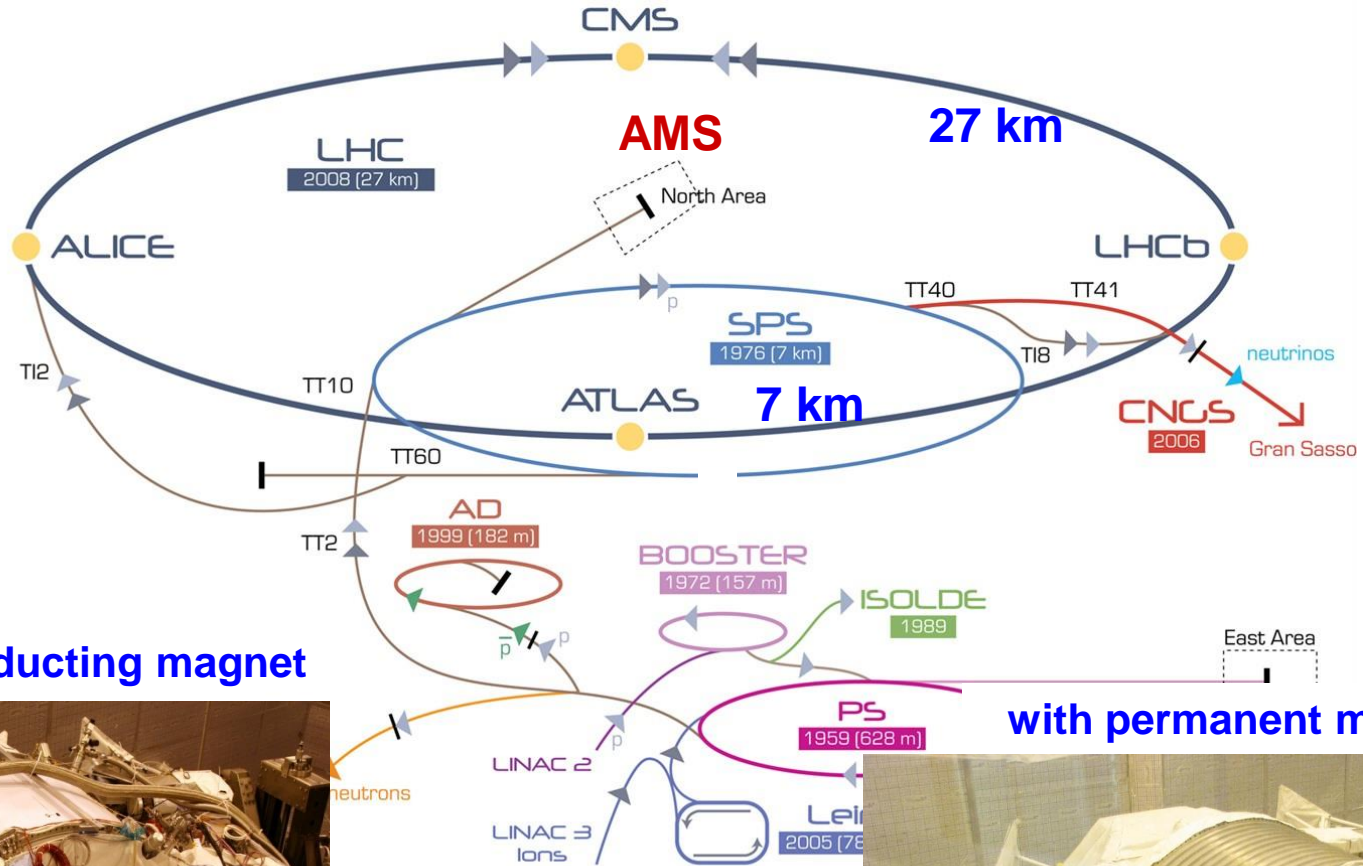


Layers 1 and 9 are far away from  
the magnet to extend the lever arm.

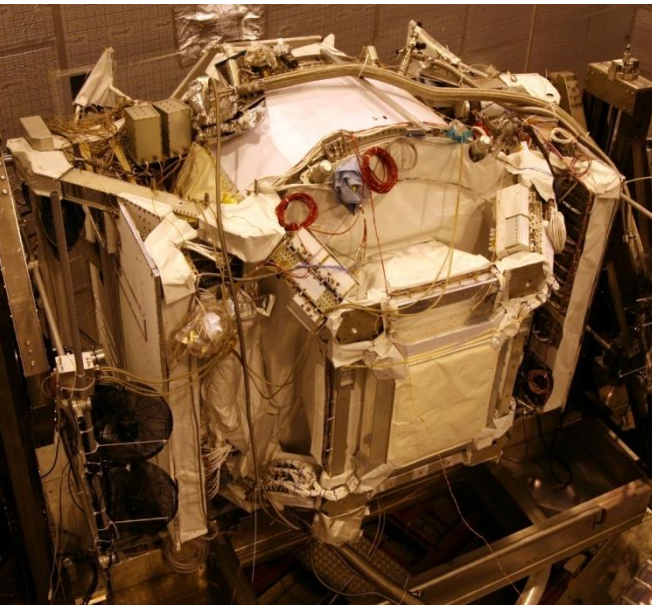


# Tests at CERN

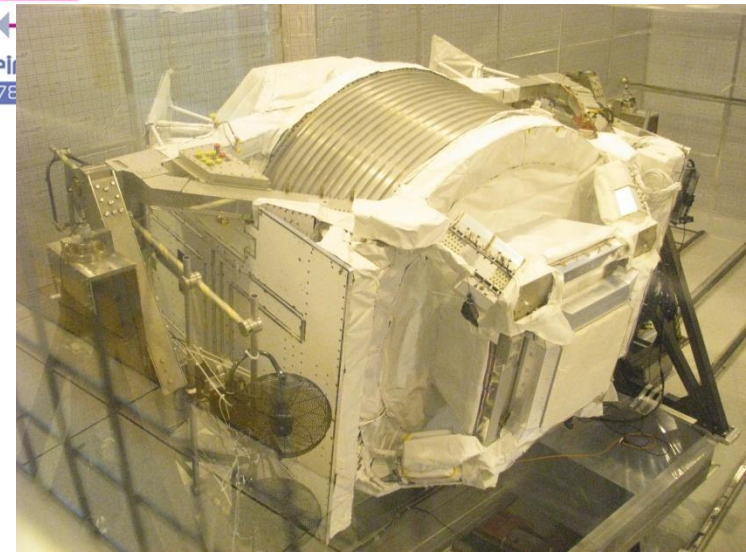
## AMS in accelerator test beams Feb 4-8 and Aug 8-20, 2010



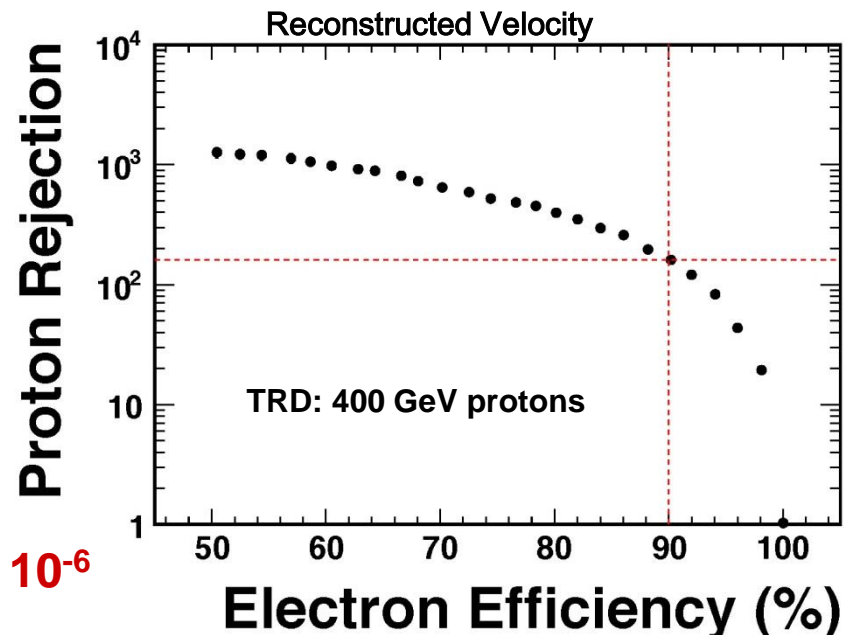
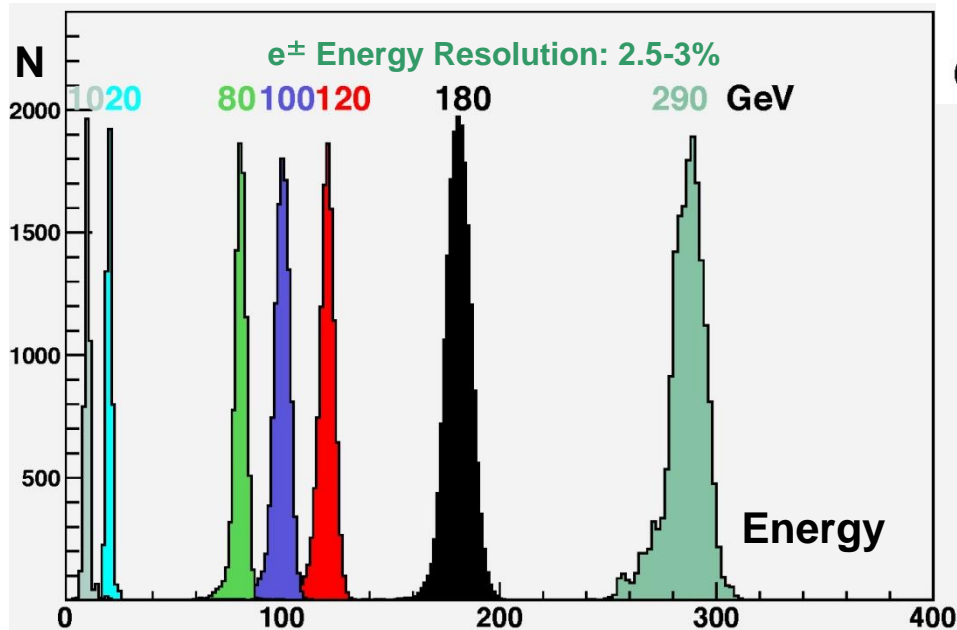
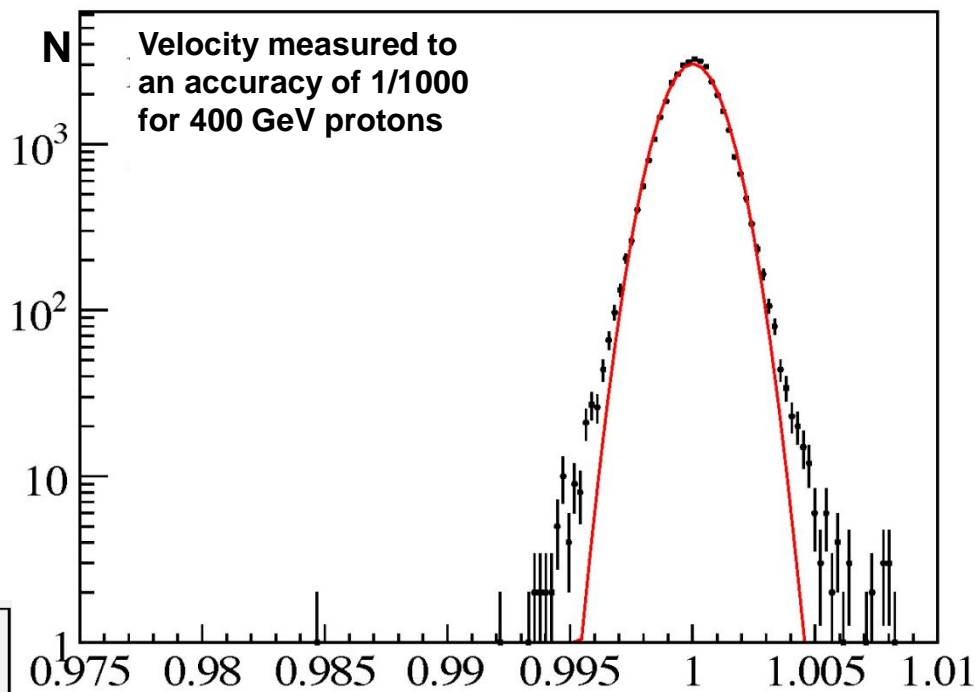
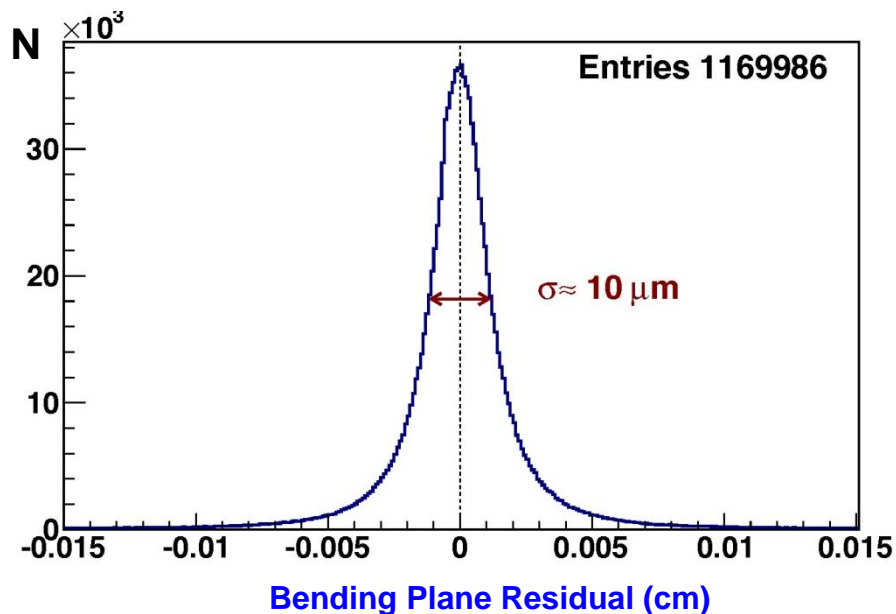
with superconducting magnet



with permanent magnet

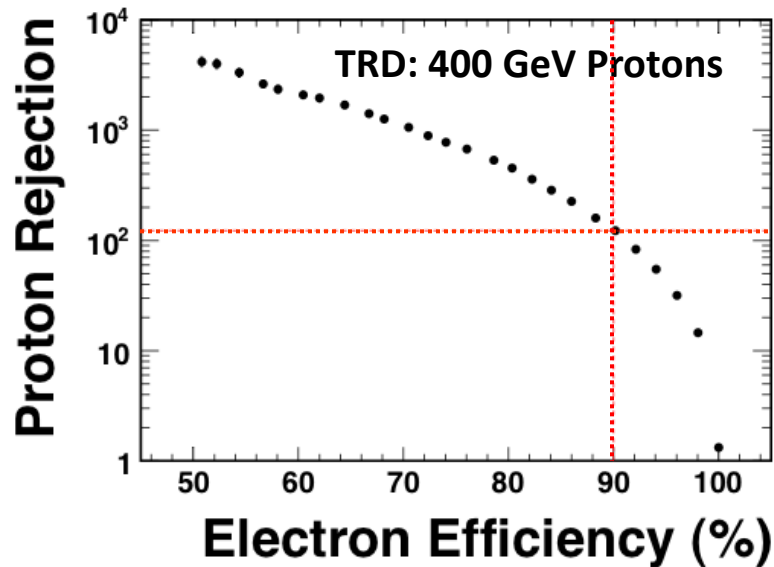
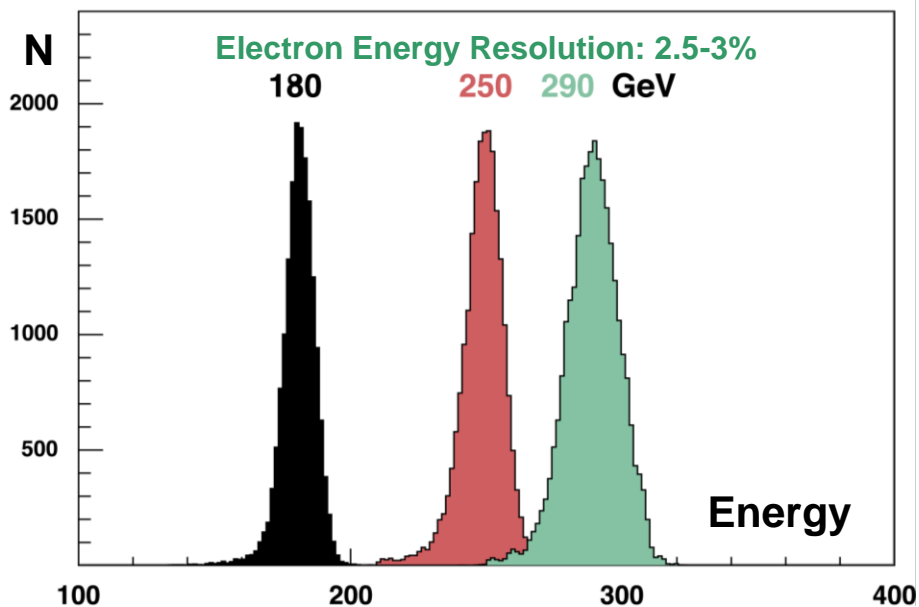
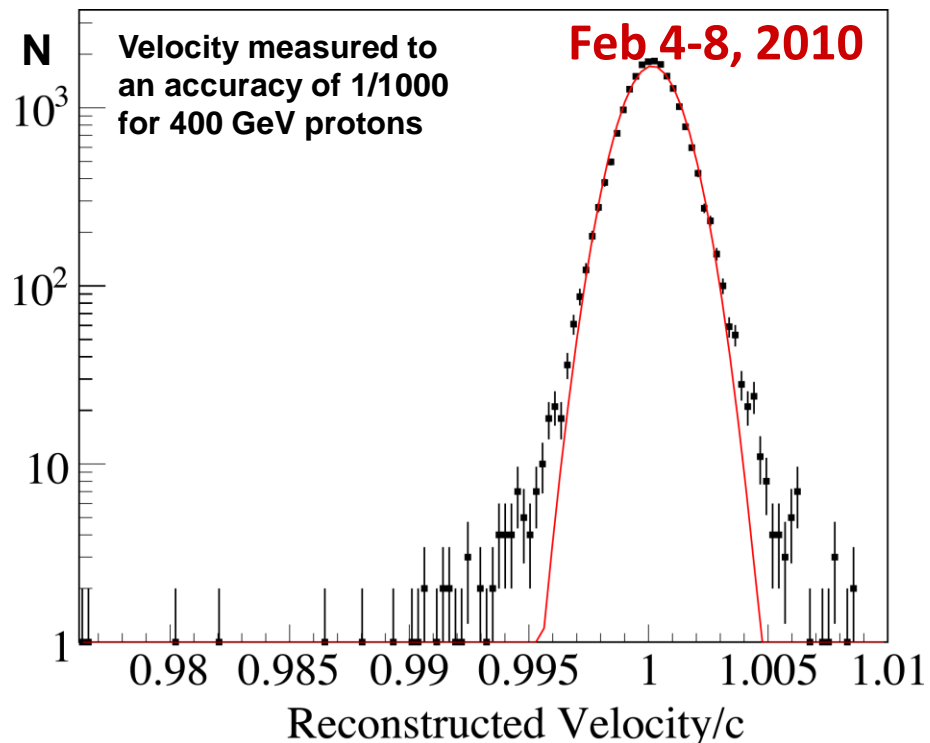
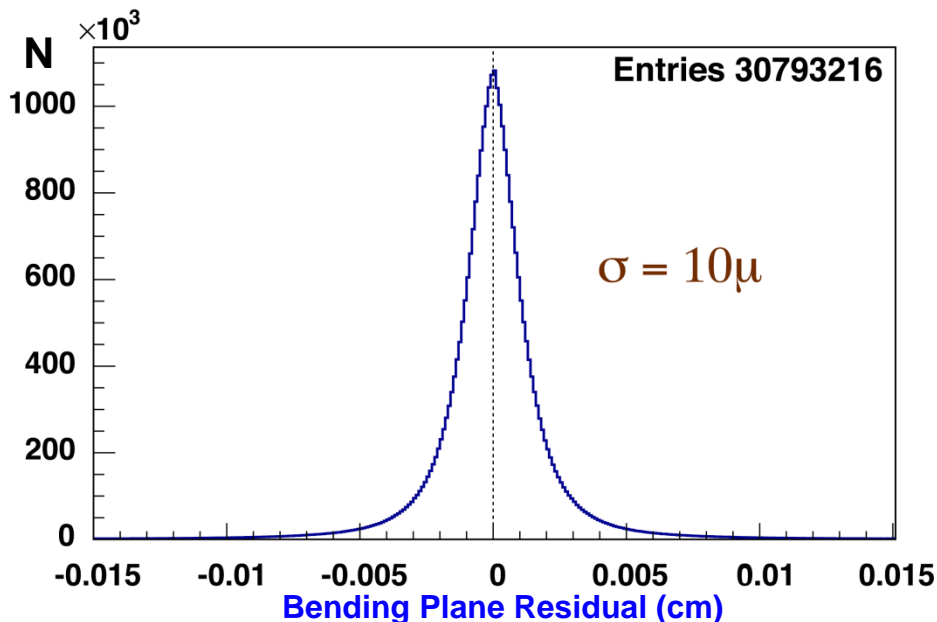


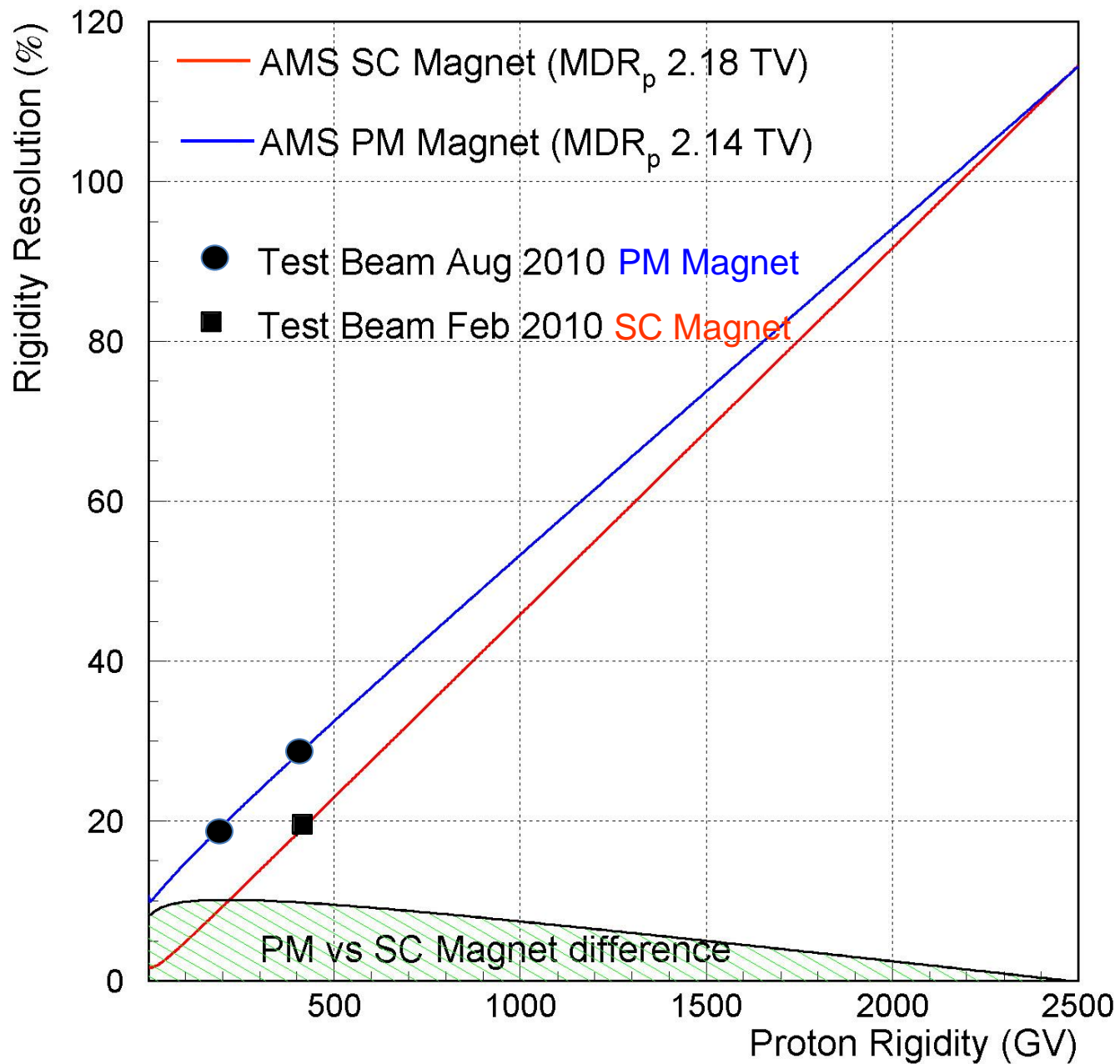
# Test Beam Results– 8-20 Aug 2010



Measured combined rejection power at 400 GeV:  $e^+/p = 10^{-6}$

# Test Beam Results of detector with superconducting magnet



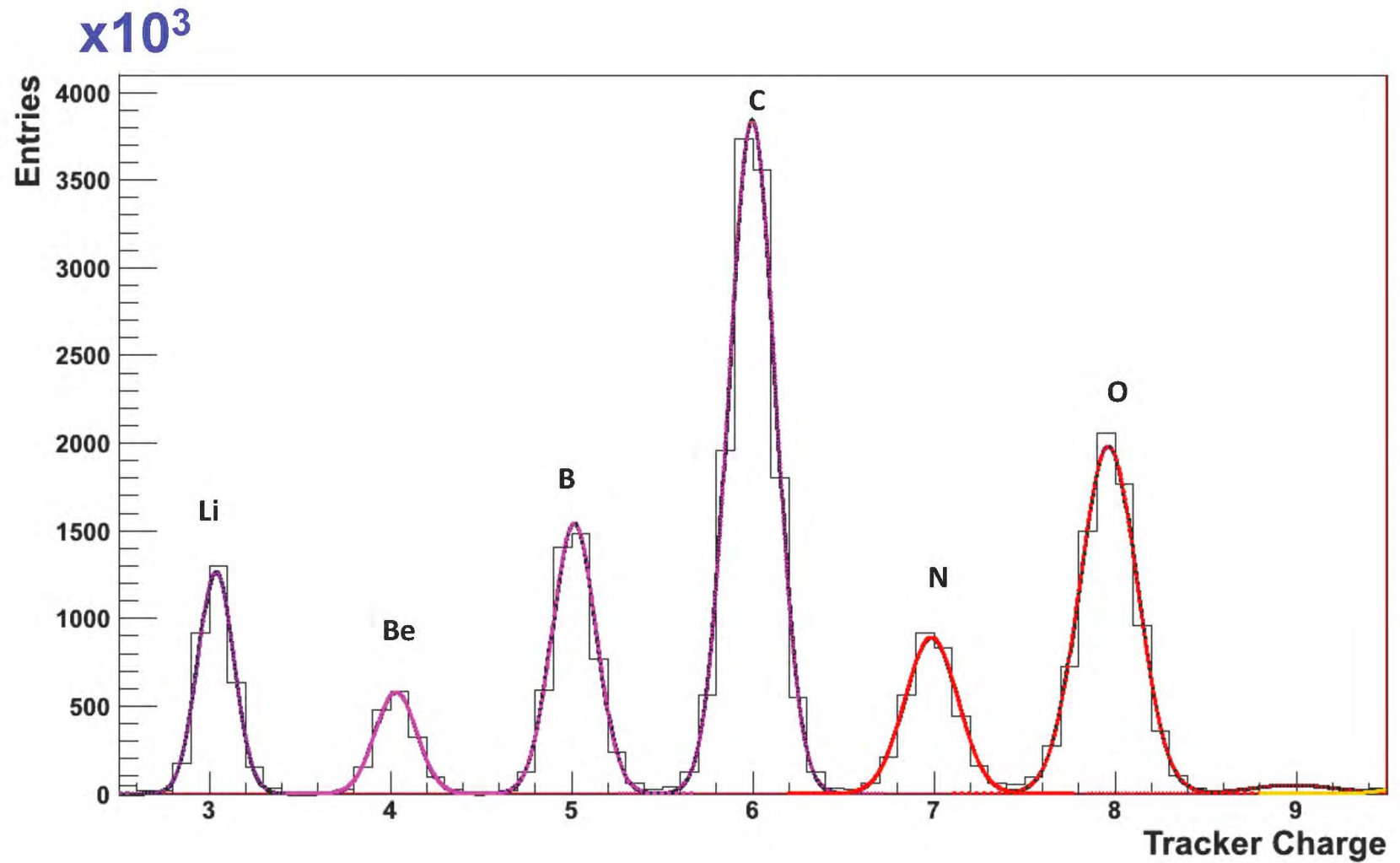


**With 9 tracker planes, the resolution of AMS with the permanent magnet is not much different from that of the superconducting magnet.**

# **Ниже приводится несколько примеров разрешающей способности элементов детектора**



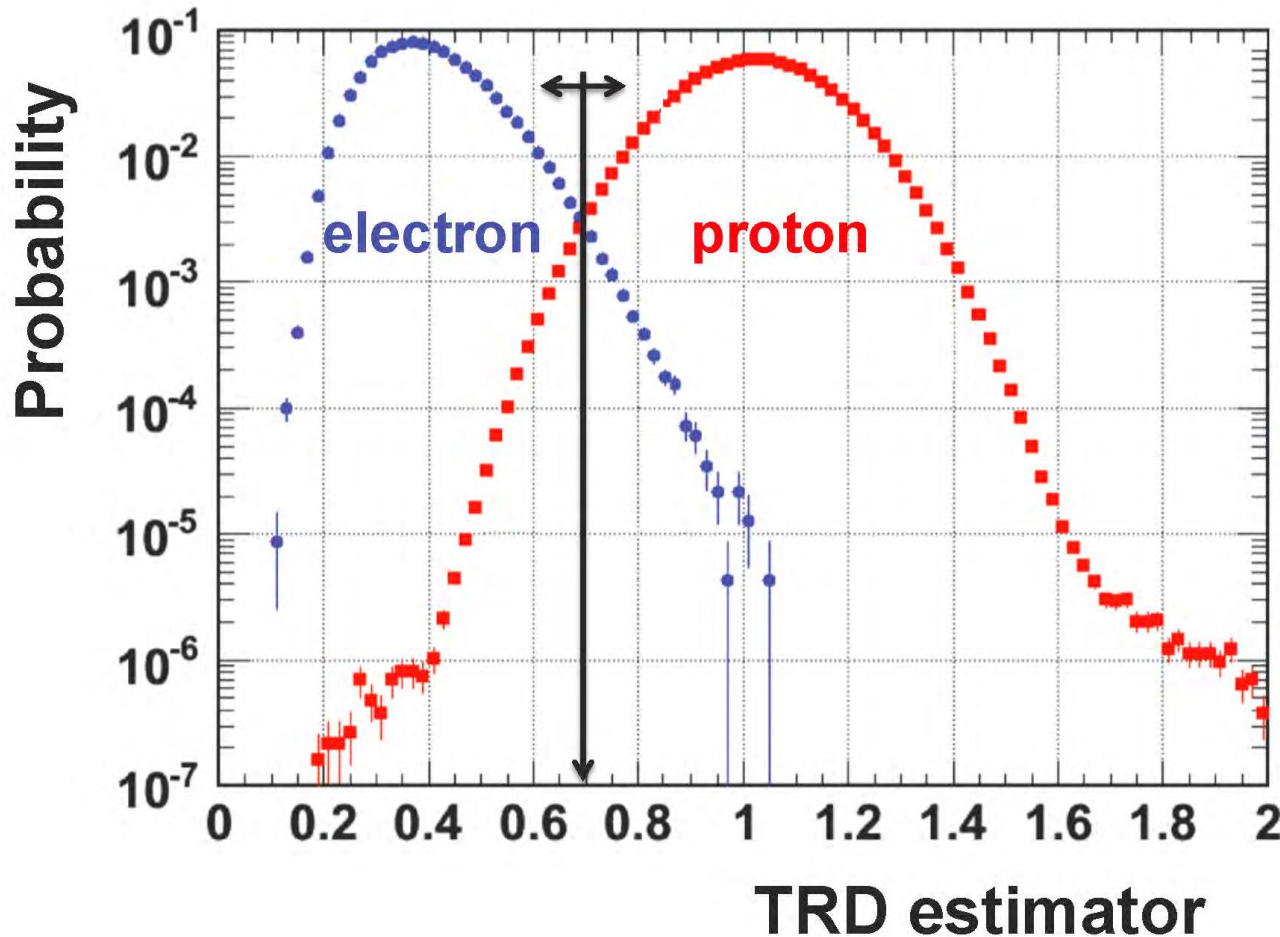
## Tracker Charge





# TRD performance on ISS

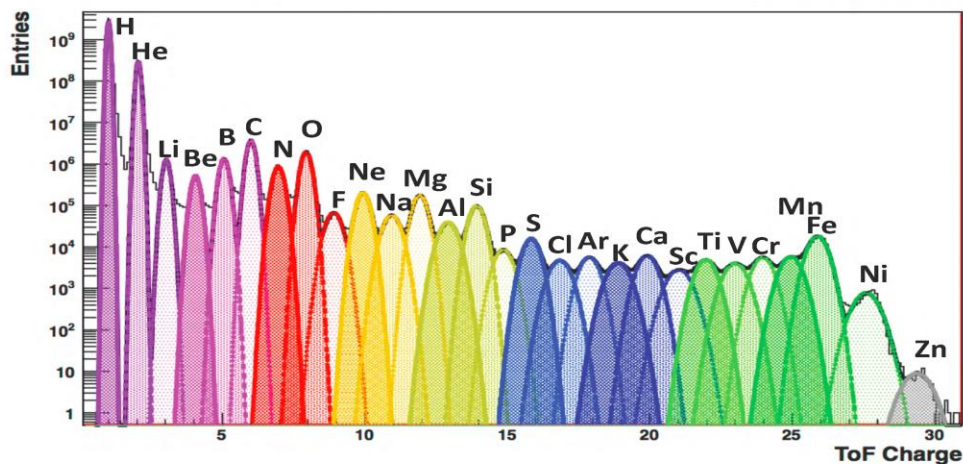
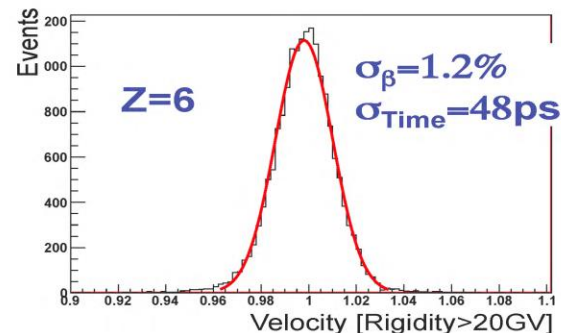
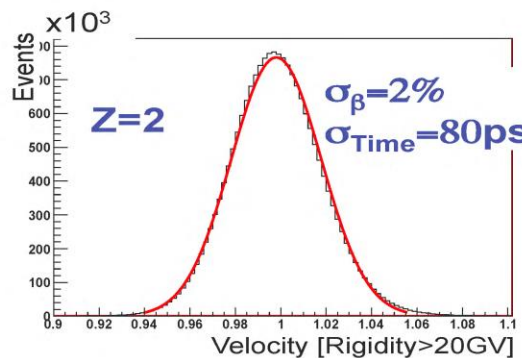
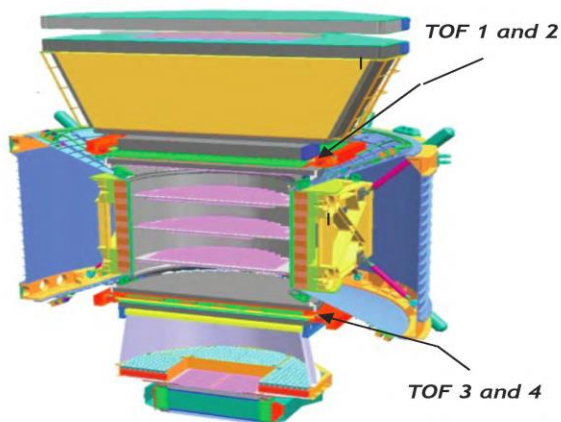
$$\text{TRD estimator} = -\ln(P_e/(P_e+P_p))$$



# Data from ISS

# Time of Flight System

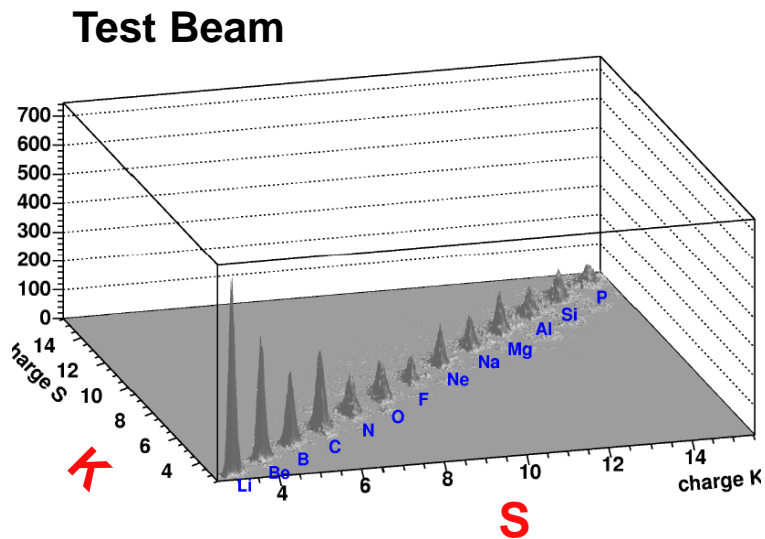
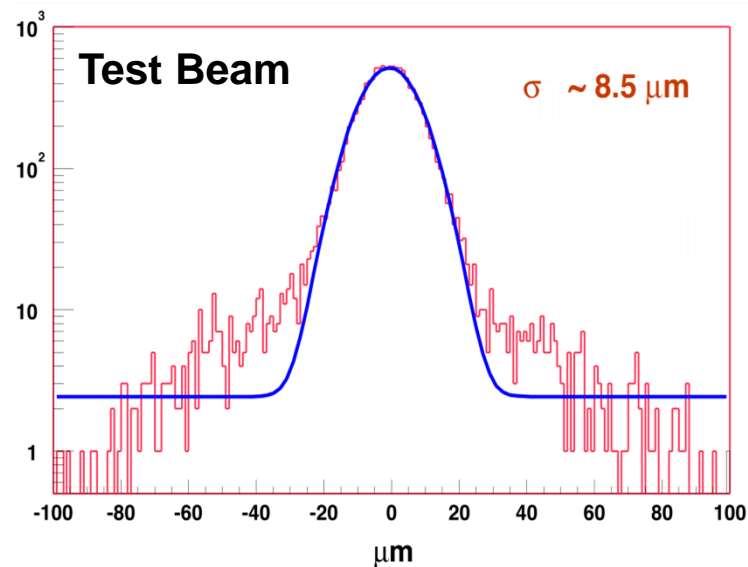
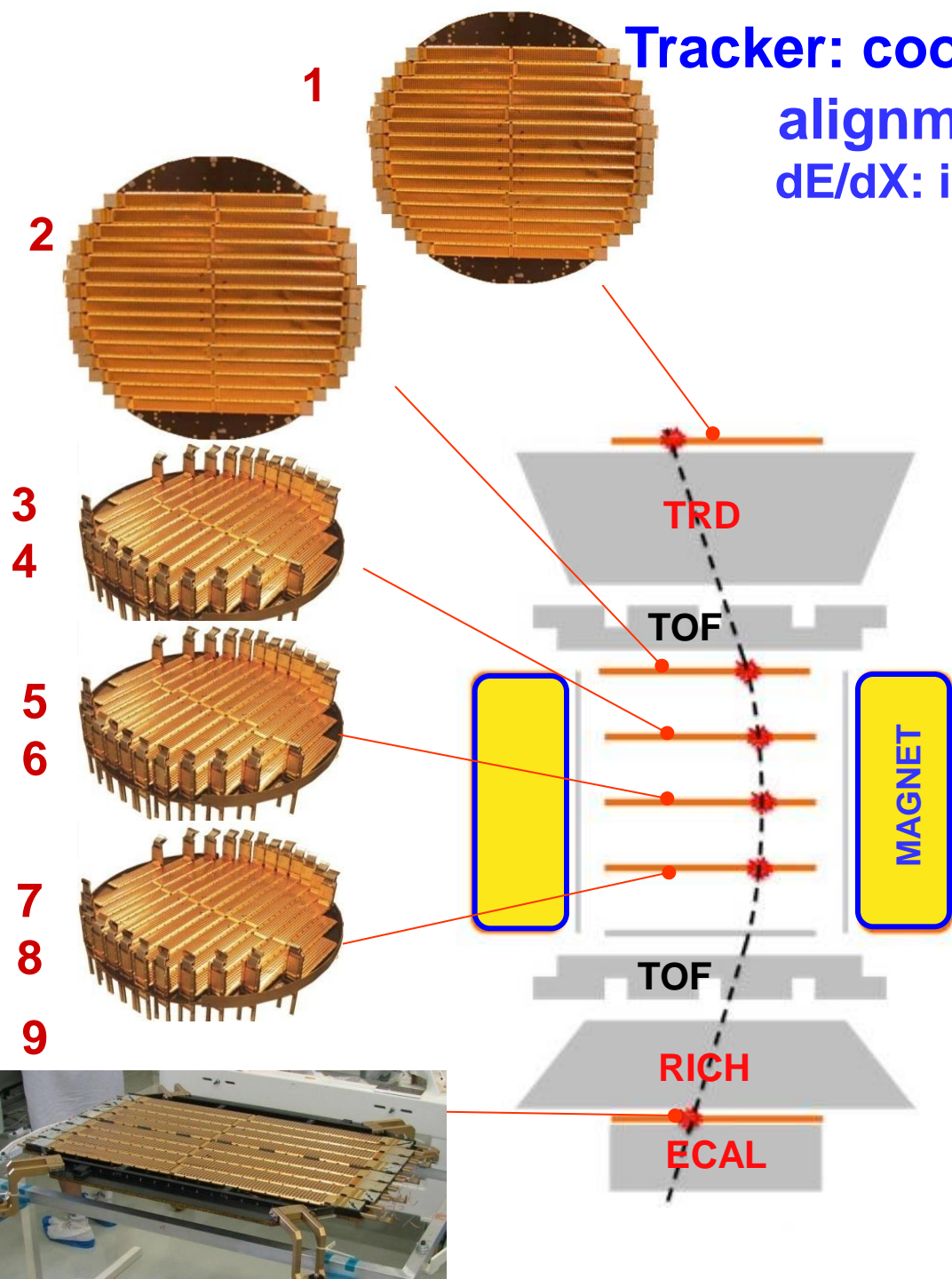
Measures Velocity and Charge of particles





**Tracker: coordinate resolution  $10\ \mu$**

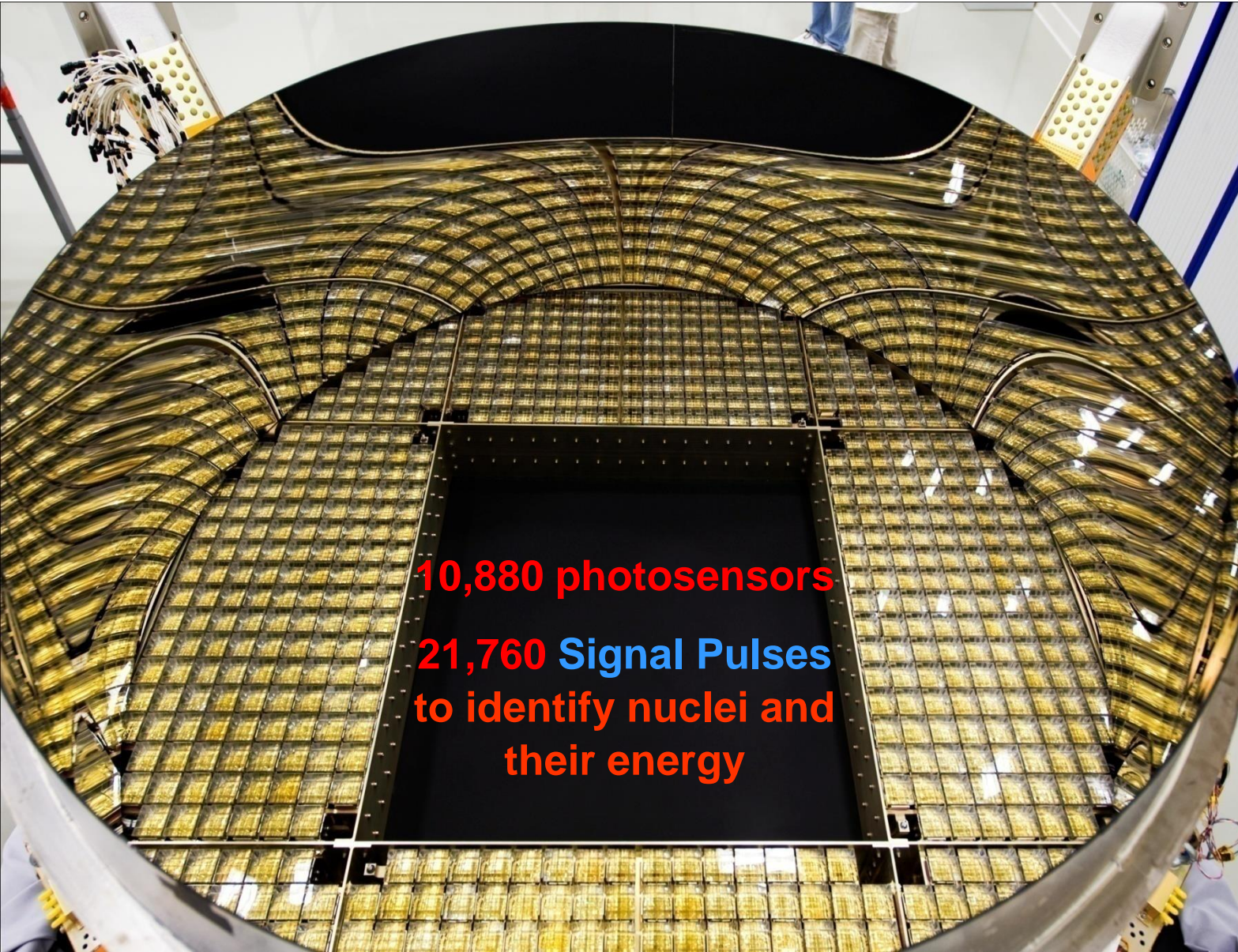
**alignment:  $3\ \mu$  with 20 UV lasers**  
**dE/dX: identify nuclei**





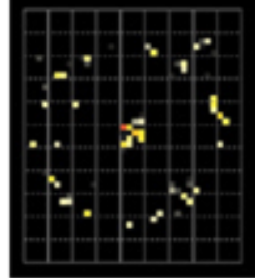
# Ring Imaging Cherenkov (RICH)

# 160 Gv

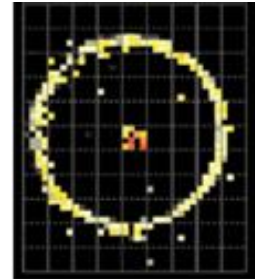


**10,880 photosensors**  
**21,760 Signal Pulses**  
**to identify nuclei and**  
**their energy**

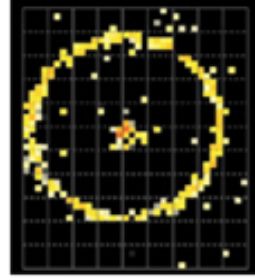
He



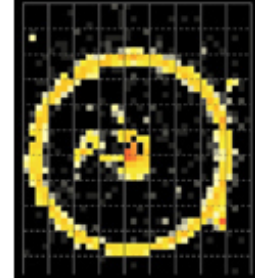
Li



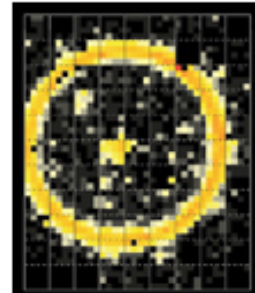
C



O

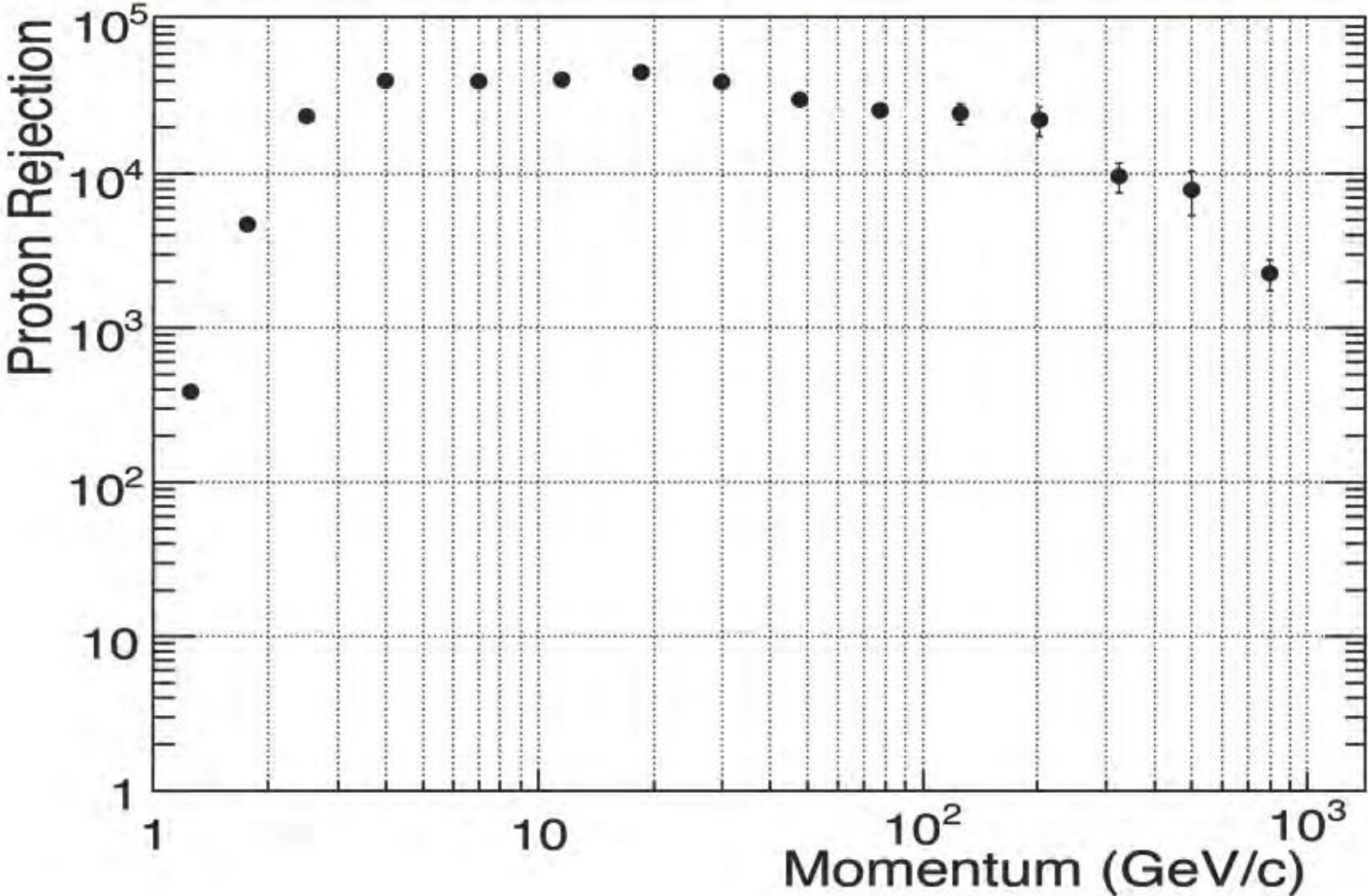


Ca





# Data from ISS: Proton rejection using the ECAL



# ТЕРМОКОНТРОЛЬ



# Thermal Control is the most challenging task in the operation of AMS

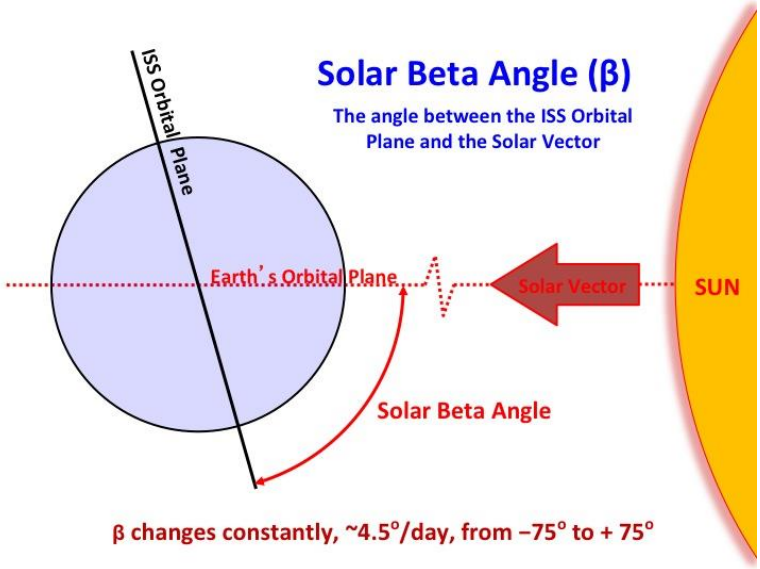
The thermal environment on ISS is constantly changing due to:

- Solar Beta Angle ( $\beta$ )
- Position of the ISS Radiators and Solar Arrays
- ISS Attitude

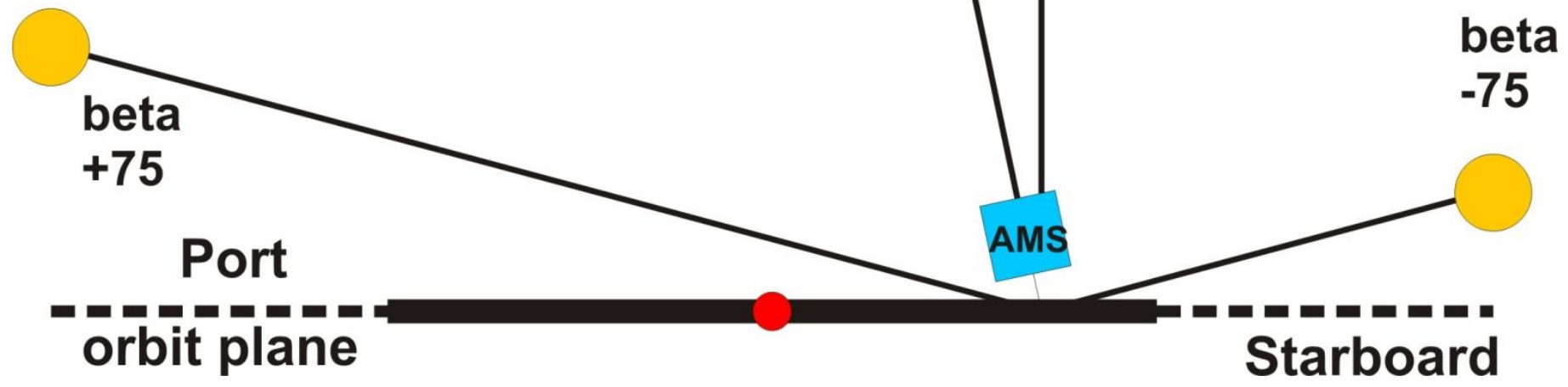
Over 1,100 temperature sensors and 298 heaters are monitored around the clock in the AMS POCC to assure components stay within thermal limits and avoid permanent damage.

### Solar Beta Angle ( $\beta$ )

The angle between the ISS Orbital Plane and the Solar Vector

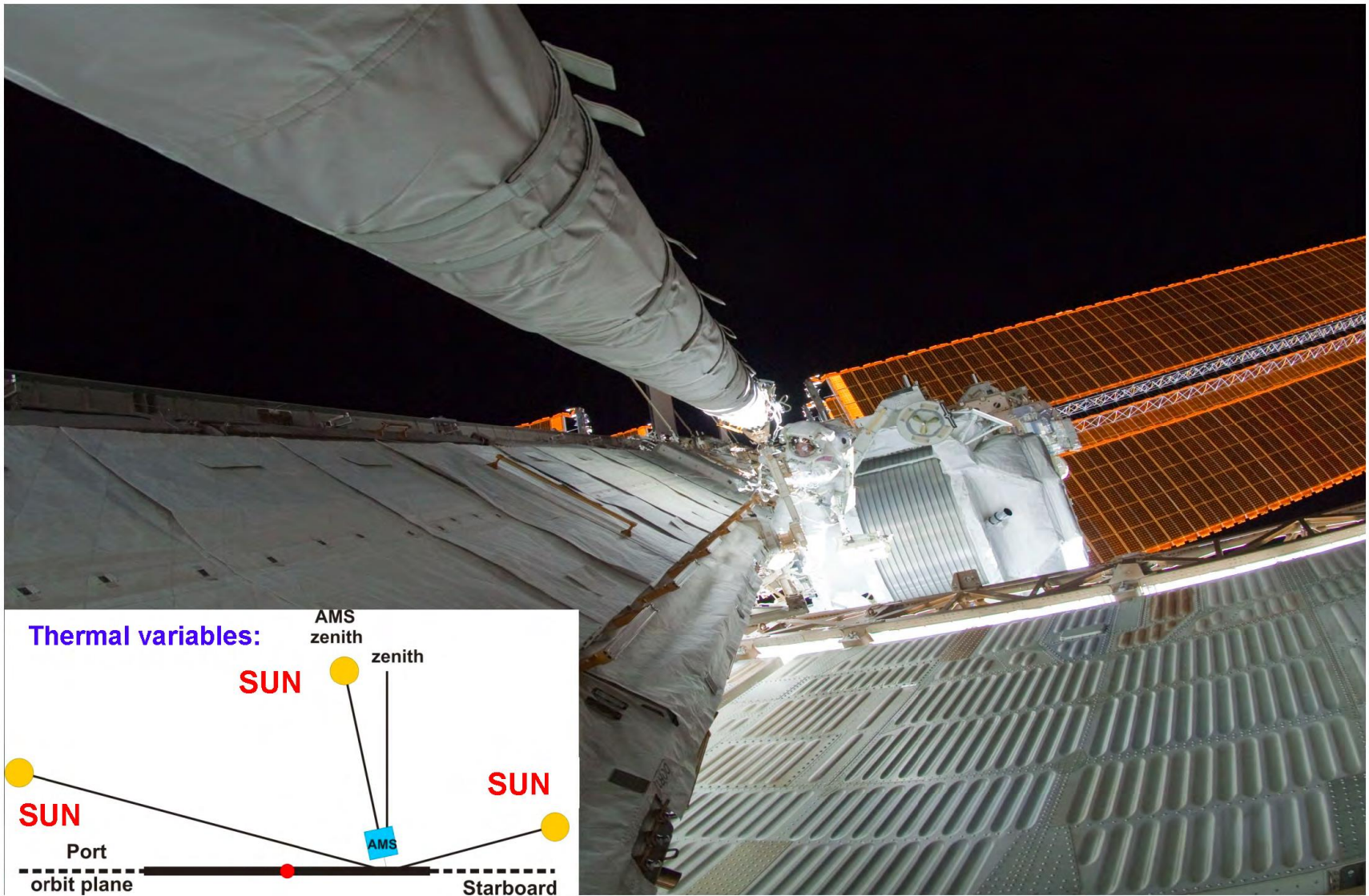


$\beta$  changes constantly,  $\sim 4.5^\circ/\text{day}$ , from  $-75^\circ$  to  $+75^\circ$





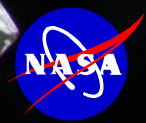
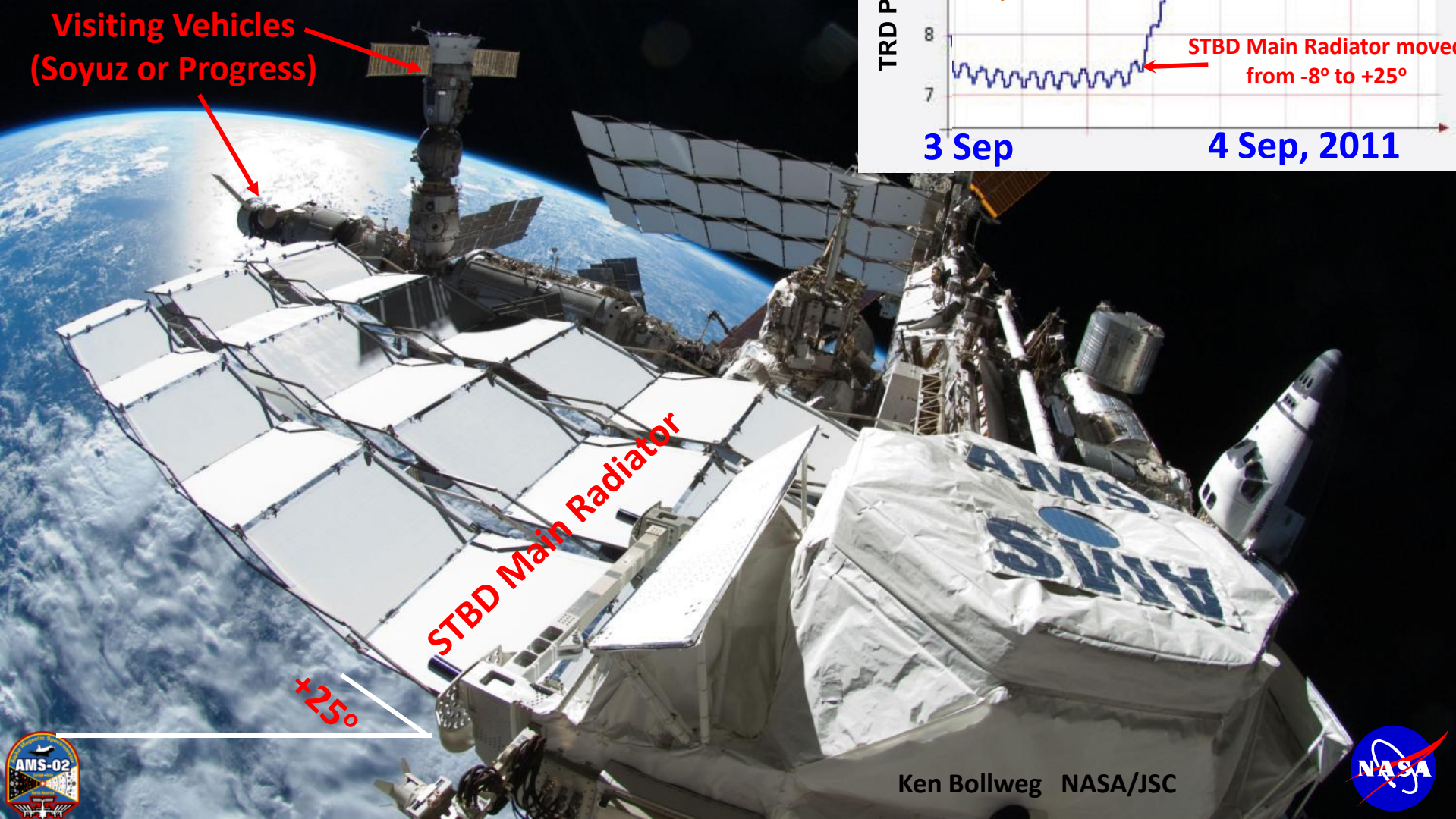
One of the major challenges of operating on the Space Station is the extreme thermal environment to which the experiment is exposed.





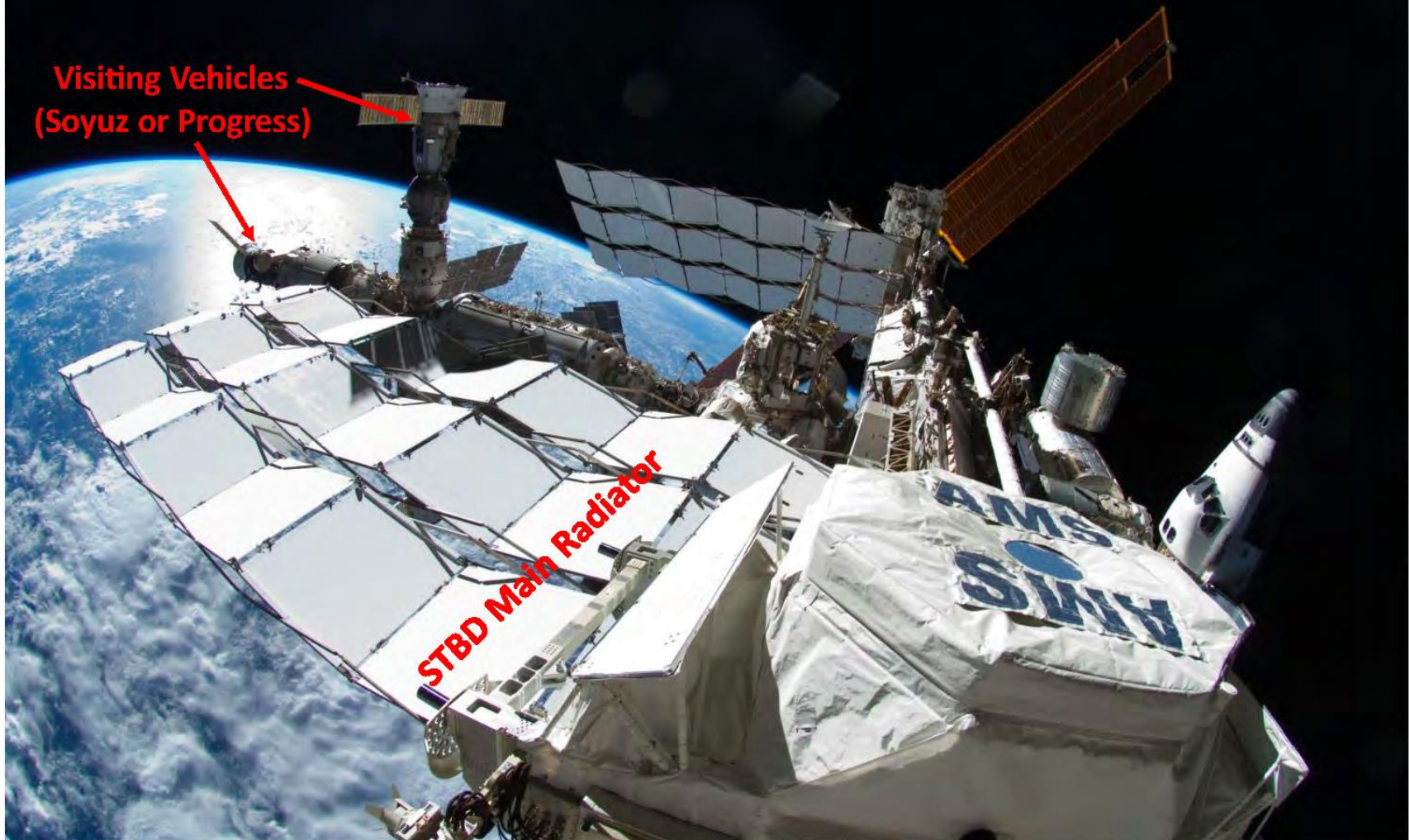
# Thermal variables:

- ISS Radiator positions
- ISS attitude changes (primarily for visiting vehicles)



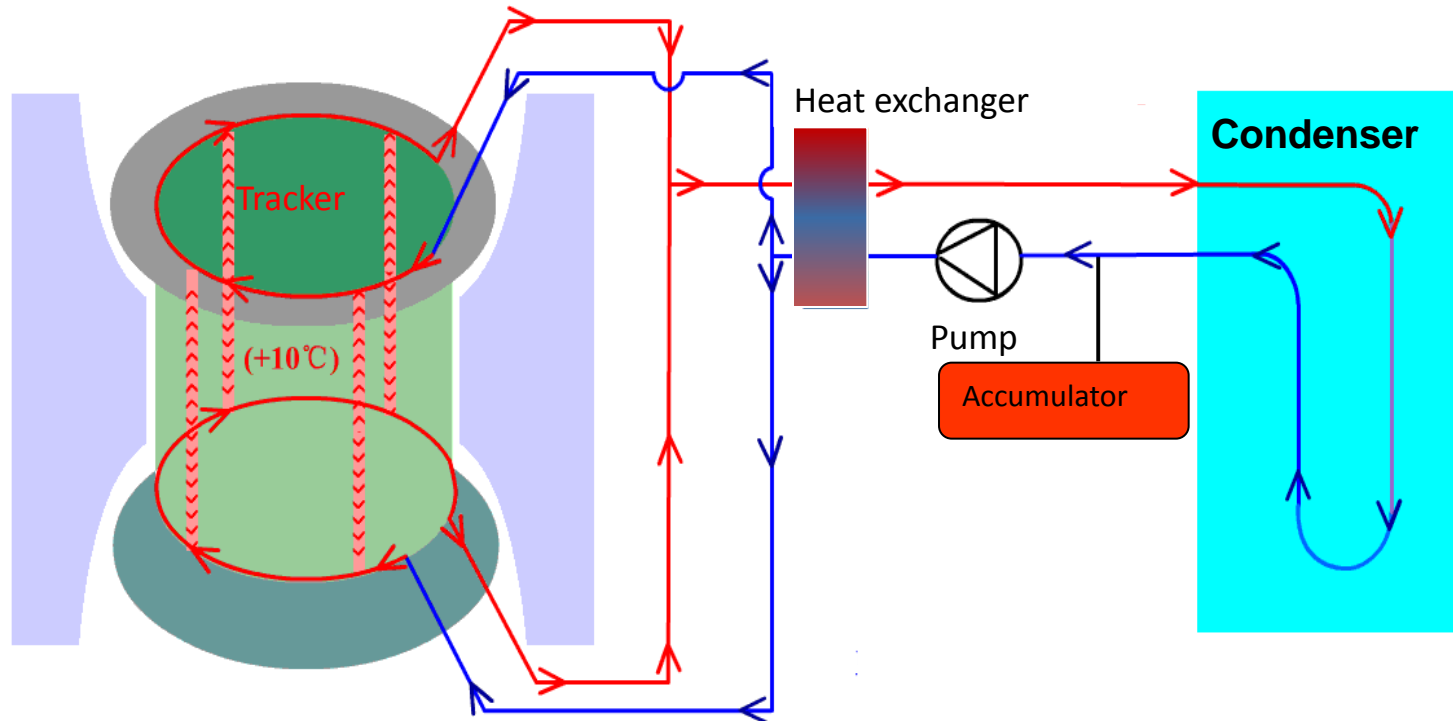
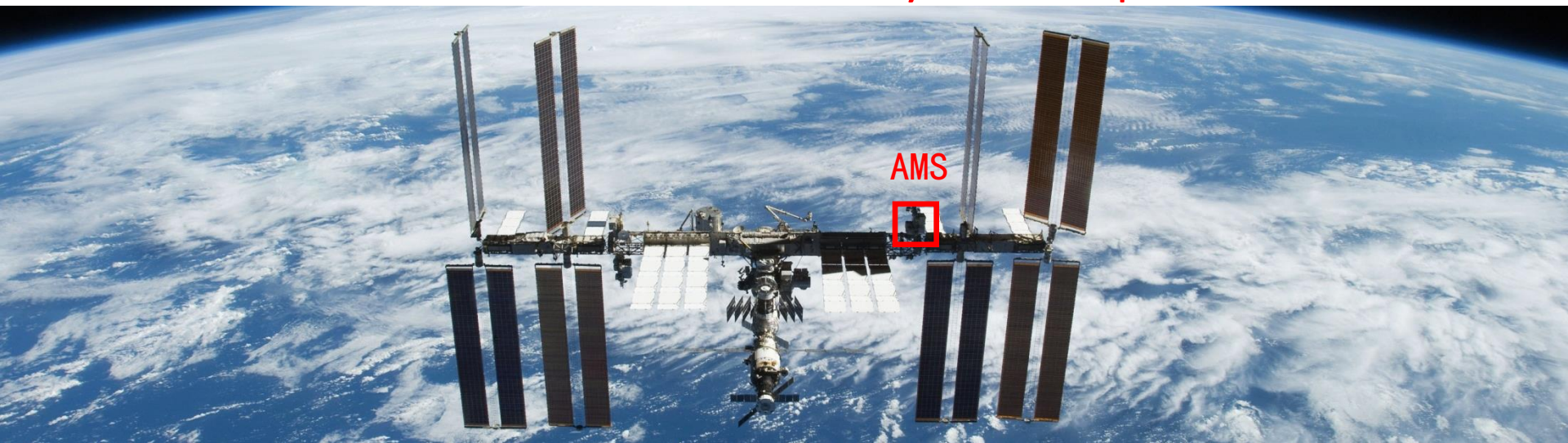
## Thermal variables:

- ISS Radiator positions
- ISS attitude changes (primarily for visiting vehicles)





# Tracker Thermal Control System in Space

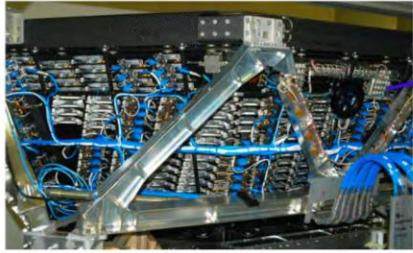


Red line: CO<sub>2</sub> gas/liquid two phase

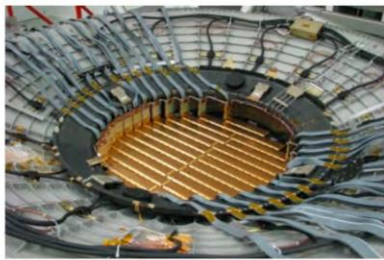
Blue line: CO<sub>2</sub> liquid phase

# AMS Flight Electronics for Thermal Control

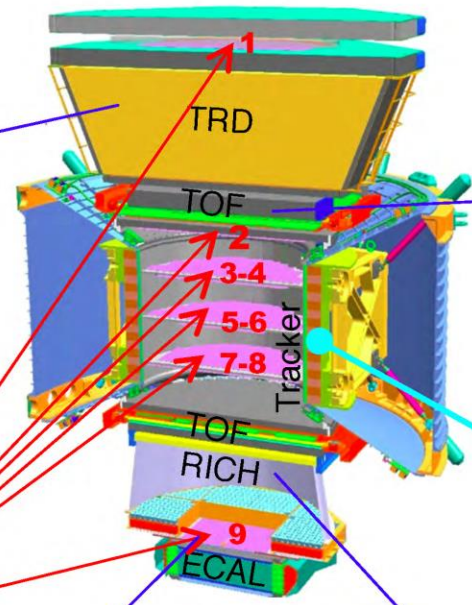
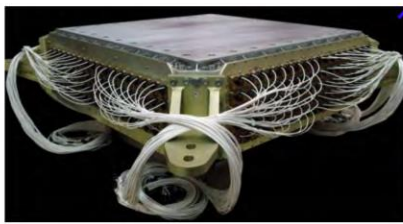
TRD  
 24 Heaters  
 8 Pressure Sensors  
 482 Temperature Sensors



Silicon Tracker  
 4 -Pressure Sensors  
 32 Heaters  
 142 Temperature Sensors



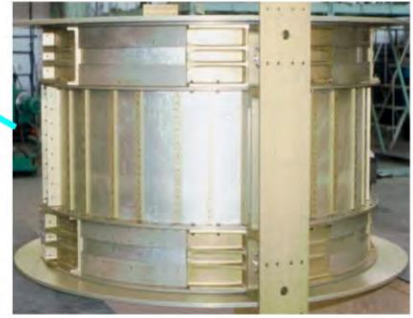
ECAL  
 80 Temperature Sensors



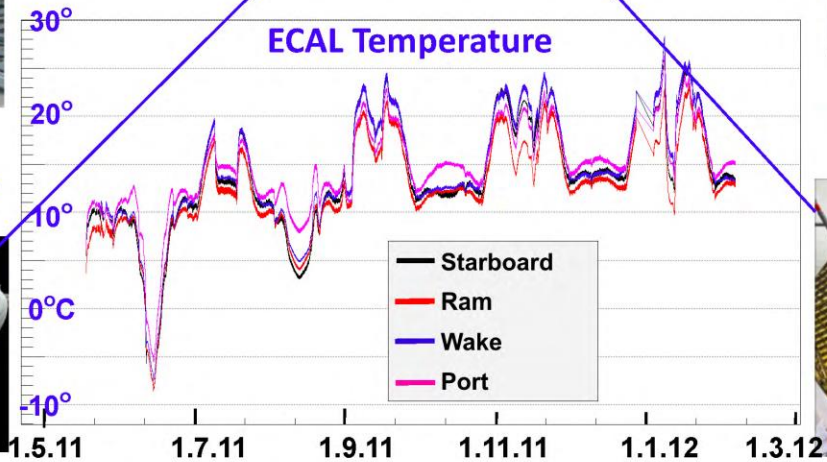
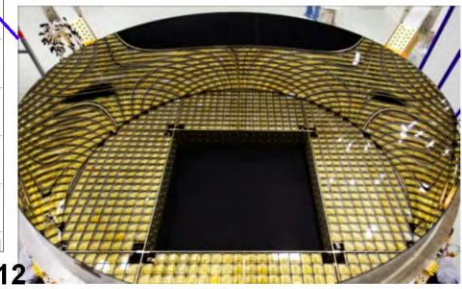
TOF & ACC  
 64 Temperature Sensors



Magnet  
 68 Temperature Sensors



RICH  
 96 Temperature Sensors





# POCC at CERN in control of AMS since 19 June 2011



**AMS**

**Physics !**

# Physics of AMS: Search for Antimatter Universe

AMS on ISS



The Universe began with the Big Bang.



After the Big Bang  
there should have been  
equal amounts of matter and **antimatter**.

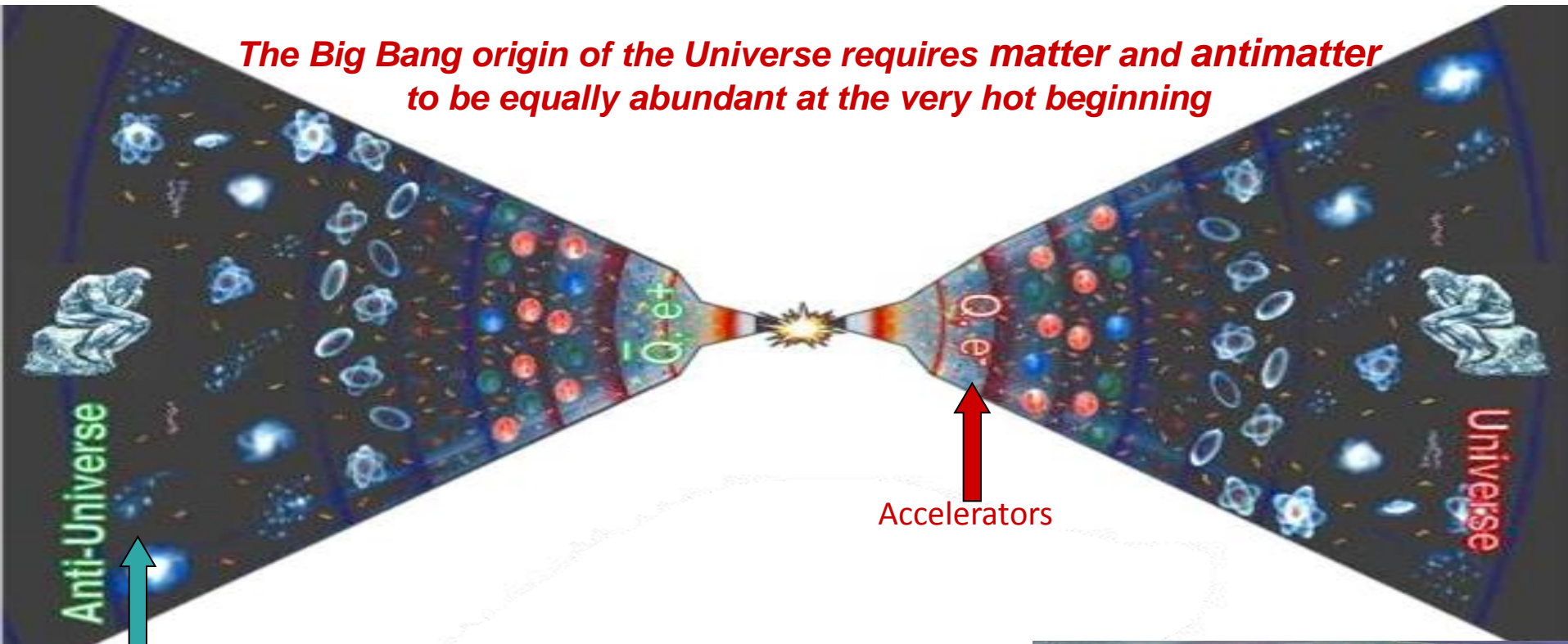
AMS on the Space Station years will search  
for the existence of **antimatter** to the edge of the universe



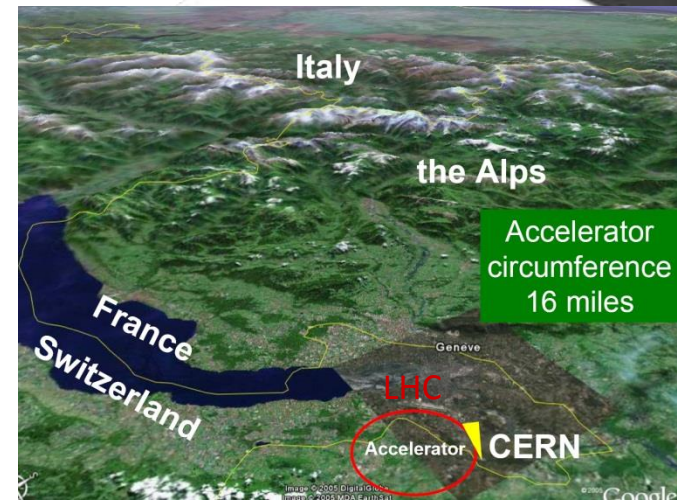
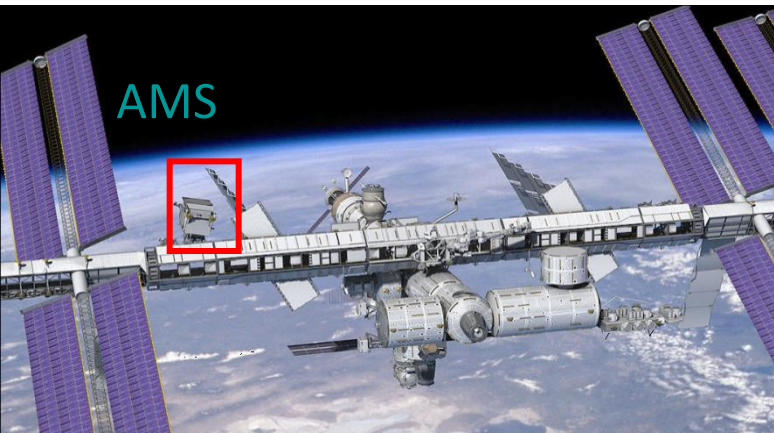
# Physics examples

Search for the existence of Antimatter in the Universe

*The Big Bang origin of the Universe requires matter and antimatter to be equally abundant at the very hot beginning*

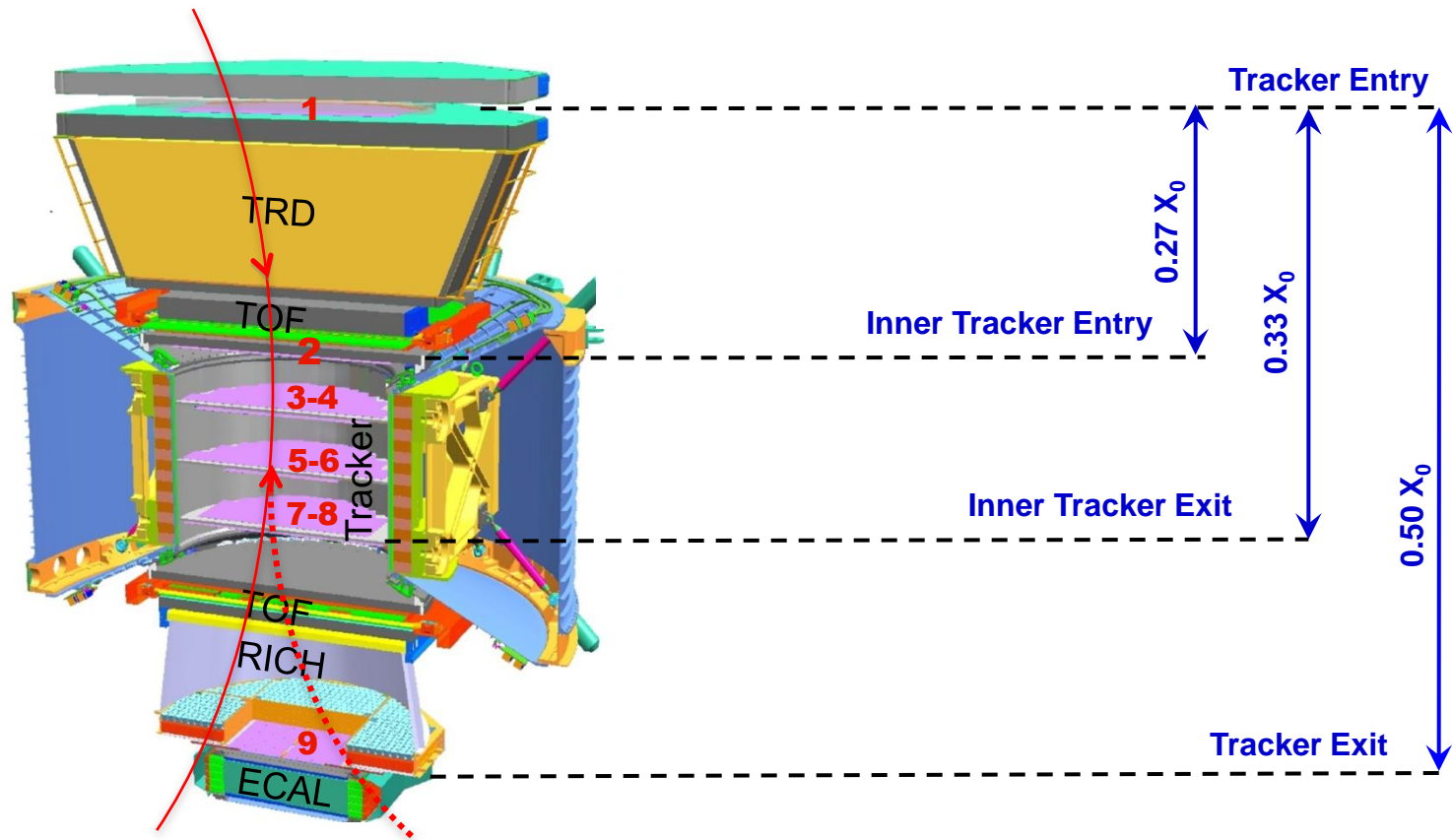


AMS in Space





# Sensitive Search for Antimatter with $\bar{\text{He}}/\text{He} > 10^{10}$



## a) Minimal material in the detector

So that the detector does not become a source of large angle scattering

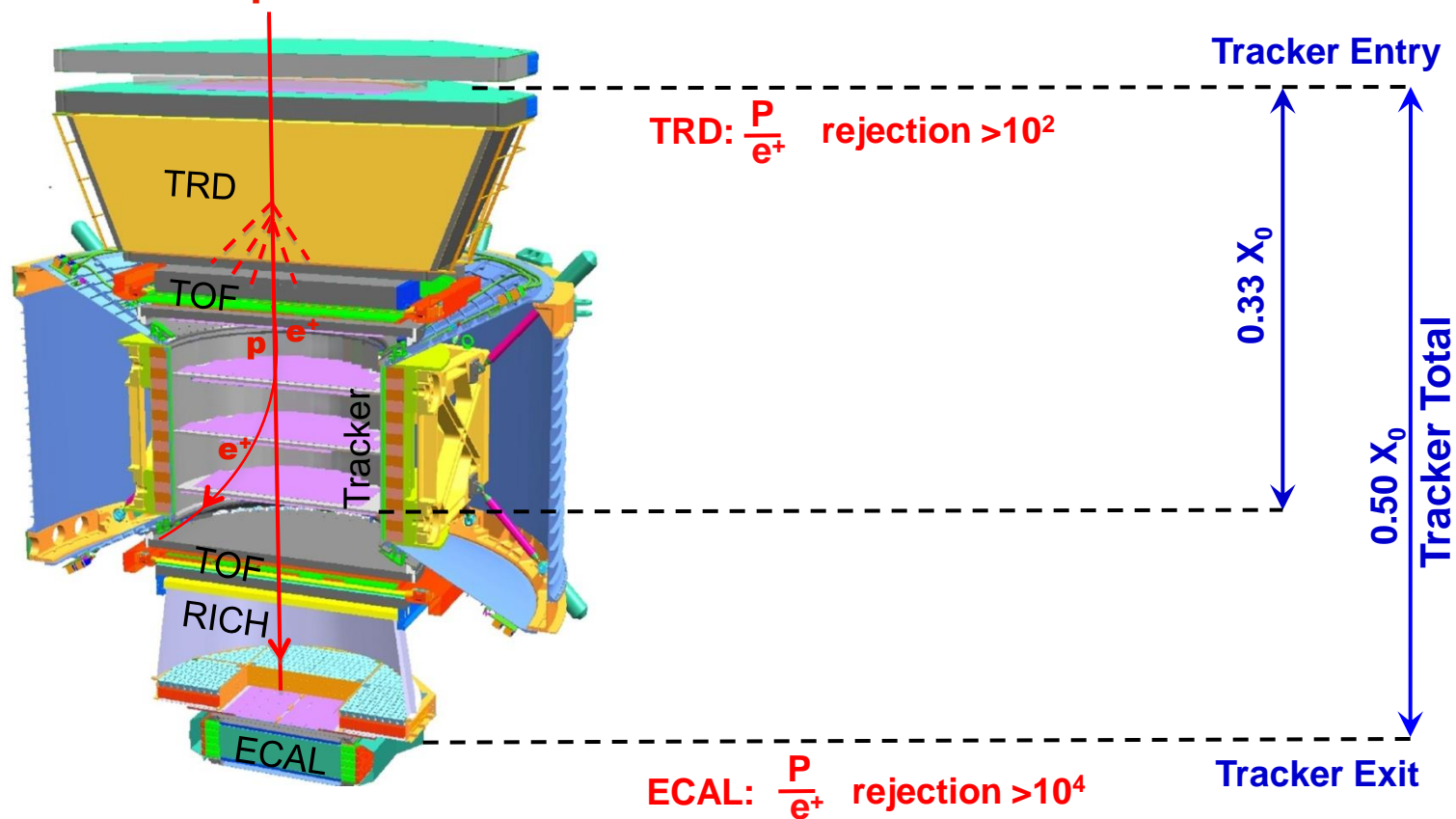
## b) Repetitive measurements of momentum

To ensure that particles which had large angle scattering are not confused with the signal.

# Physics of AMS: Search for the origin of Dark Matter:

Collision of Cosmic Rays produce  $e^+$  ...  
Collisions of Dark Matter will produce additional  $e^+$   
These characteristics of additional  $e^+$  can be measured very accurately  
by AMS

# Sensitive Search for the origin of Dark Matter with $p/e^+ > 10^6$



a) Minimal material in the TRD and TOF

So that the detector does not become a source of  $e^+$

b) A magnet separates TRD and ECAL so that  $e^+$  produced in TRD will be swept away and not enter ECAL

In this way the rejection power of TRD and ECAL are independent

c) Matching momentum of 9 tracker planes with ECAL momentum measurements

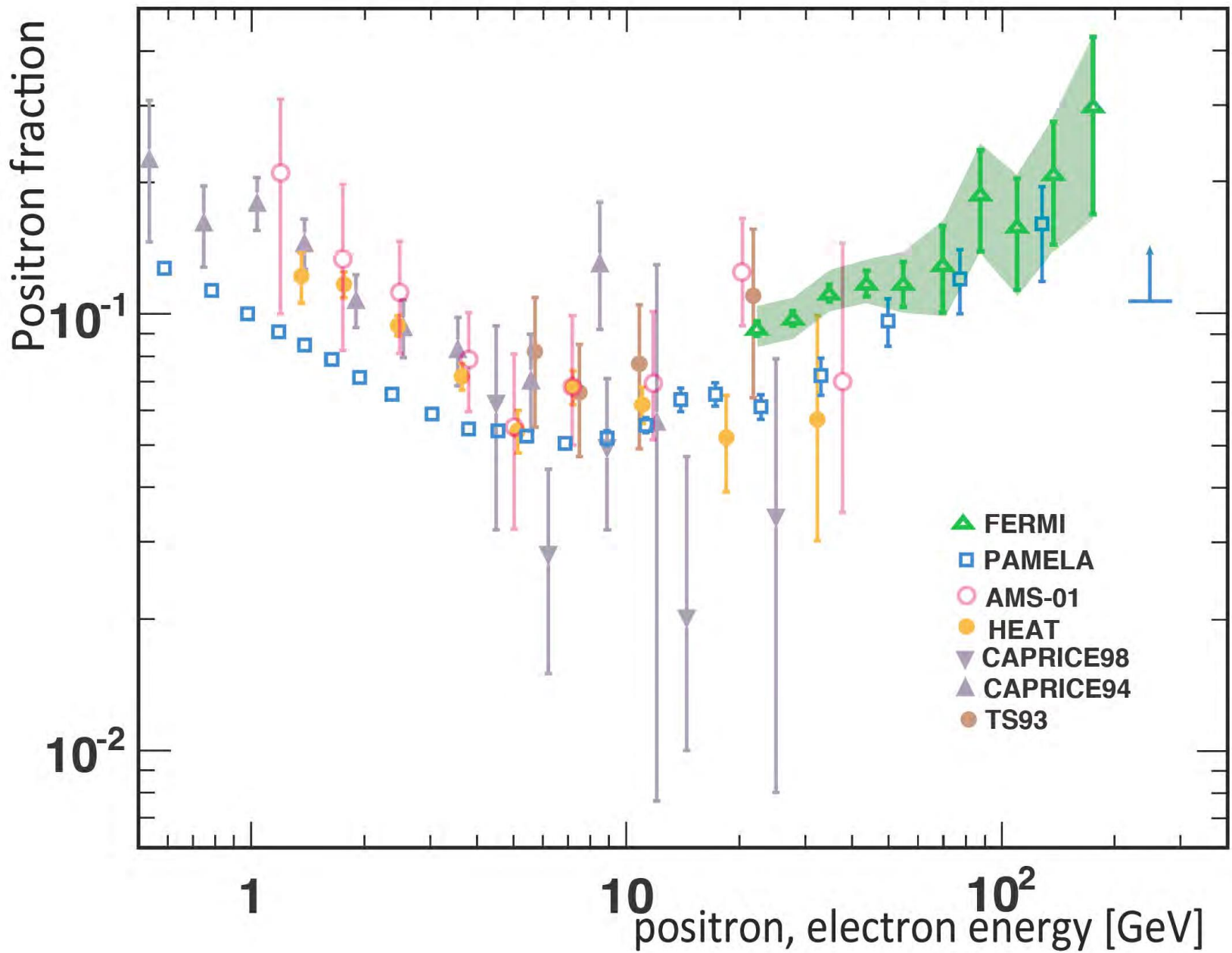


## First Data from AMS and detector performance

The detectors function exactly as designed and, in ten months, we have collected over 14 billion events.

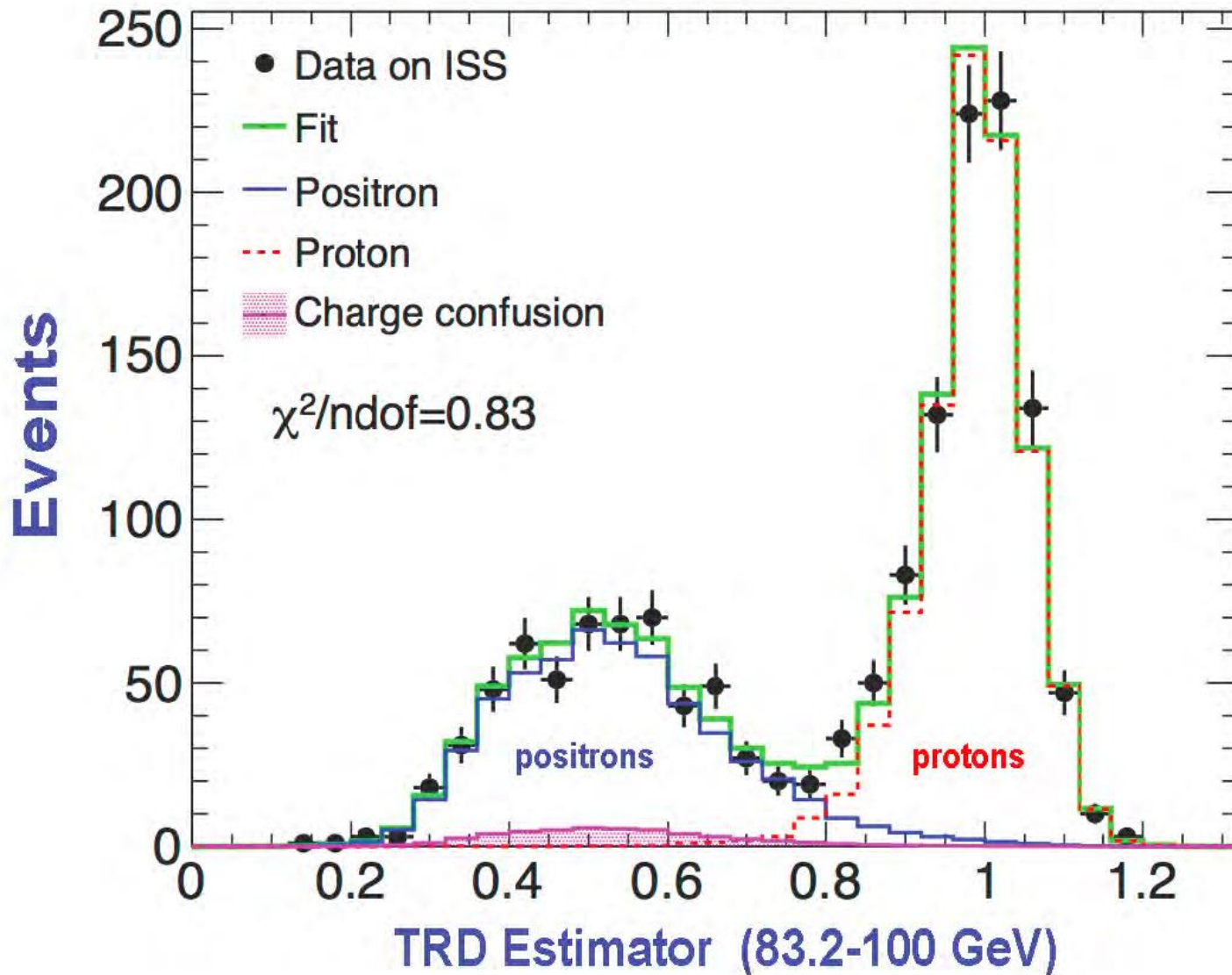
Every year, we will collect  $16 \cdot 10^9$  events and in 10-20 years we will collect  $160\text{-}320 \cdot 10^9$  events.

**Over the first eighteen months of operation in space AMS has collected over 25 billion events  
6.8 million are electrons or positrons**

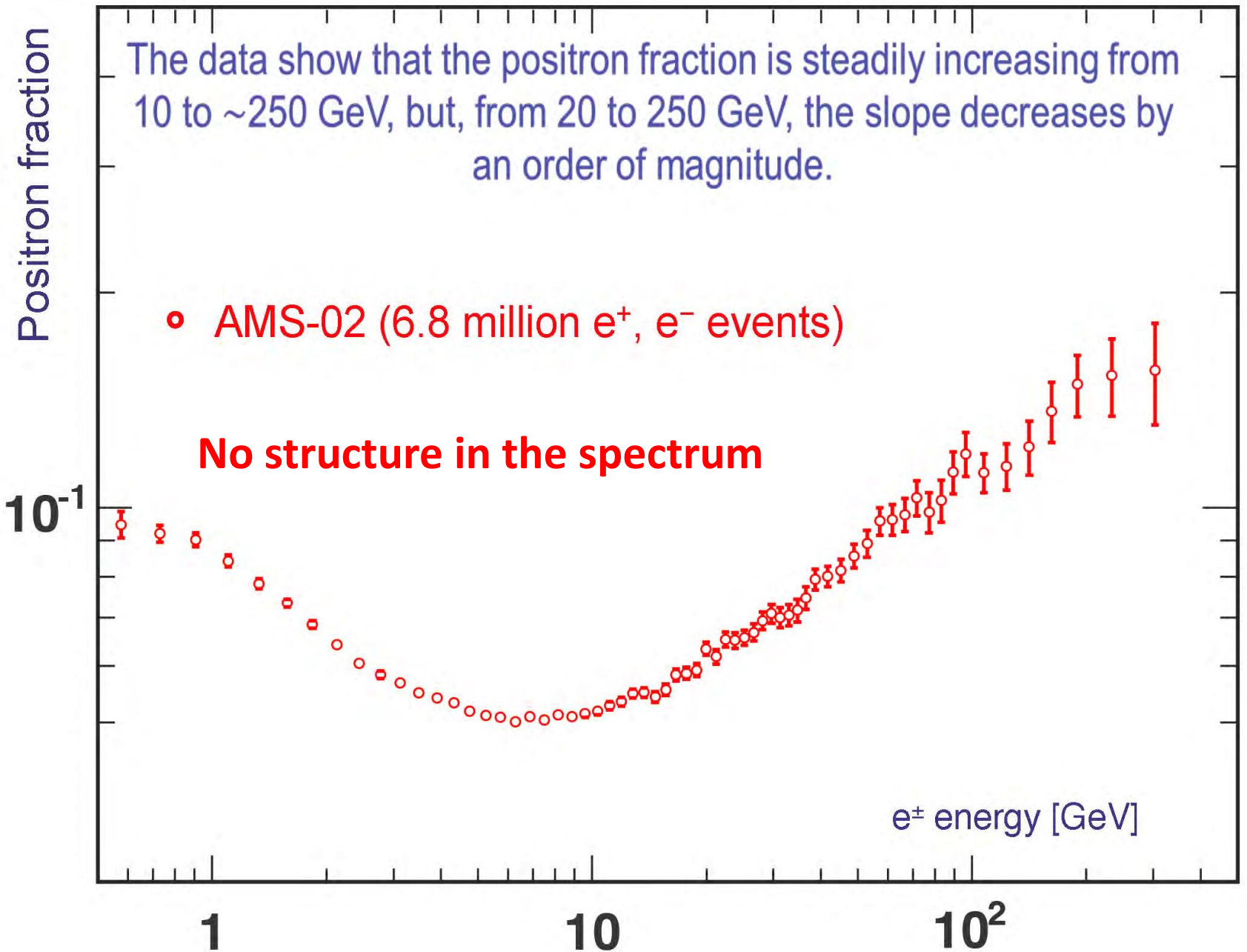


## Example of Positron Selection:

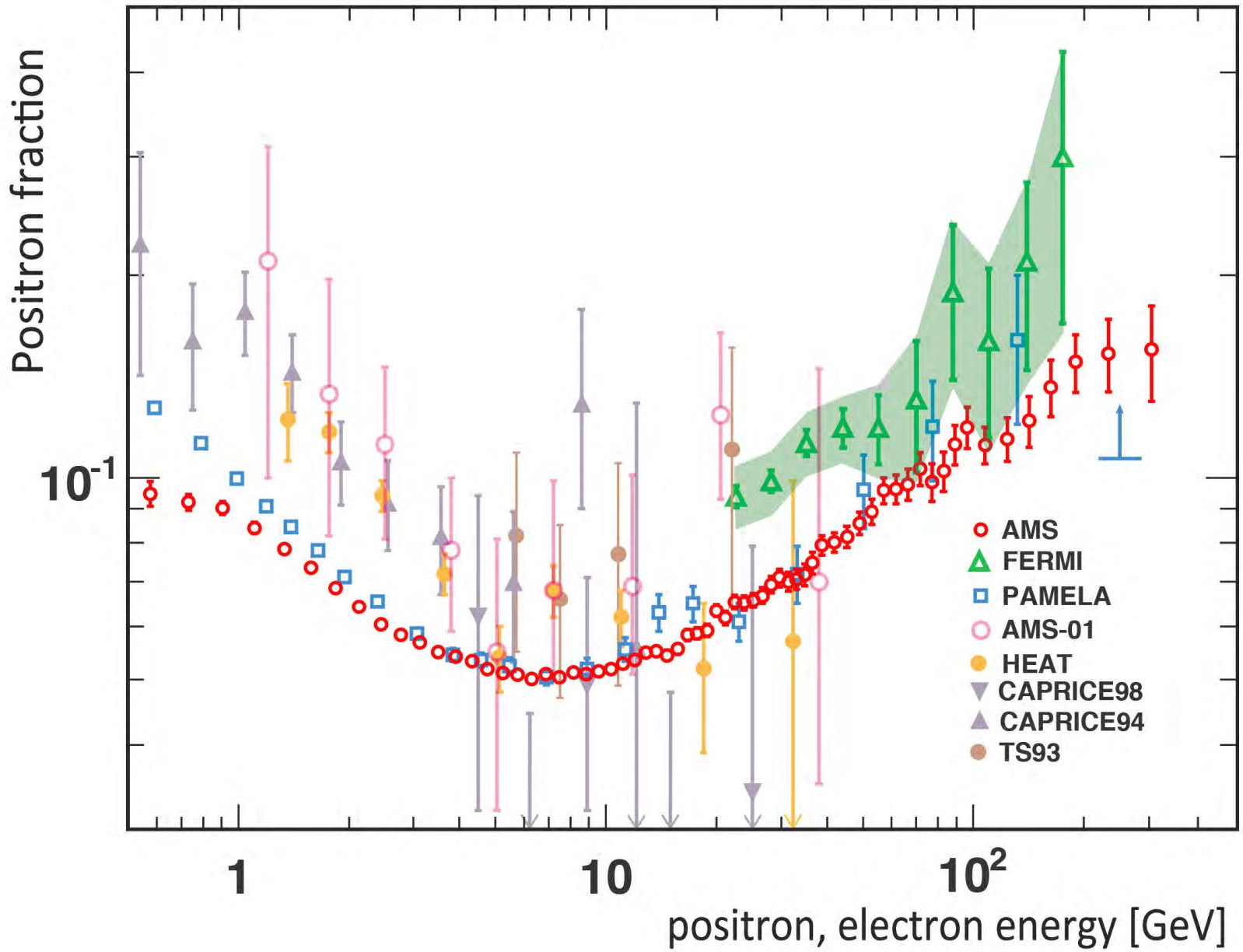
The TRD Estimator shows clear separation between **protons** and positrons with a small **charge confusion** background



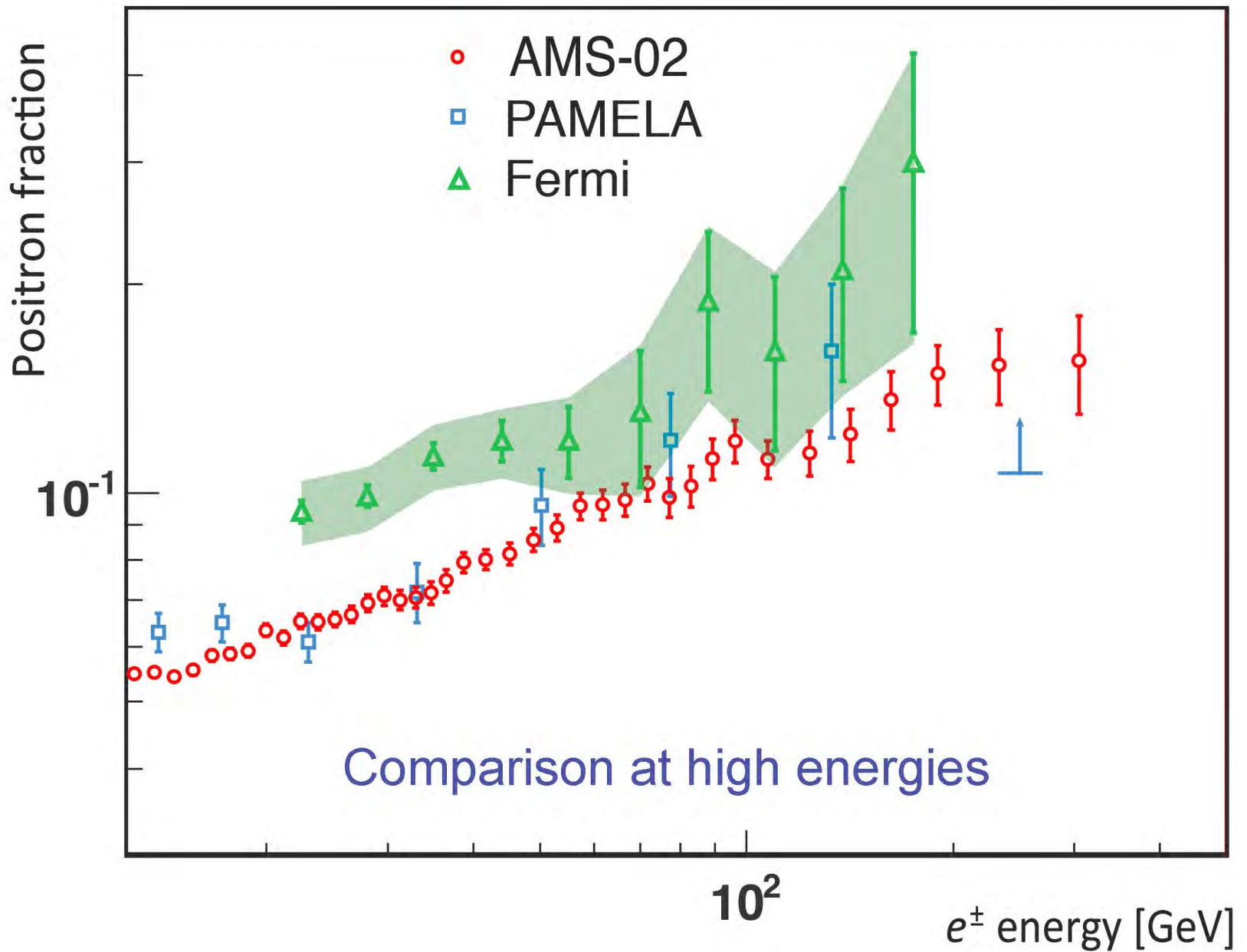


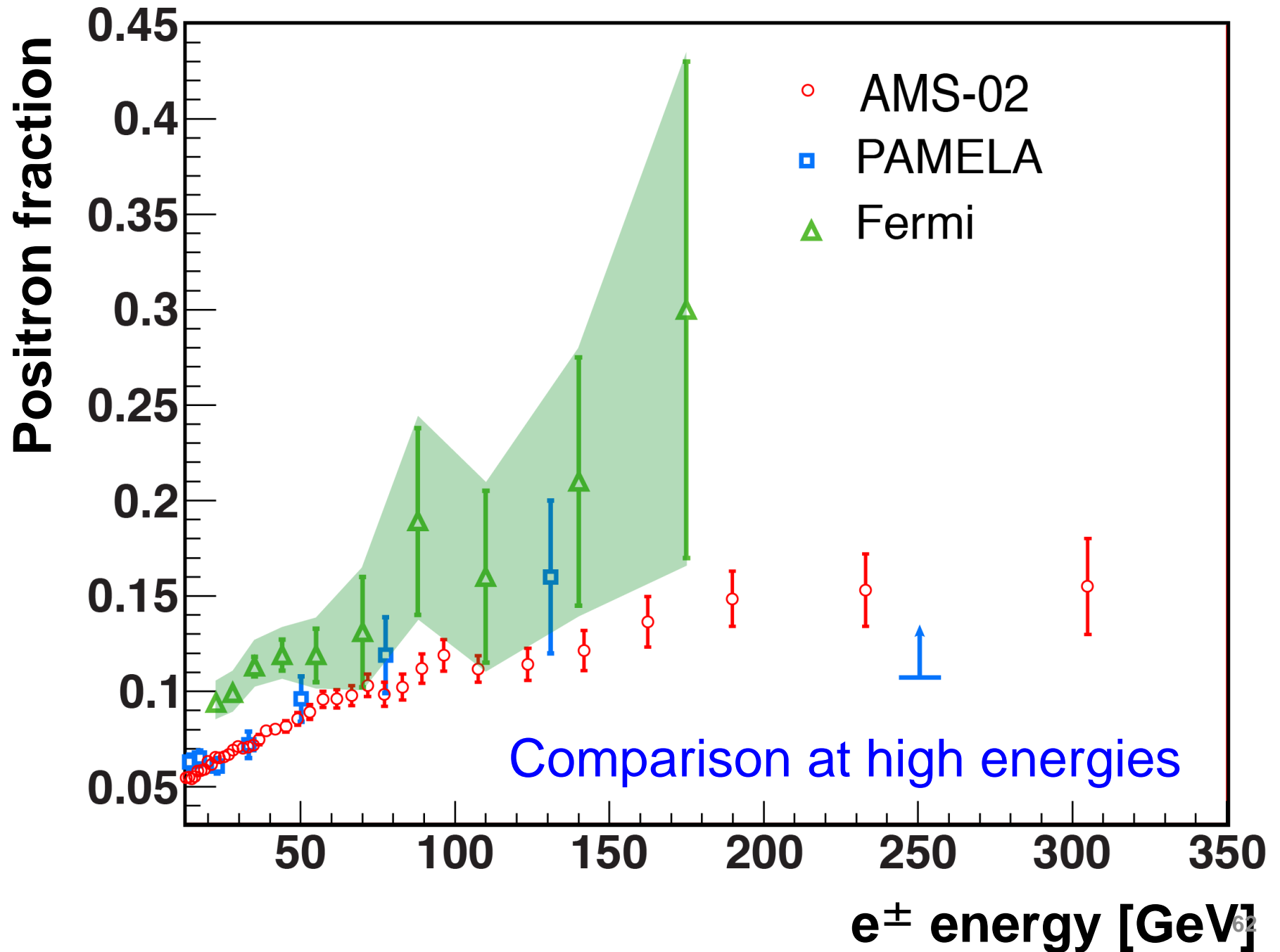


Positron events, positron fraction in each energy bin				Systematic Errors					
Energy [GeV]	$N_{e^+}$	Fraction	statistical error	acceptance asymmetry	event selection	bin-to-bin migration	reference spectra	charge confusion	total systematic uncertainty
Energy[GeV]	$N_{e^+}$	Fraction	$\sigma_{stat.}$	$\sigma_{acc.}$	$\sigma_{sel.}$	$\sigma_{mig.}$	$\sigma_{ref.}$	$\sigma_{c.c.}$	$\sigma_{syst.}$
33.80 -35.57	807	0.0718	0.0026	0.0001	0.0003	0.0000	0.0001	0.0004	0.0005
35.57 -37.40	787	0.0747	0.0027	0.0001	0.0003	0.0000	0.0001	0.0004	0.0005
37.40 -40.00	982	0.0794	0.0026	0.0002	0.0004	0.0000	0.0001	0.0004	0.0006
40.00 -43.39	976	0.0802	0.0026	0.0002	0.0005	0.0000	0.0001	0.0004	0.0007
43.39 -47.01	856	0.0817	0.0029	0.0002	0.0005	0.0000	0.0001	0.0004	0.0007
47.01 -50.87	739	0.0856	0.0032	0.0002	0.0006	0.0000	0.0001	0.0004	0.0008
50.87 -54.98	605	0.0891	0.0038	0.0002	0.0006	0.0000	0.0001	0.0004	0.0008
54.98 -59.36	558	0.0957	0.0041	0.0002	0.0008	0.0000	0.0001	0.0005	0.0010
59.36 -64.03	448	0.0962	0.0047	0.0002	0.0009	0.0000	0.0002	0.0006	0.0011
64.03 -69.00	392	0.0978	0.0050	0.0002	0.0010	0.0000	0.0002	0.0007	0.0013
69.00 -74.30	324	0.1032	0.0057	0.0002	0.0010	0.0000	0.0002	0.0009	0.0014
74.30 -80.00	276	0.0985	0.0062	0.0002	0.0010	0.0000	0.0002	0.0010	0.0014
80.00 -86.00	232	0.1023	0.0067	0.0002	0.0010	0.0000	0.0002	0.0010	0.0014
86.00 -92.50	240	0.1120	0.0075	0.0002	0.0010	0.0000	0.0003	0.0011	0.0015
92.50 -100.0	226	0.1189	0.0081	0.0002	0.0011	0.0000	0.0003	0.0012	0.0017
100.0 -115.1	304	0.1118	0.0066	0.0002	0.0015	0.0000	0.0003	0.0015	0.0022
115.1 -132.1	223	0.1142	0.0080	0.0002	0.0019	0.0000	0.0004	0.0019	0.0027
132.1 -151.5	156	0.1215	0.0100	0.0002	0.0021	0.0000	0.0005	0.0024	0.0032
151.5 -173.5	144	0.1364	0.0121	0.0002	0.0026	0.0000	0.0006	0.0045	0.0052
173.5 -206.0	134	0.1485	0.0133	0.0002	0.0031	0.0000	0.0009	0.0050	0.0060
206.0 -260.0	101	0.1530	0.0160	0.0003	0.0031	0.0000	0.0013	0.0095	0.0101
260.0 -350.0	72	0.1550	0.0200	0.0003	0.0056	0.0000	0.0018	0.0140	0.0152









In conclusion, the first 6.8 million primary positron and electron events collected with AMS on the ISS show:

- i. At energies  $< 10$  GeV, a **decrease** in the positron fraction with increasing energy.
- ii. A steady **increase** in the positron fraction from 10 to  $\sim 250$  GeV.
- iii. The determination of the behavior of the positron fraction from 250 to 350 GeV and beyond requires more statistics.
- iv. The slope of the positron fraction versus energy decreases by an order of magnitude from 20 to 250 GeV and no fine structure is observed.
- v. The positron to electron ratio is **consistent with isotropy**;  $\delta \leq 0.036$  at the 95% C.L.

**These observations show the existence of new physical phenomena, whether from a particle physics or an astrophysical origin.**



**Работа вызвала очень большой интерес: десяток публикаций только в апреле, через несколько дней после появления нашей статьи.**

A.De Simone, A. Riotto and W. Xue, arXiv:1304.1336

Interpretation of **AMS-02** Results: Correlations among Dark Matter Signals

Q. Yuan, X. -J. Bi, G. -M. Chen, Y. -Q. Guo, S. -J. Lin and X. Zhang, arXiv:1304.1482

Implications of the **AMS-02** positron fraction in cosmic rays

M. Ibe, S. Iwamoto, S. Matsumoto, T. Moroi and N. Yokozaki, arXiv:1304.1483 Recent

Result of the **AMS-02** Experiment and

Decaying Gravitino Dark Matter in Gauge Mediation

T. Linden and S. Profumo, arXiv:1304.1791

PROBING THE PULSAR ORIGIN OF THE ANOMALOUS POSITRON FRACTION

WITH AMS-02 AND ATMOSPHERIC CHERENKOV TELESCOPES

Cholis and D. Hooper, arXiv:1304.1840

Dark Matter and Pulsar Origins of the Rising Cosmic Ray Positron Fraction in Light of  
New Data From **AMS**

Y. Kajiyama, H. Okada and T. Toma, arXiv:1304.2680  
New Interpretation of the Recent Result of **AMS-02**  
And Multi-component Decaying Dark Matters  
with non-Abelian Discrete Flavor Symmetry

Q. Yuan and X-J. Bi, arXiv:1304.2687  
Reconcile the **AMS-02** positron fraction and Fermi-LAT/HESS total  $e^\pm$  spectra by  
the primary electron spectrum hardening

Peng-Fei Yin, Zhao-Huan Yu, Qiang Yuan and Xiao-Jun Bi, arXiv:1304.4128  
Pulsar interpretation for the **AMS-02** result

H. -B. Jin, Y. -L. Wu and Y. -F. Zhou, arXiv:1304.1997  
Implications of the first **AMS-02** measurement for  
dark matter annihilation and decay

J. Kopp, arXiv:1304.1184 (April 3, 2013)  
Constraints on dark matter annihilation from **AMS-02** results



# Источники позитронов высоких энергий это остатки взрывов сверхновых (SNR) и пульсары

-Ускорение в ударных волнах и магнитных возмущениях.

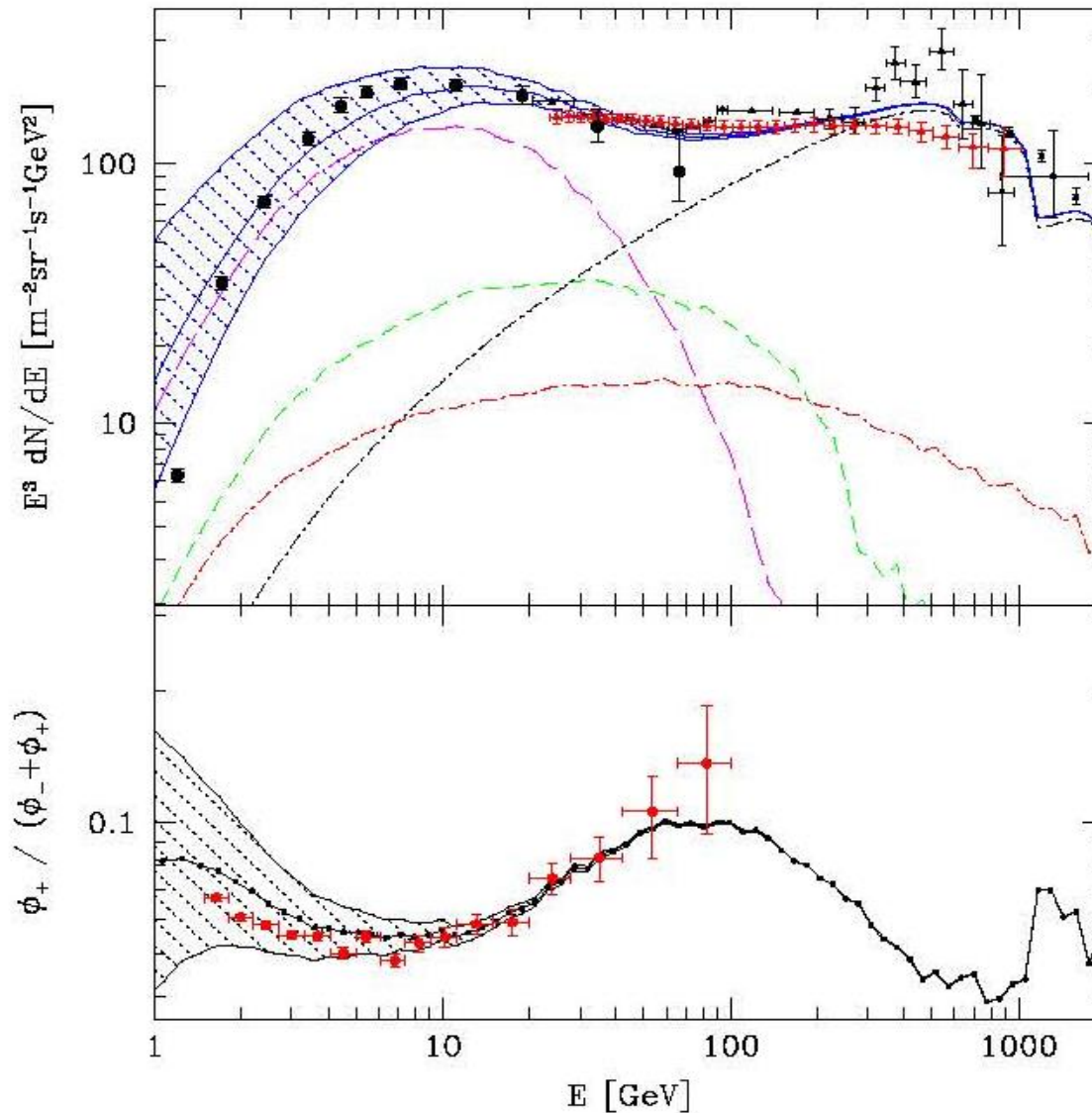
-Ускоренные космические лучи рожают вторичные электроны и позитроны в адронных взаимодействиях.

-Парное рождение в фотон-фотонных взаимодействиях.

-Парное рождение в магнитных полях.

-Аннигиляция или распад частиц темной материи.

# Predictions of inhomogeneous SNR Models compared with data.



Предсказания SNR моделей: В области 100 GeV доля  $e^+$  испытывает максимум, затем спад и осцилляции **в** **прямом** **противоречии** с данными АМС-02

# PULSARS

**Pulsars are strongly magnetized, rapidly rotating neutron stars that emit broad-band pulsed electromagnetic radiation . They are important particle accelerators.**

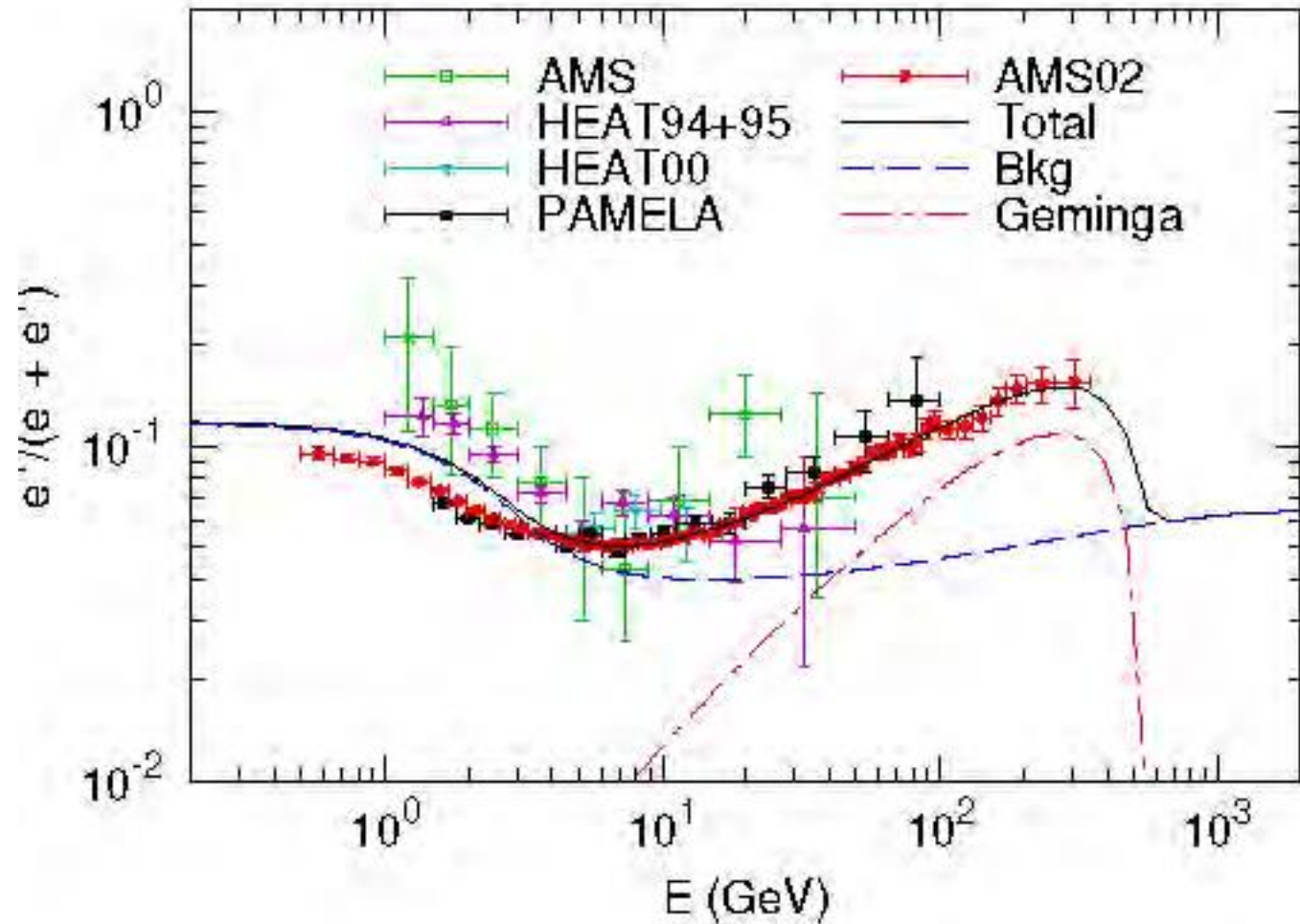
**Далее обсуждаются результаты совсем недавних работ по интерпретации наших данных**

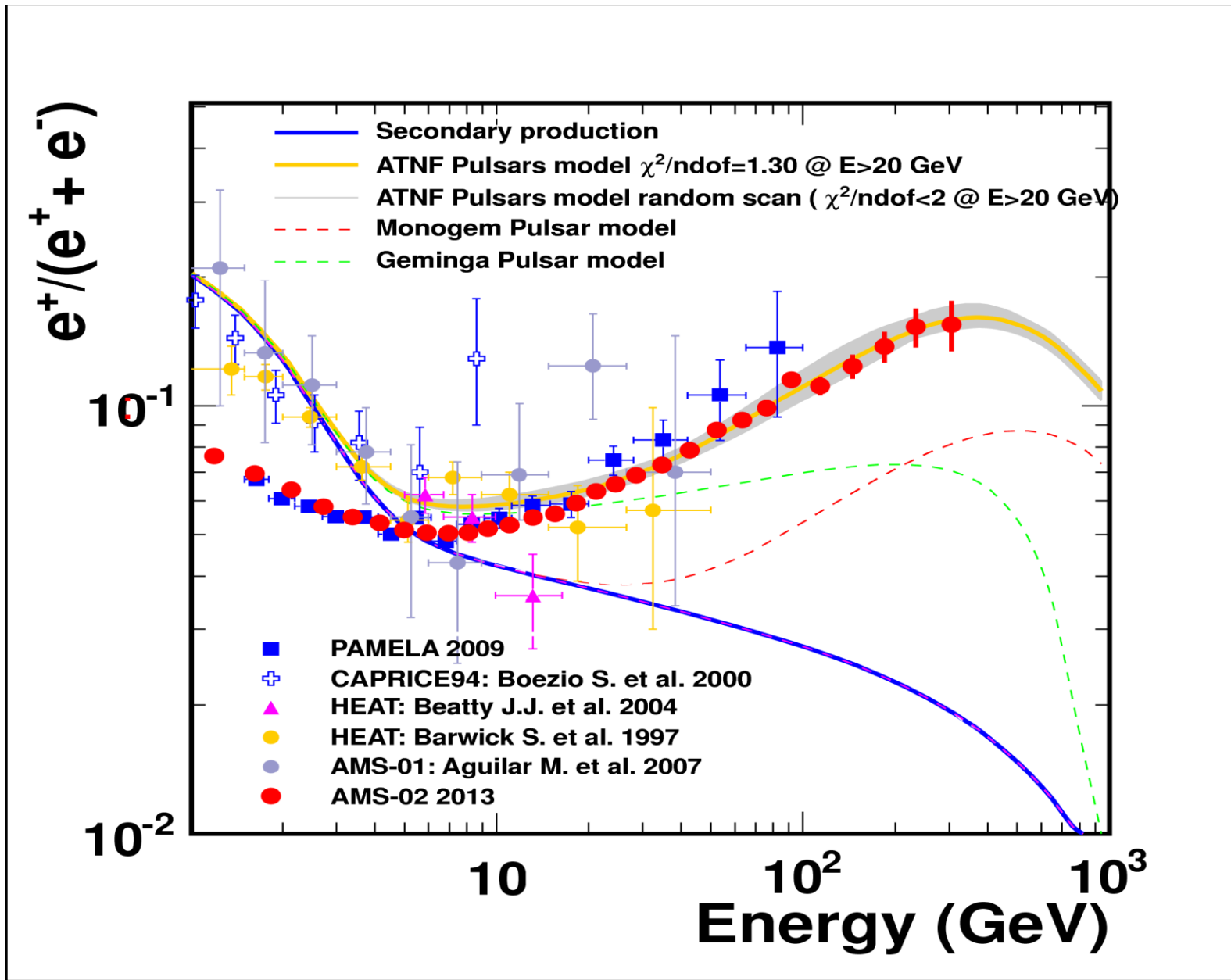


# Pulsar interpretation for the AMS-02 result

Peng-Fei Yin, Zhao-Huan Yu, et al

By fitting the data we find that the positrons from a single nearby pulsar, such as Geminga or Monogem, with the spectral index  $-2$  can interpret the AMS-02 result. We also investigate the possibility that high energy positrons are generated by multiple known pulsars in the ATNF catalogue. Such a scenario can also fit the AMS-02 data well.





**Если все электроны и позитроны происходят от одного пульсара, то можно думать, что возникнет пространственная анизотропия.**

**В тоже время электроны и позитроны, происходящие из темной материи пространственно изотропны.**

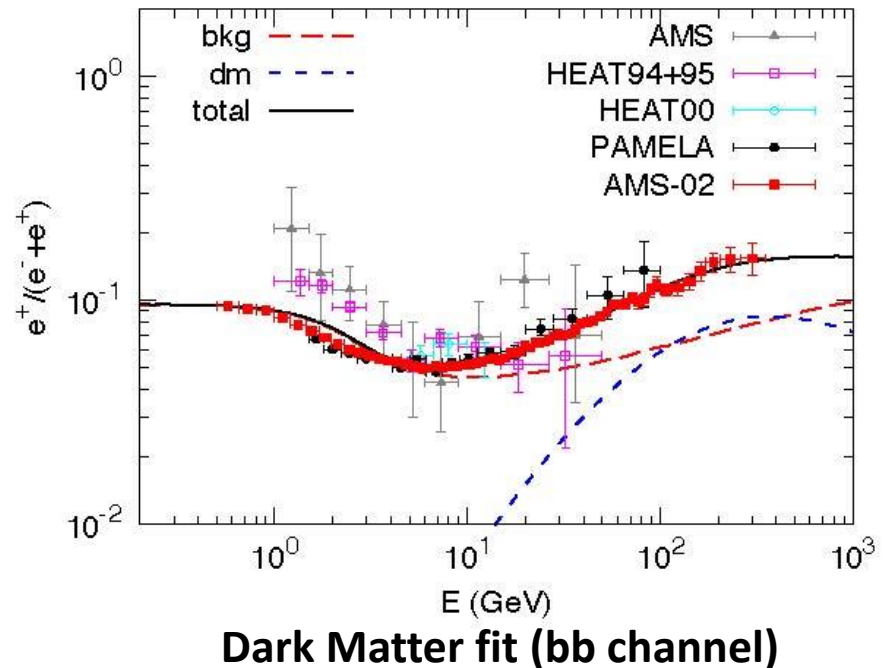
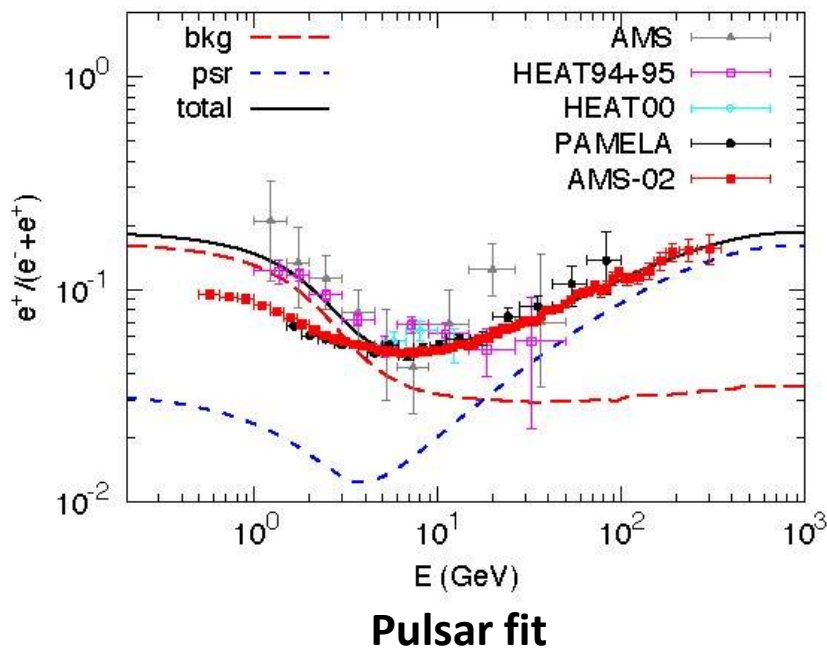
**Limits on the amplitude of a dipole anisotropy in any axis in galactic coordinates on the positron to electron ratio**

**$\delta \leq 0.036$  at the 95% confidence level**



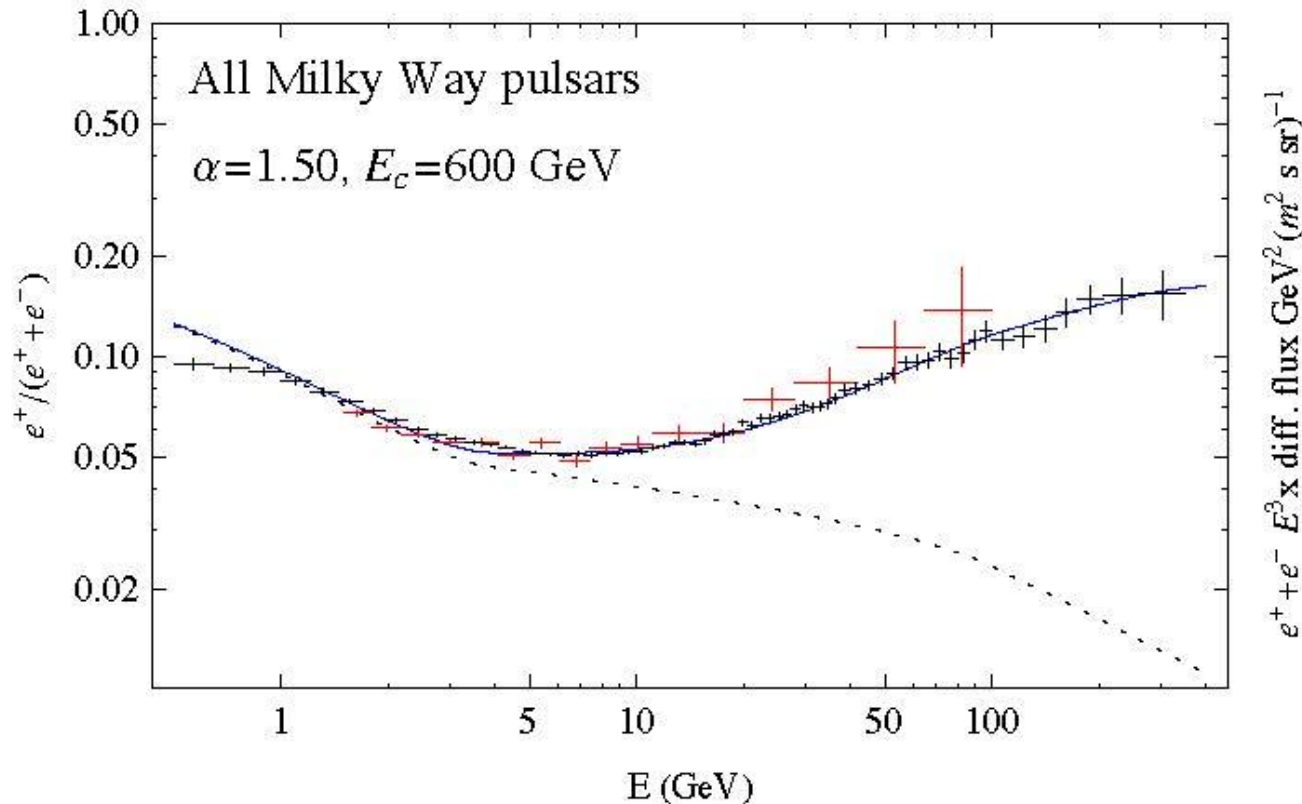
If we fit only the AMS-02 positron fraction and PAMELA electron spectrum data **both the pulsar and DM** annihilates/decays into  $\tau^+\tau^-$ ,  $W^+W^-$  and  $b^+b^-$  **can fit the data.**

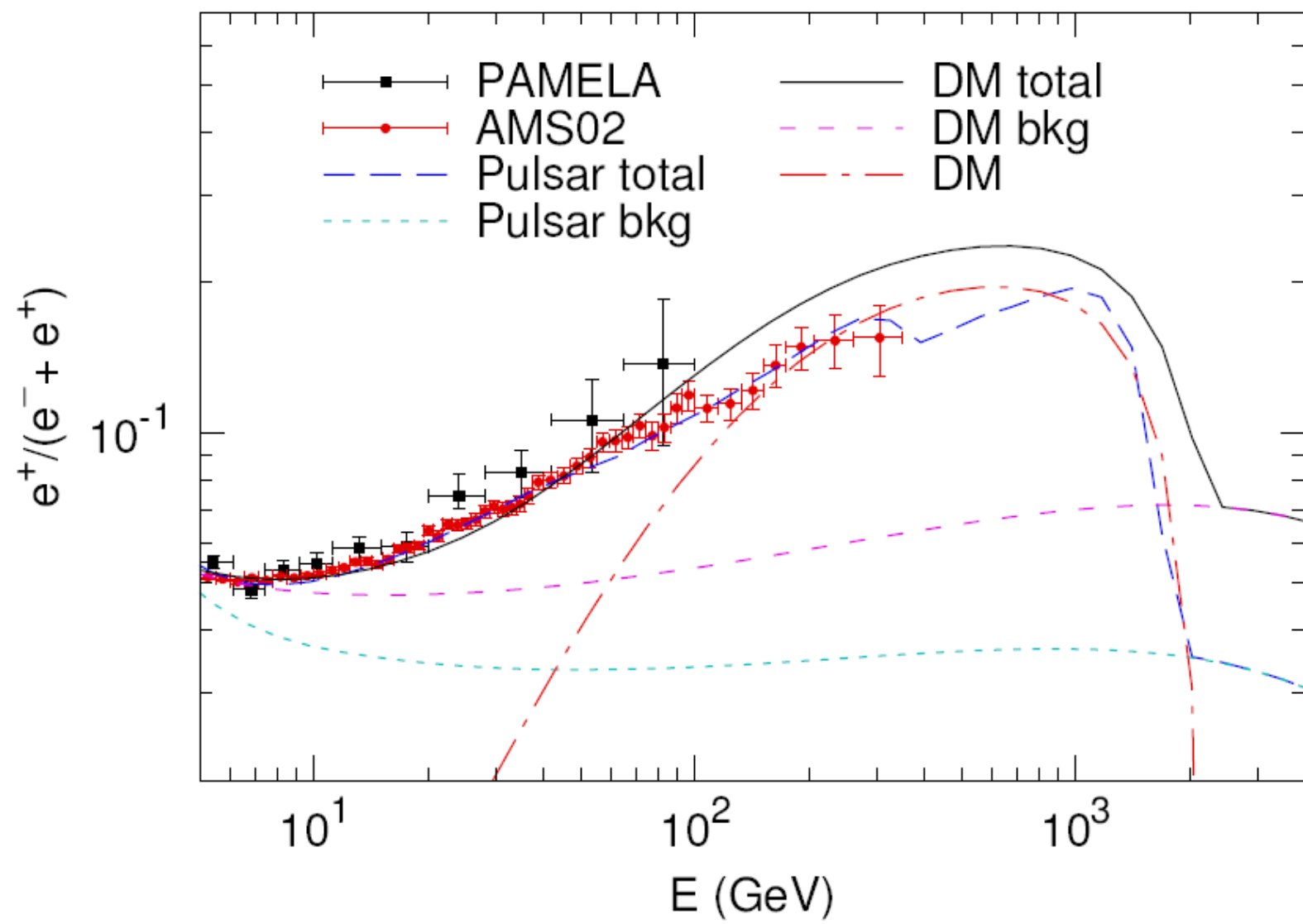
Our study illustrates the remarkable potential on understanding the physics of the  $e^\pm$  excesses from the very precise measurement done by AMS-02.



## Pulsar fit

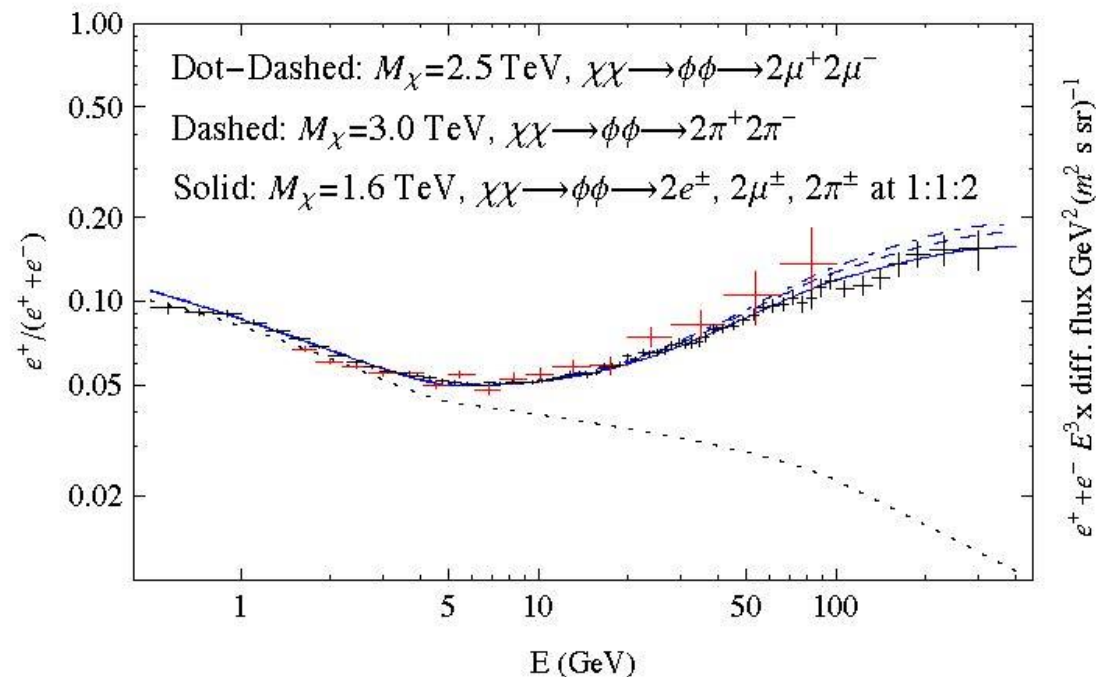
**For reasonable choices of spectral parameters and spatial distributions, the sum of all pulsars in the Milky Way could account for the observed positrons.**







**We find that models in which the dark matter annihilates directly to leptons are no longer capable of producing the observed rise in the positron fraction. Models in which dark matter annihilates to light intermediate states which then decay into combination of muons or pions can accommodate the new data.**



The inhomogeneous distribution of supernova remnants model has a prediction that the positron-to-electron ratio is expected to decrease above an energy  $\sim 100\text{GeV}$ .

The pulsar model, instead, **predicts an increasing positron-to-electron ratio up to the energy  $\sim 1\text{TeV}$** . Both the inhomogeneous SNR model and the pulsar model predict a possible wobble-like structure in the TeV energy range.

**Модель с неоднородным распределением остатков взрыва сверхновой предсказывает уменьшение отношения  $e^+/e^-$  при энергиях выше 100 Гэв.**

**Модель с пульсарами наоборот предсказывает рост этого отношения вплоть до 1 Тэв.**

The models assume that the detected cosmic ray  $e^+$  excesses are due to one physical process. In reality it is possible that the detected excesses are mainly contributed by astrophysical processes, and the DM annihilation/decay signals are outshone. **If so, the extraction of the DM properties via indirect detection experiments would be even more challenging.**

В моделях предполагается, что избыток  $e^+$  возникает только в одном физическом процессе. На самом деле вполне возможно, что наблюдаемый избыток в основном происходит из астрофизических процессов а сигнал темной материи теряется на этом фоне.



Since electroweak corrections induce correlations among the fluxes of stable particles from dark matter annihilations, the recent AMS-02 data imply a well-defined **prediction for the correlated flux of antiprotons.**

Если избыток позитронов связан с темной материей, аналогичный избыток должен наблюдаться, например, в антипротонах, в противном случае интерпретация избытка позитронов, как проявления темной материи, не проходит.

## Отсюда немедленно следуют ближайшие задачи АМС:

- Увеличение энергии (т.е. статистики)
- Падает ли  $e^+$ -
- Наблюдение антипротонов
- Наблюдение ядер бора / углерода

**Благодарю за внимание**







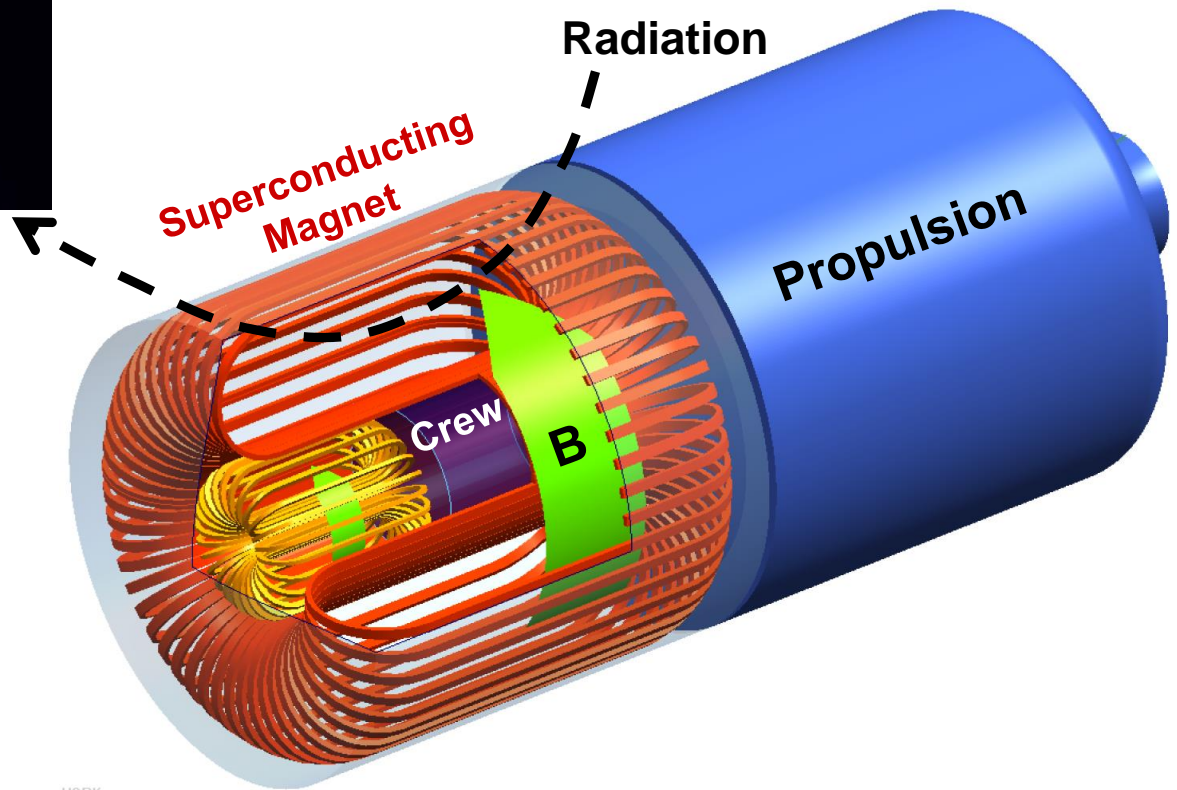
# Applications of AMS Technology to Exploration to Mars:



1. Trip duration: 3 years

2. Cosmic radiation is ~ 90 rem/y  
**Lethal dose ~ 300rem**

3. **Radiation Protection**



**YANKEE GO HOME!**

**MARS  
FOR  
MARTIANS**

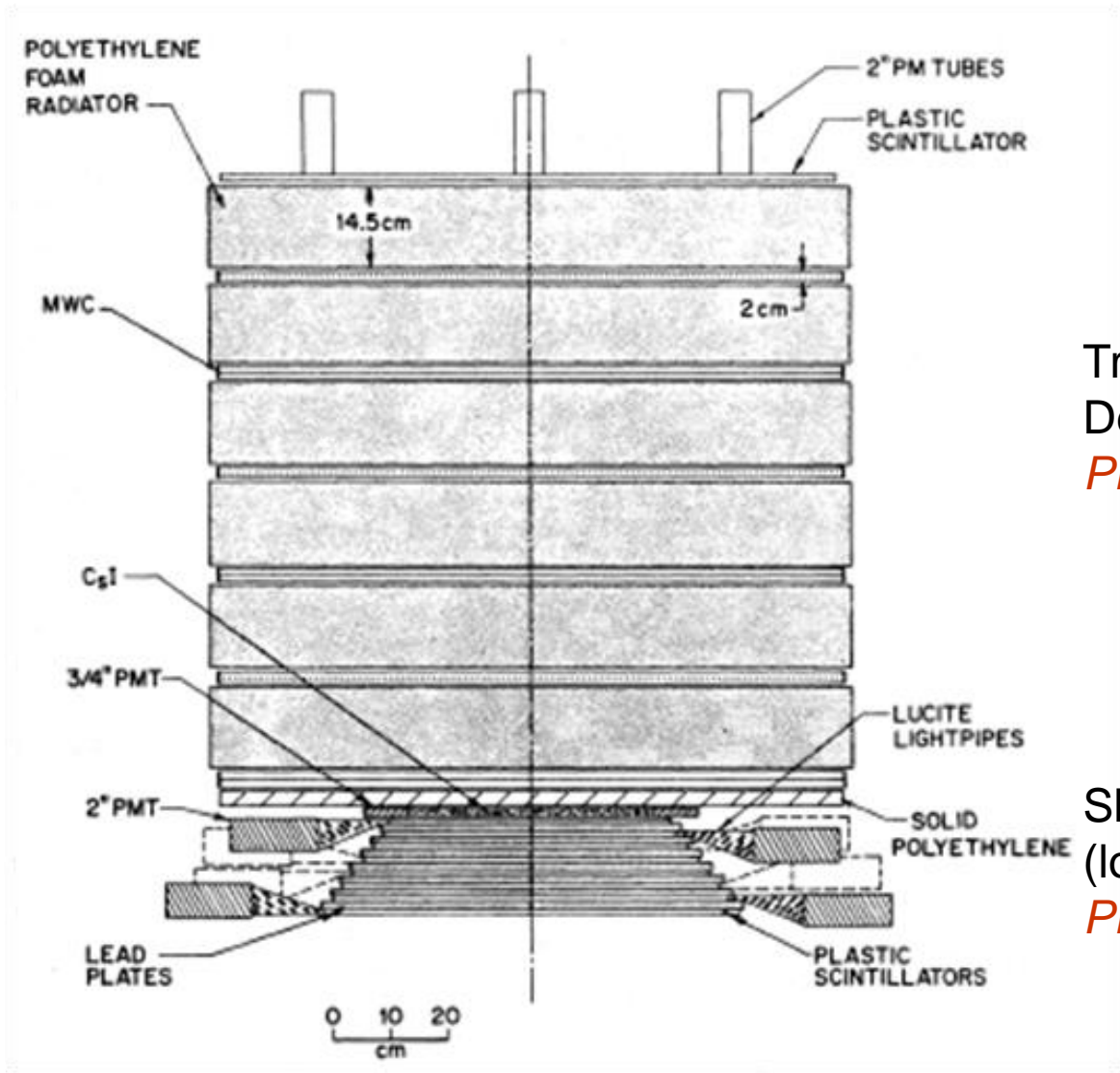


**MARK YOUR  
SPIRIT**





# “TREE” INSTRUMENT (Chicago 1970's) *measures $e^+ + e^-$*



Transition Radiation  
Detector (TRD):  
*Proton rejection 100*

Shower Counter  
(longitudinal profile)  
*Proton rejection 100*

# The highest energy particles are produced in the cosmos

**Primary Cosmic Ray interacts with the atmosphere and produces secondary particles**



**Largest Accelerator on Earth (LHC) will produce particles of 7 TeV**



**Cosmic Rays with energies about 100 Million TeV have been detected.**