Recent cosmic-ray e^- and e^+ results

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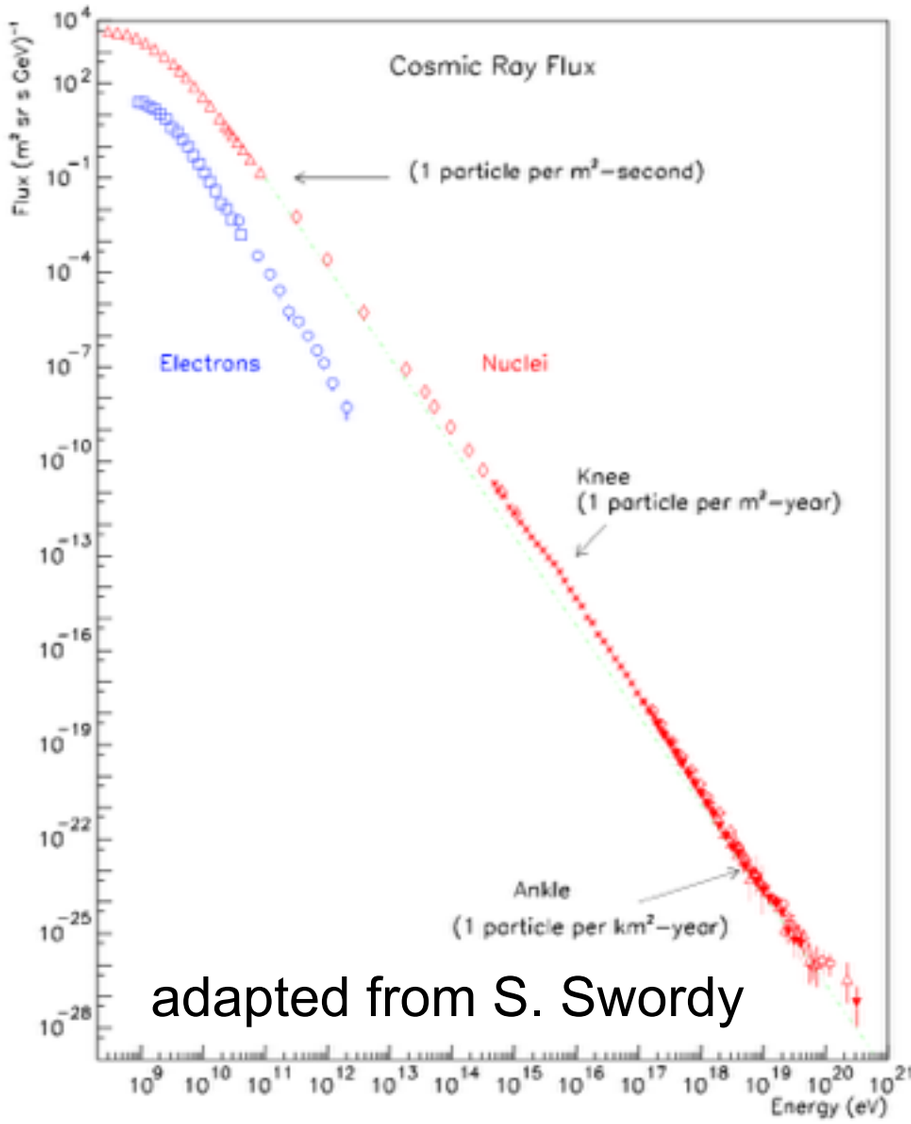
Why studying CR electrons and positrons?

- Only minor fraction of cosmic rays (<1%)
- But with complementary characteristics
  - strong radiative losses
  - short lifetimes and propagation distances
- Rather than probing the Galactic “average”, sensitivity to small-scale differences in the source distribution
- The larger the energy the smaller the scales: 1 TeV electrons are $<10^5$ years young and have traversed distances <1 kpc
- TeV electrons give us a snapshot of our local neighbourhood



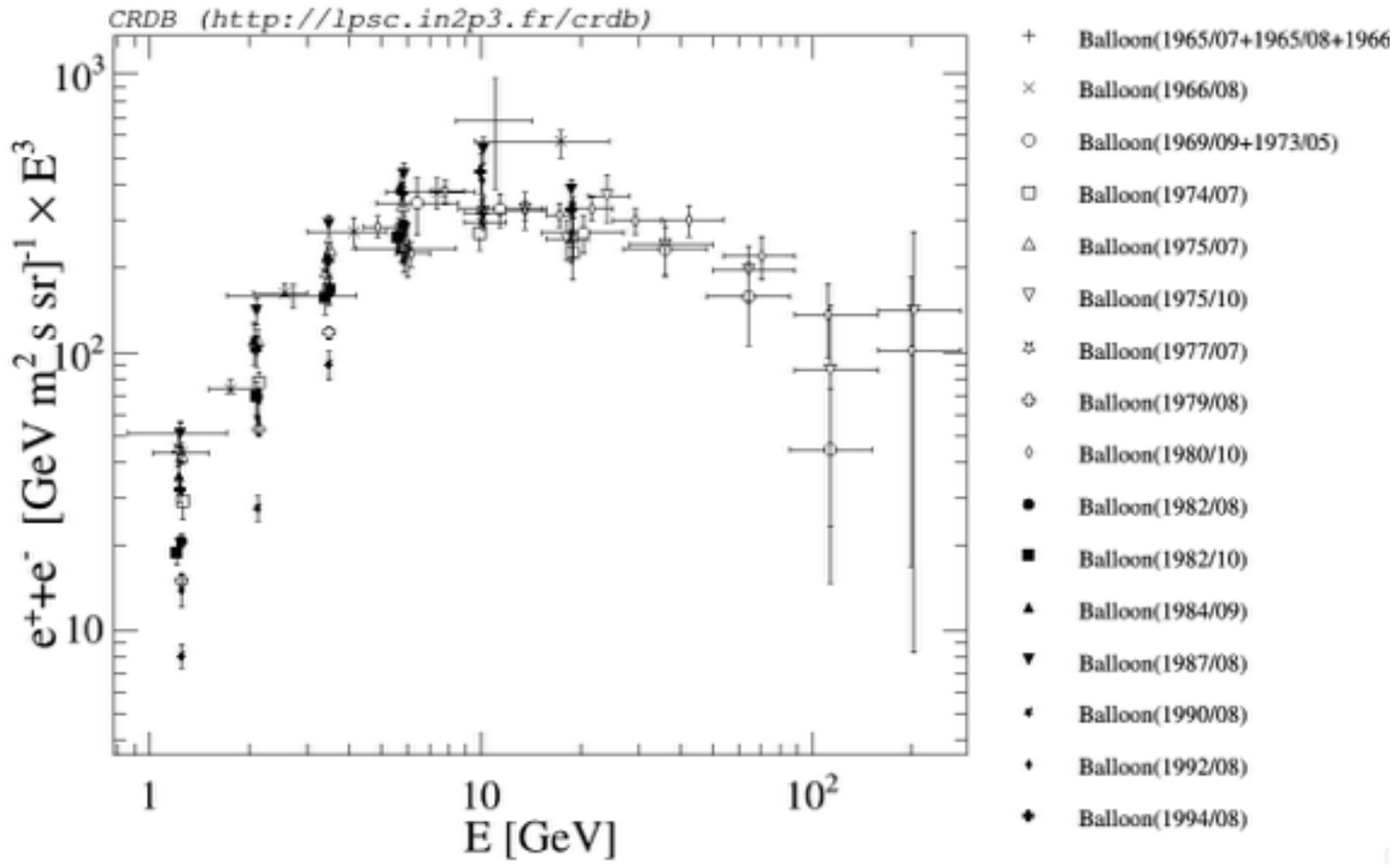
adapted from S. Swordy

e^- and e^+ measurements

Observables	Requirements
e^-+e^+ spectrum	calorimeter
e^+/e^-+e^+	magnet
anisotropy	direction reconstruction, high statistics, good control of systematics

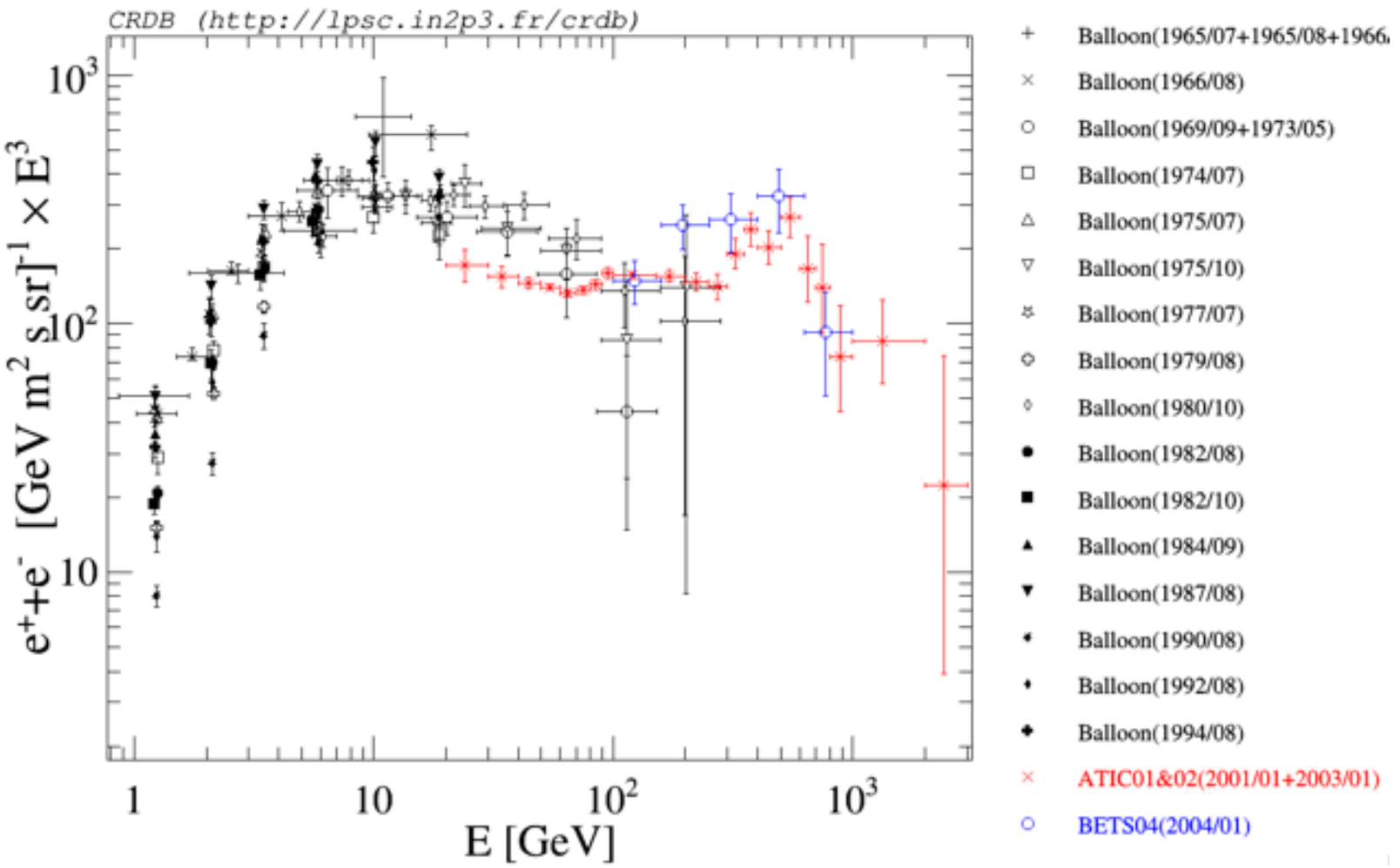
e^- and e^+ measurements: spectrum

- As of the 90's, measurements exclusively by balloon experiments
- Low intensity, large CR p background
  → need for large acceptance, long exposure & excellent e/p separation
- Turn at ~10 GeV, beyond that energy, steep spectrum with spectral index ~-3.3
- Running out of statistics at ~100 GeV



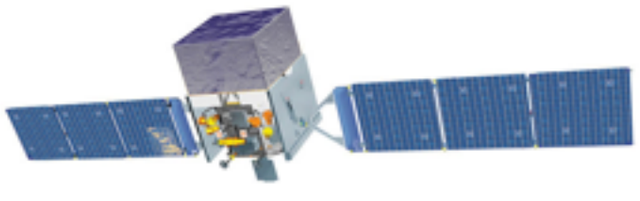
e^- and e^+ measurements: spectrum

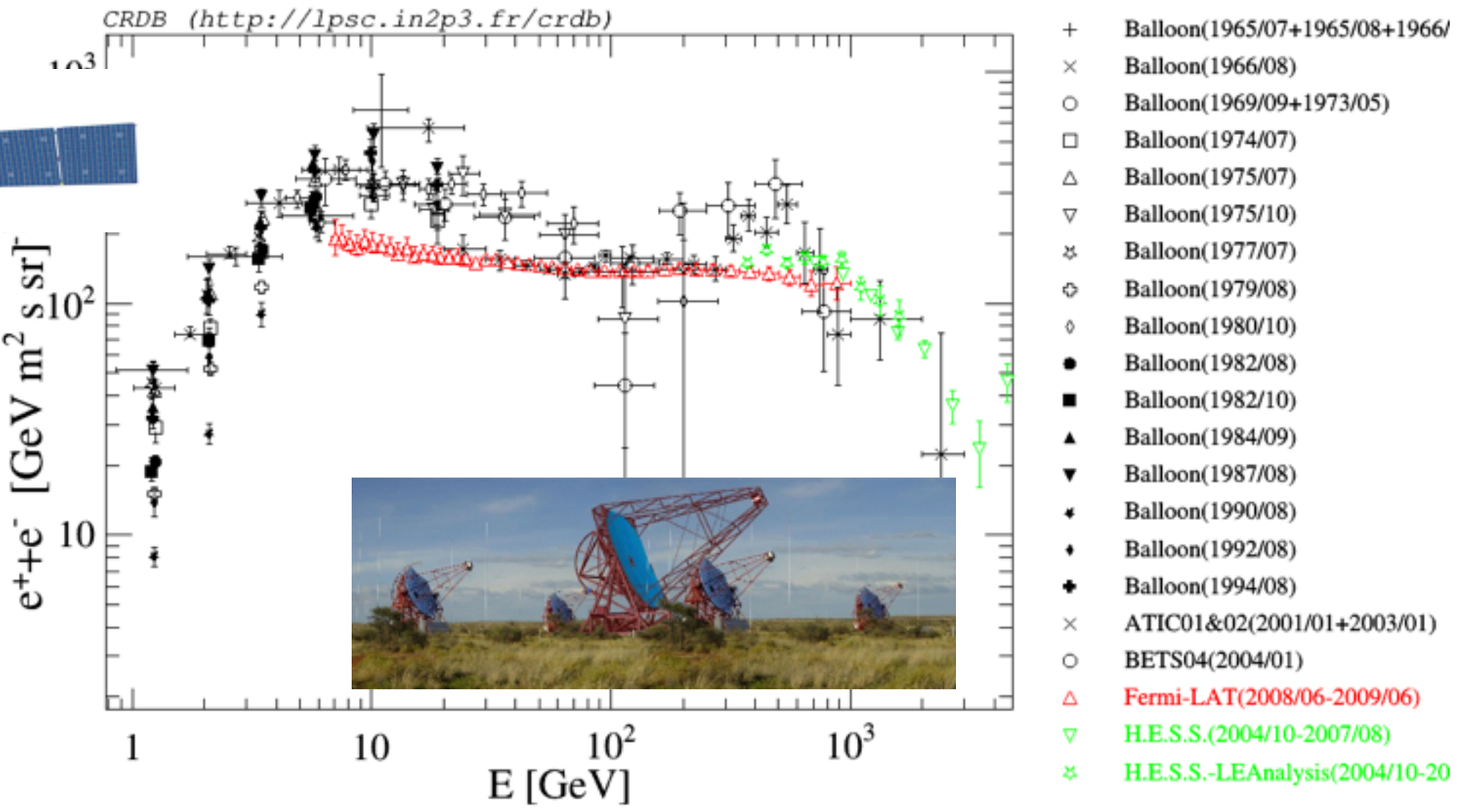
- Atic and PPB-Bets: extension to ~1 TeV
- Data suggest a signal of Kaluza-Klein dark matter in the spectrum



e^- and e^+ measurements: spectrum

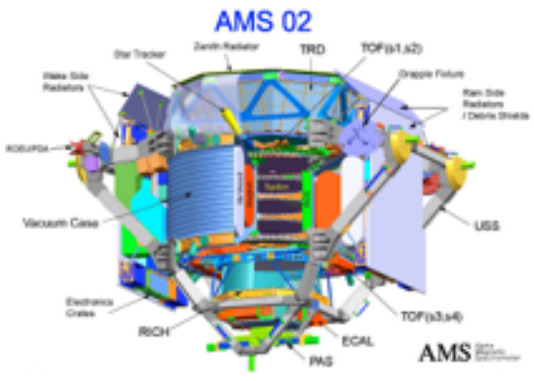
- Ruled out by high-statistics Fermi-LAT and H.E.S.S. data, now covering an energy range from few GeV to multiple TeV
- Spectrum flatter than thought before, with sharp break at around a TeV

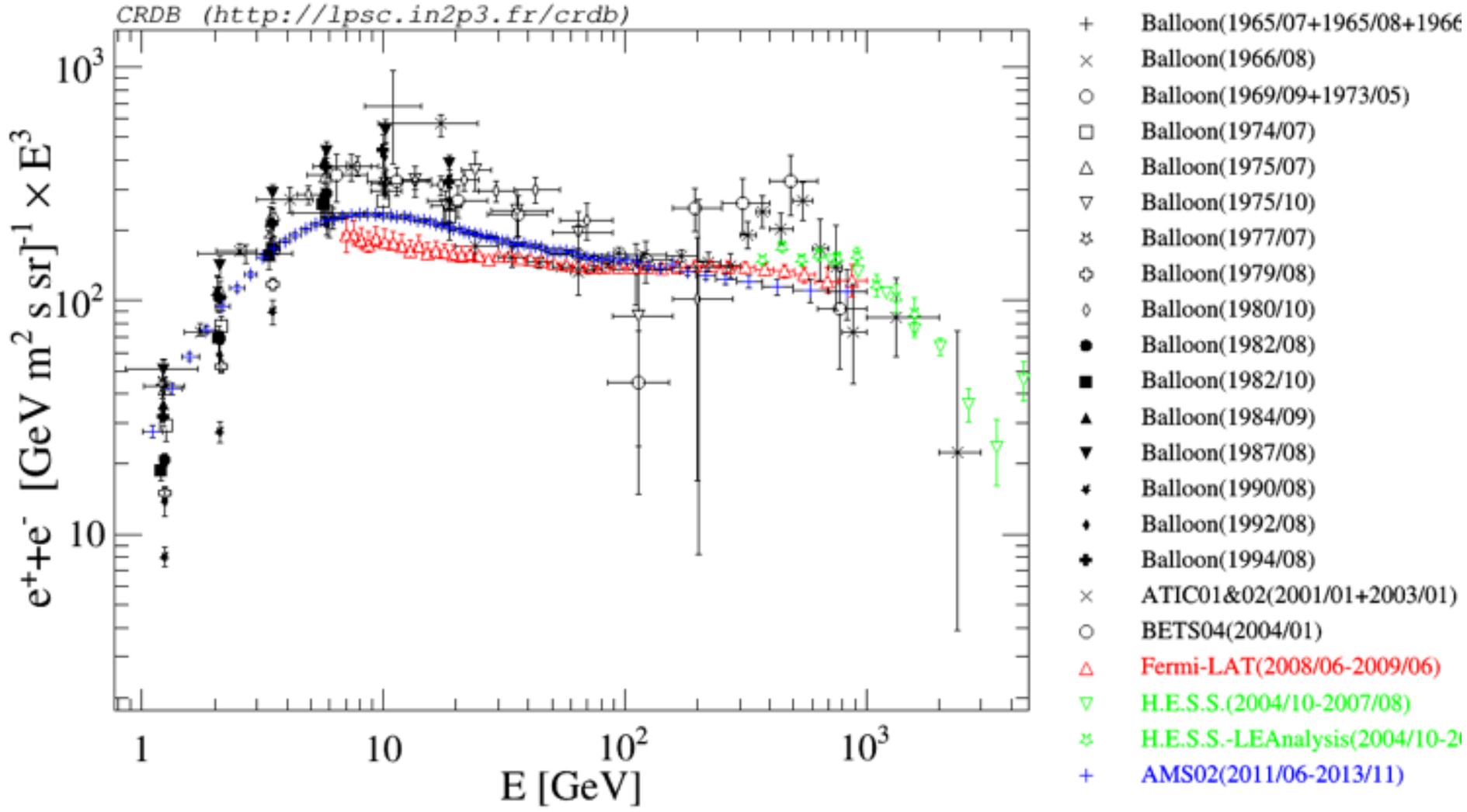




e^- and e^+ measurements: spectrum

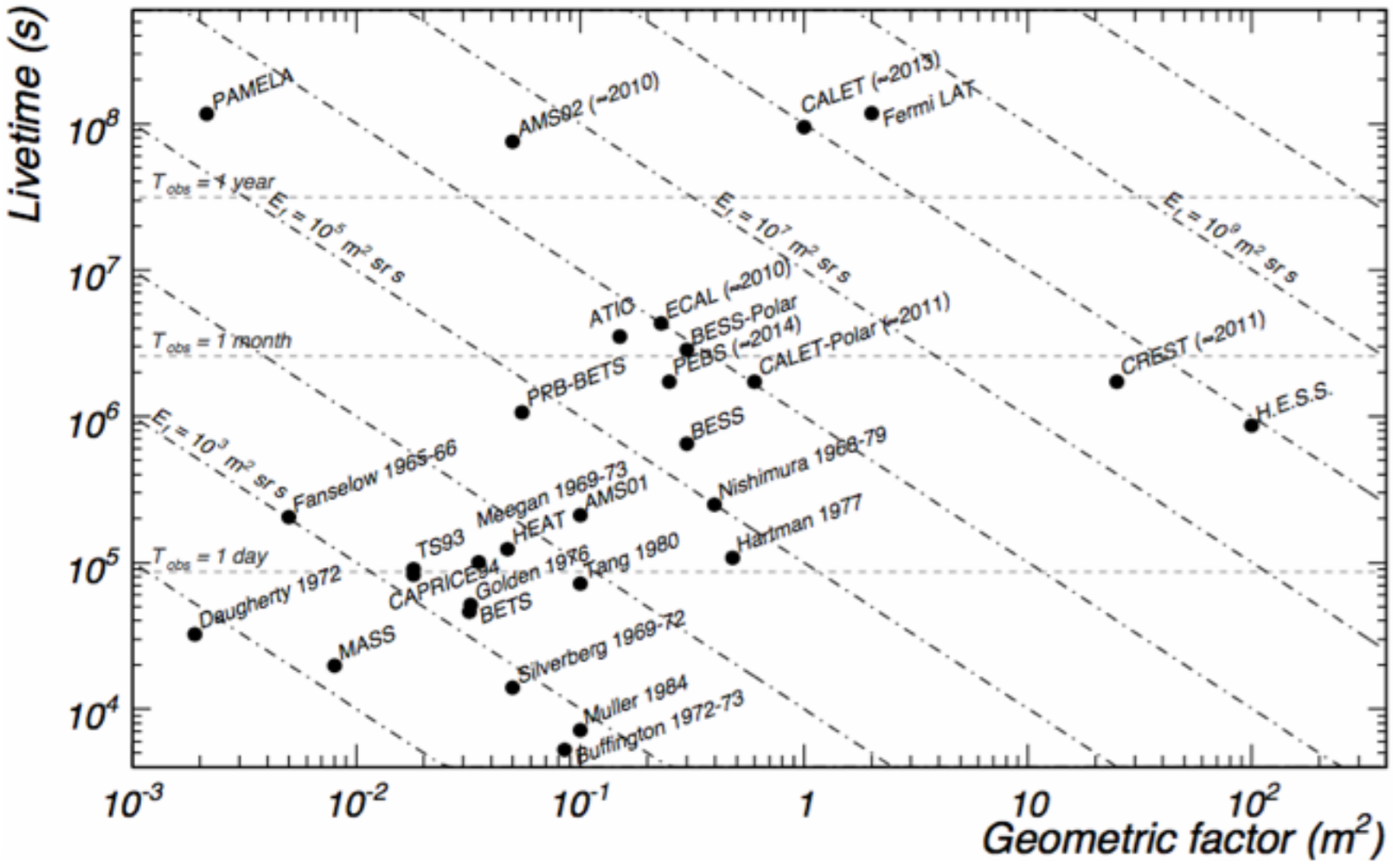
- With AMS-02 high-statistics measurements starting from ~1 GeV
- Some tension between Fermi-LAT and AMS-02 data?





How to obtain good statistics

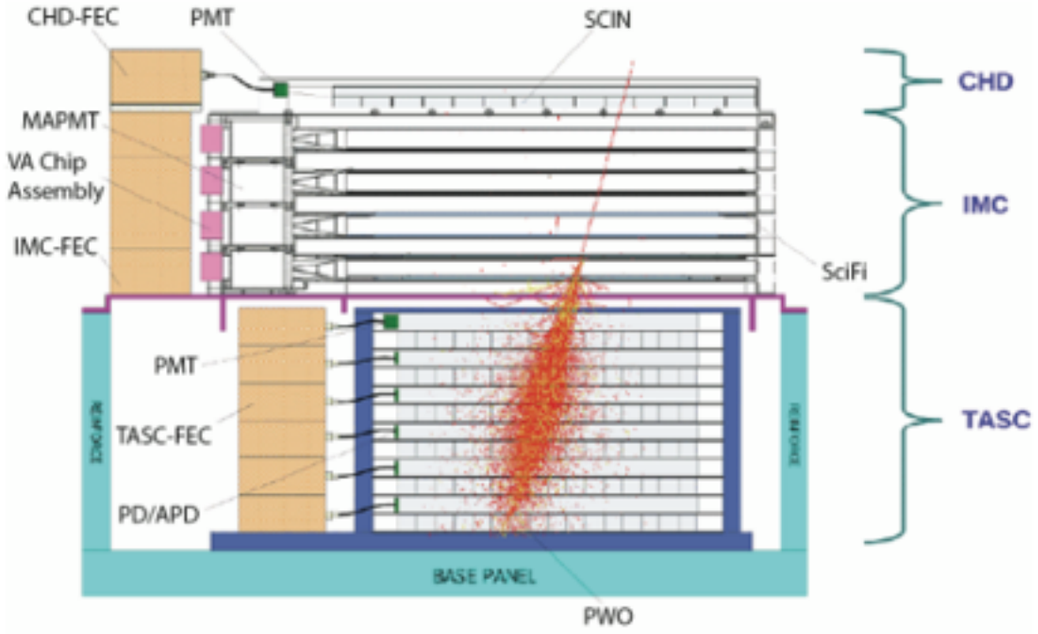
- Large livetimes and geometric factors (A_{eff} (E) * Ω(E))
- Instruments with many years of observation time compete with large detection area/large field of view experiments

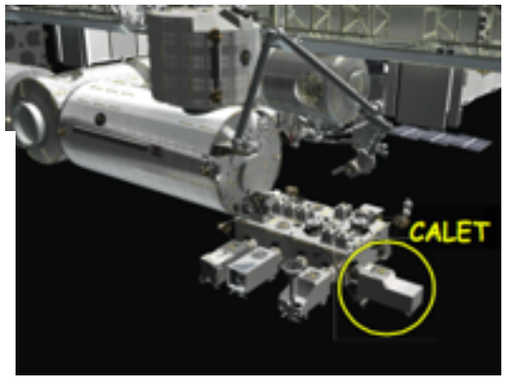


from L. Baldini

Statistics are not everything – even higher energies?

- Also needed: detector depth and capability to resolve TeV energies
- Satellites with denser detectors:
  CALET: fully active calorimeter with 30 X_0, launched August 2015
  DAMPE: 31 X_0, launched Dec 2015, **GAMMA-400**: 54 X_0, planned for 2023-2025





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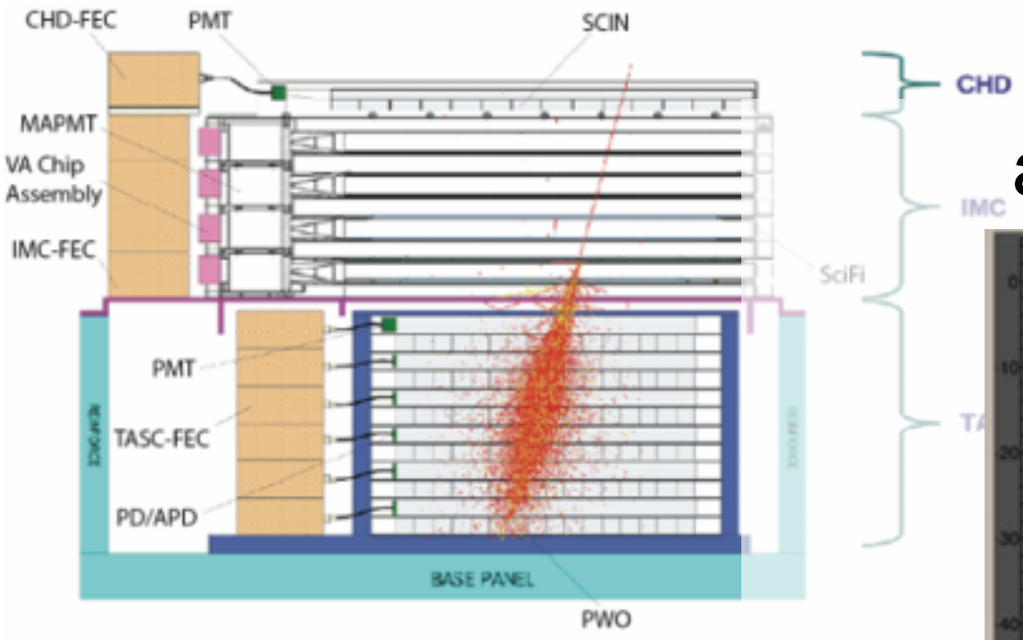
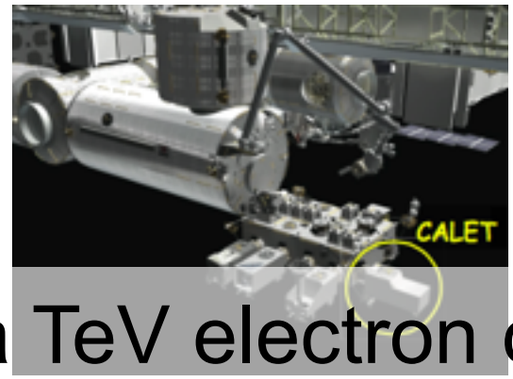
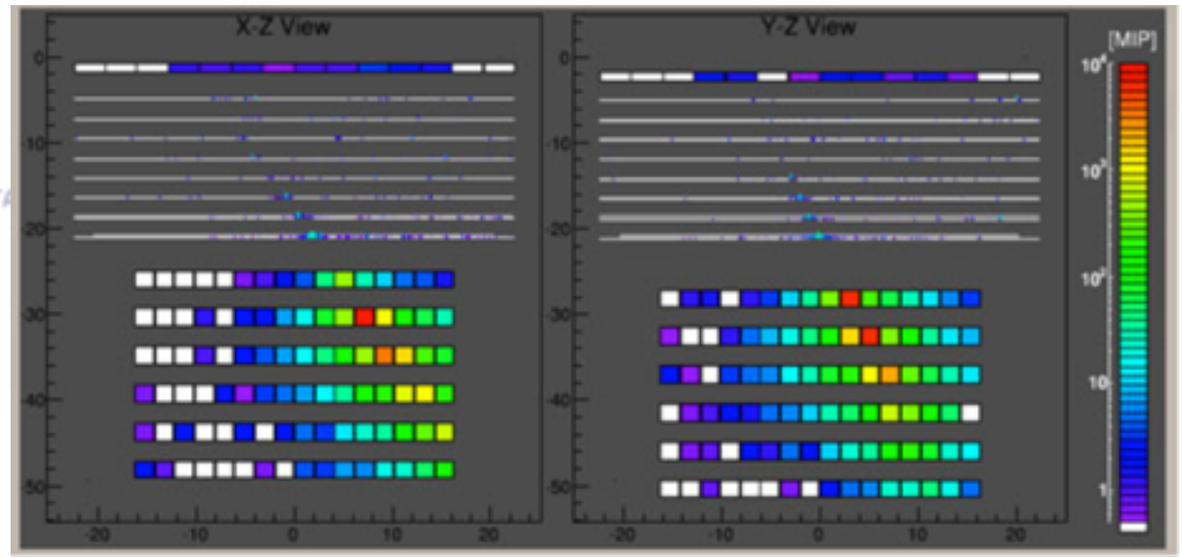




a TeV electron candidate event



JAXA PR Oct 2015

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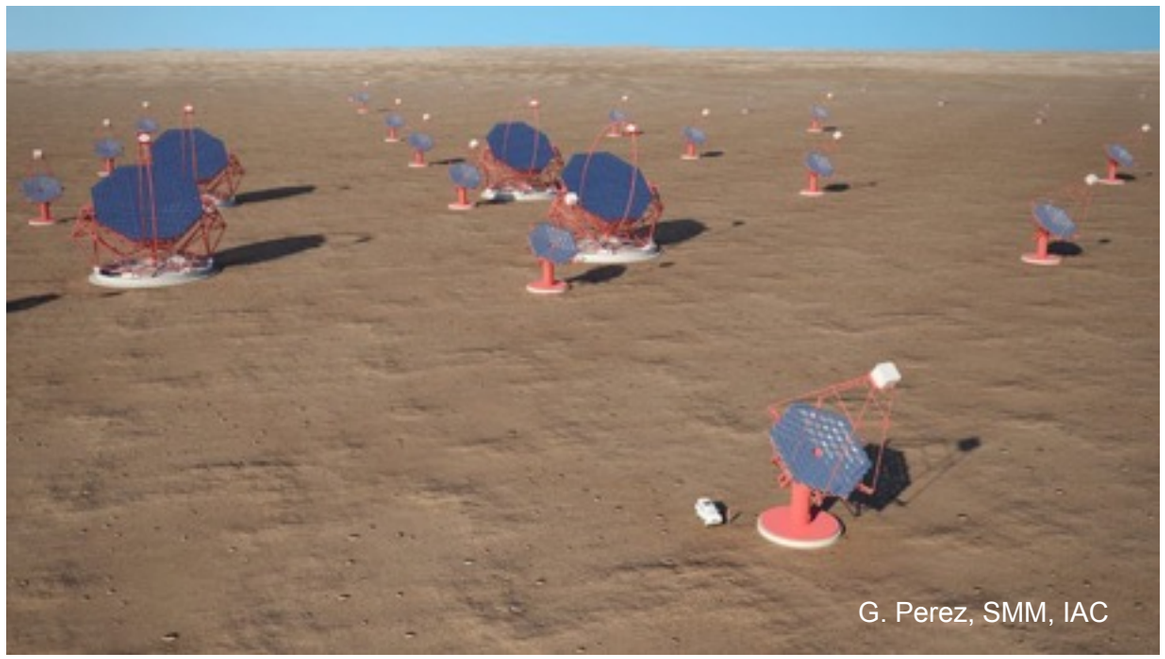
  CTA: 5-10 × sensitivity of current instruments (H.E.S.S., MAGIC, VERITAS), acceptance increasing with energy



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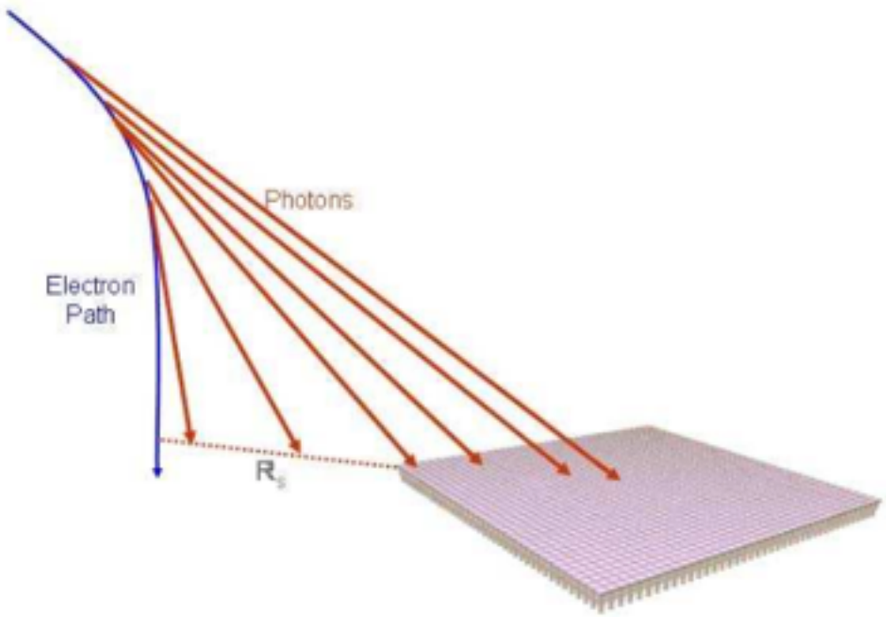
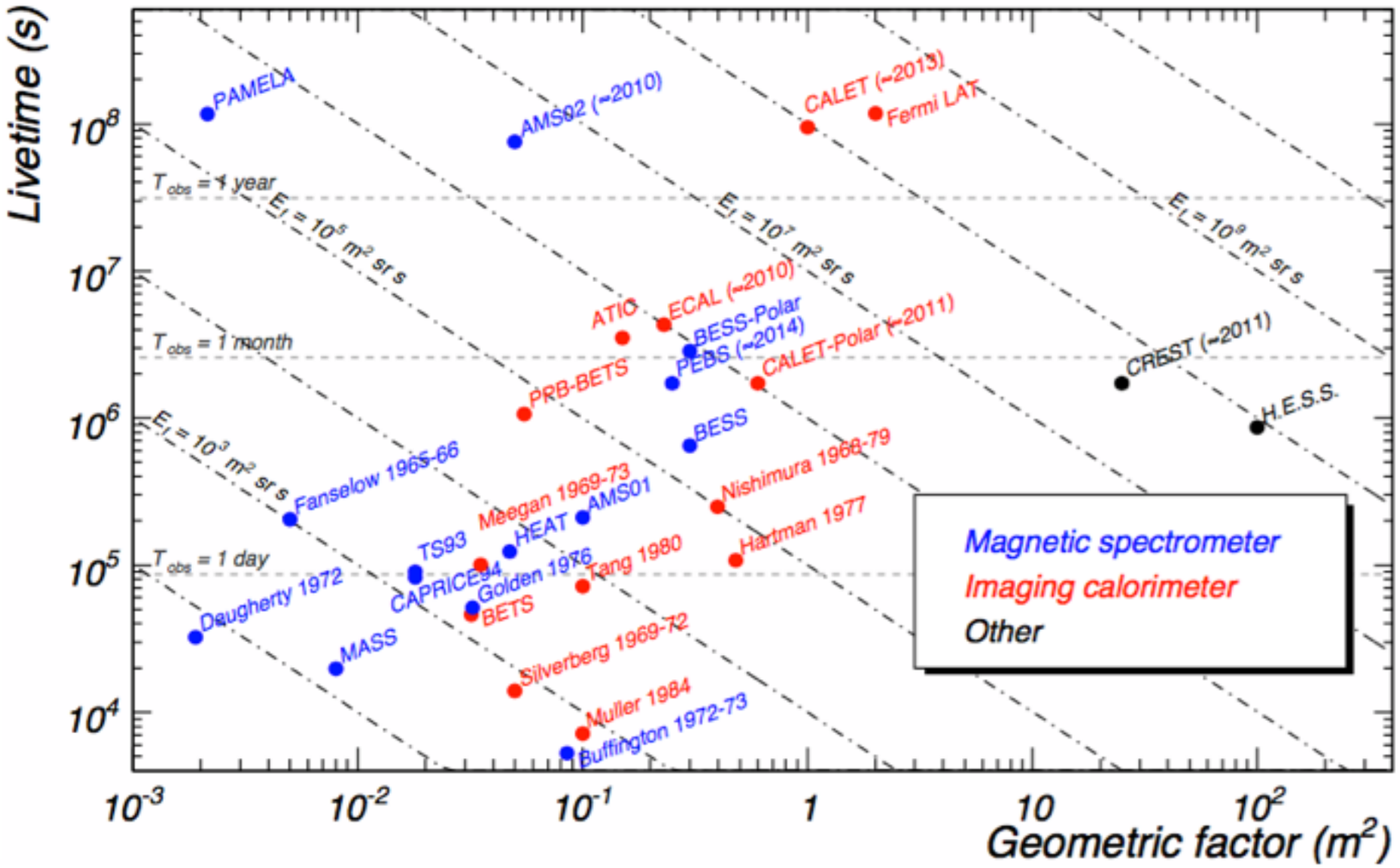
- Measurement of synchrotron photons in Earth's magnetic field:
  CREST: 10 day balloon flight in Antarctica 2011/2012, acceptance increasing with energy



e^- and e^+ measurements: e^+ fraction

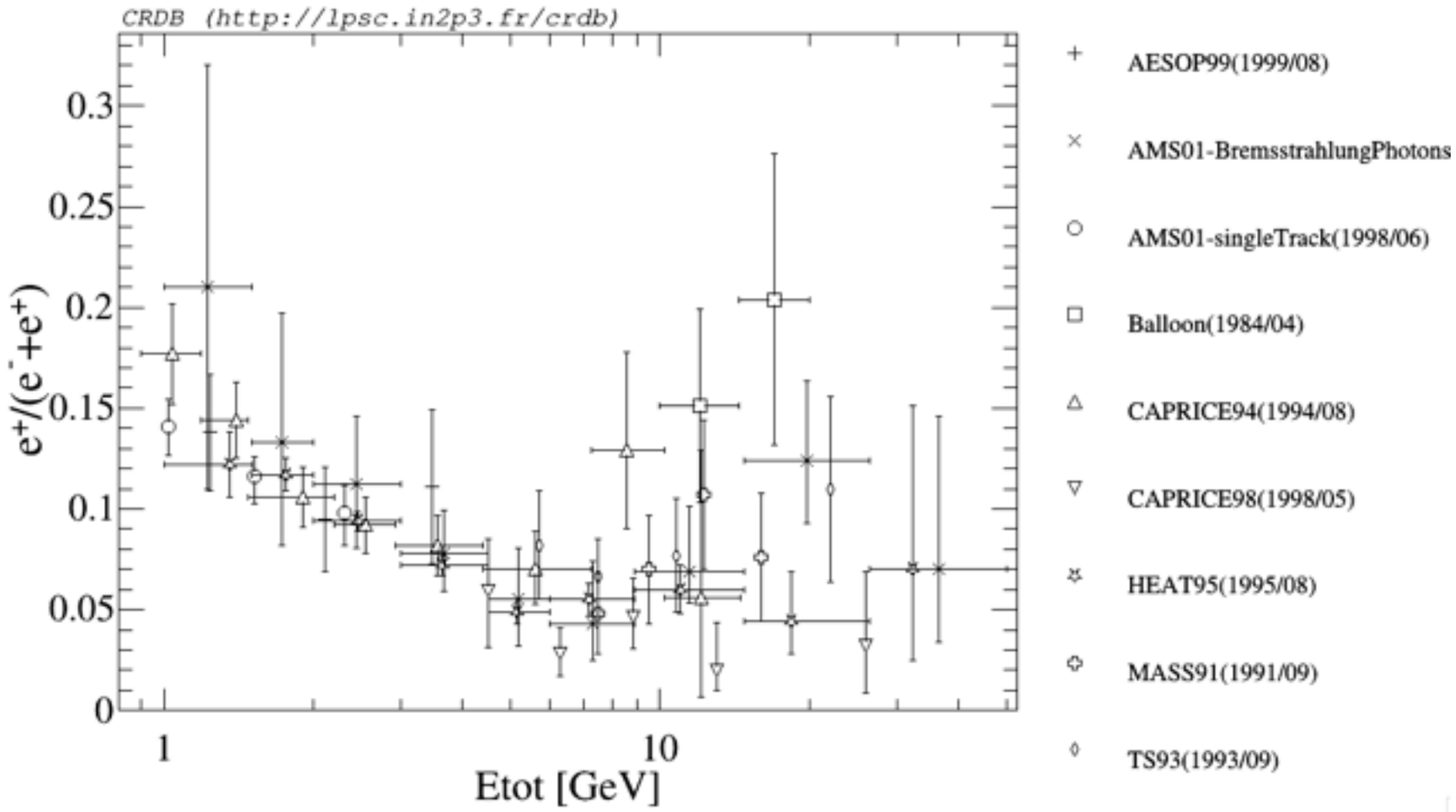
- Charge separation → need of magnets!



from L. Baldini

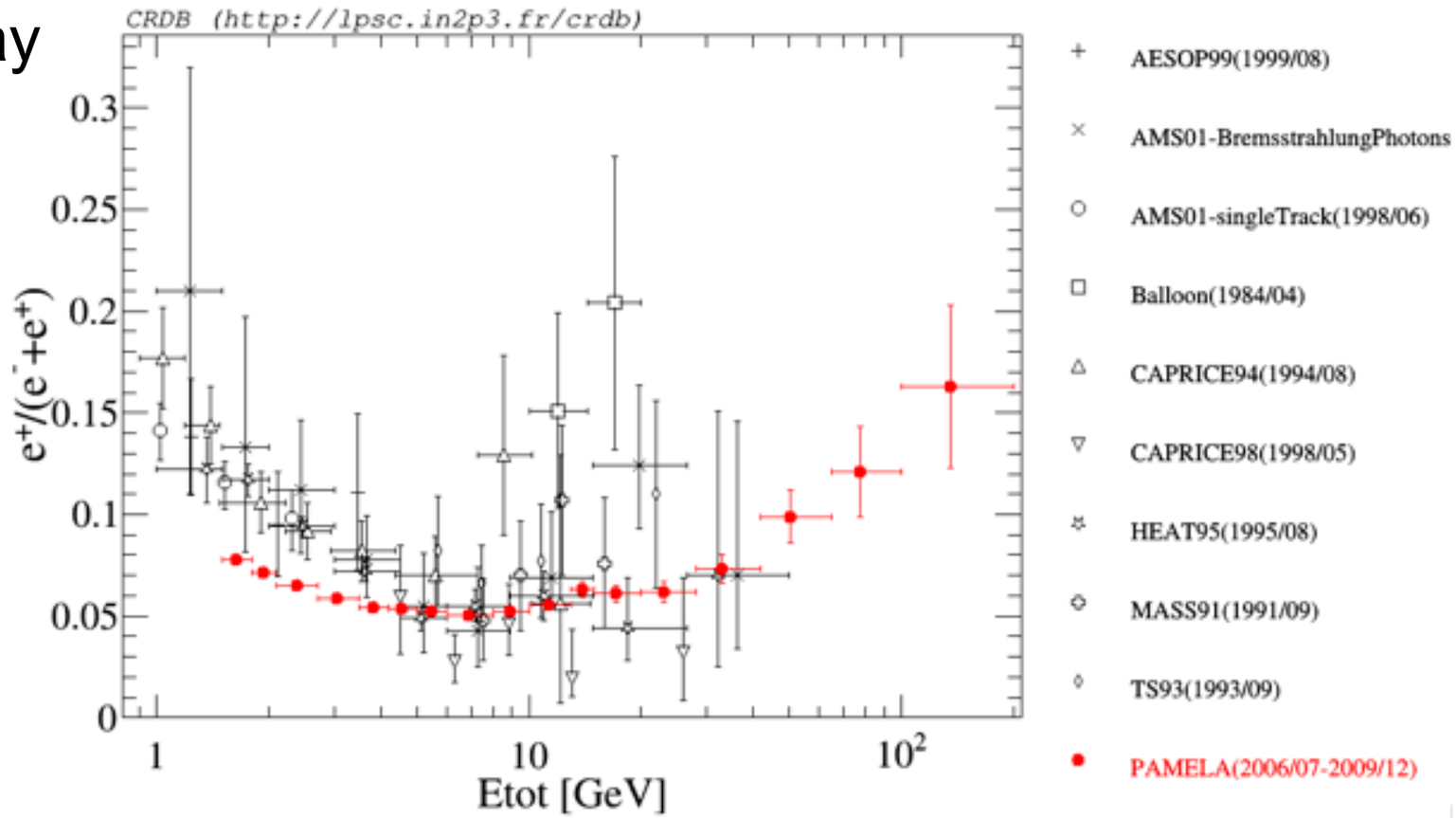
e^- and e^+ measurements: e^+ fraction

- First indications of rise in positron fraction already seen in early balloon data
- In contradiction with purely secondary production of positrons
- In view of low statistics not taken too seriously



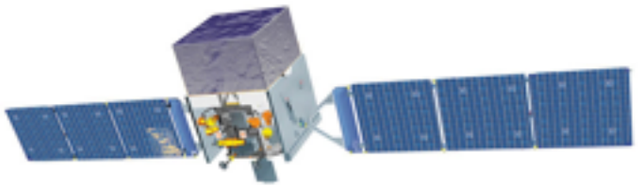
e^- and e^+ measurements: e^+ fraction

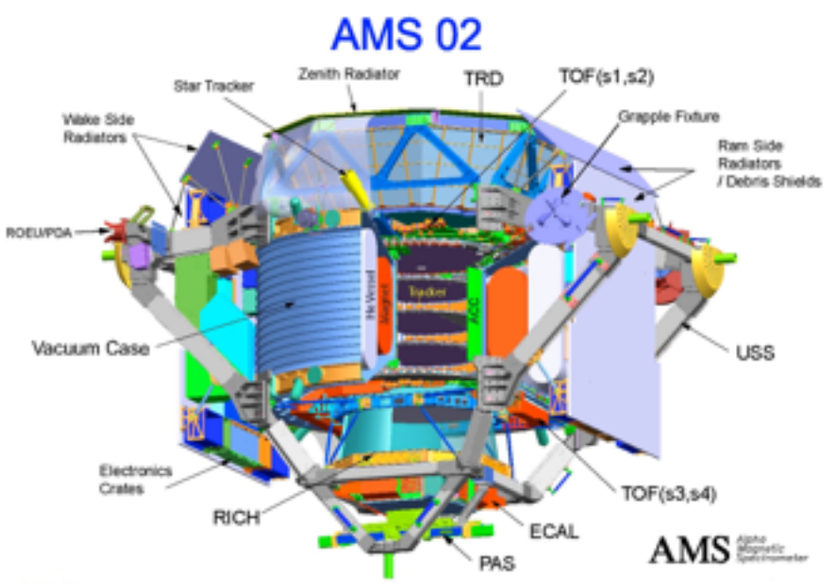
- High-statistics Pamela data trigger discussion about primary origin of positrons → dark matter signal?
- Alternative explanations invoke astrophysical sources:
  - Pulsars & their nebulae
  - SNRs if injection by decay of radioactive elements (^{44}Ti, ^{56}Ni)

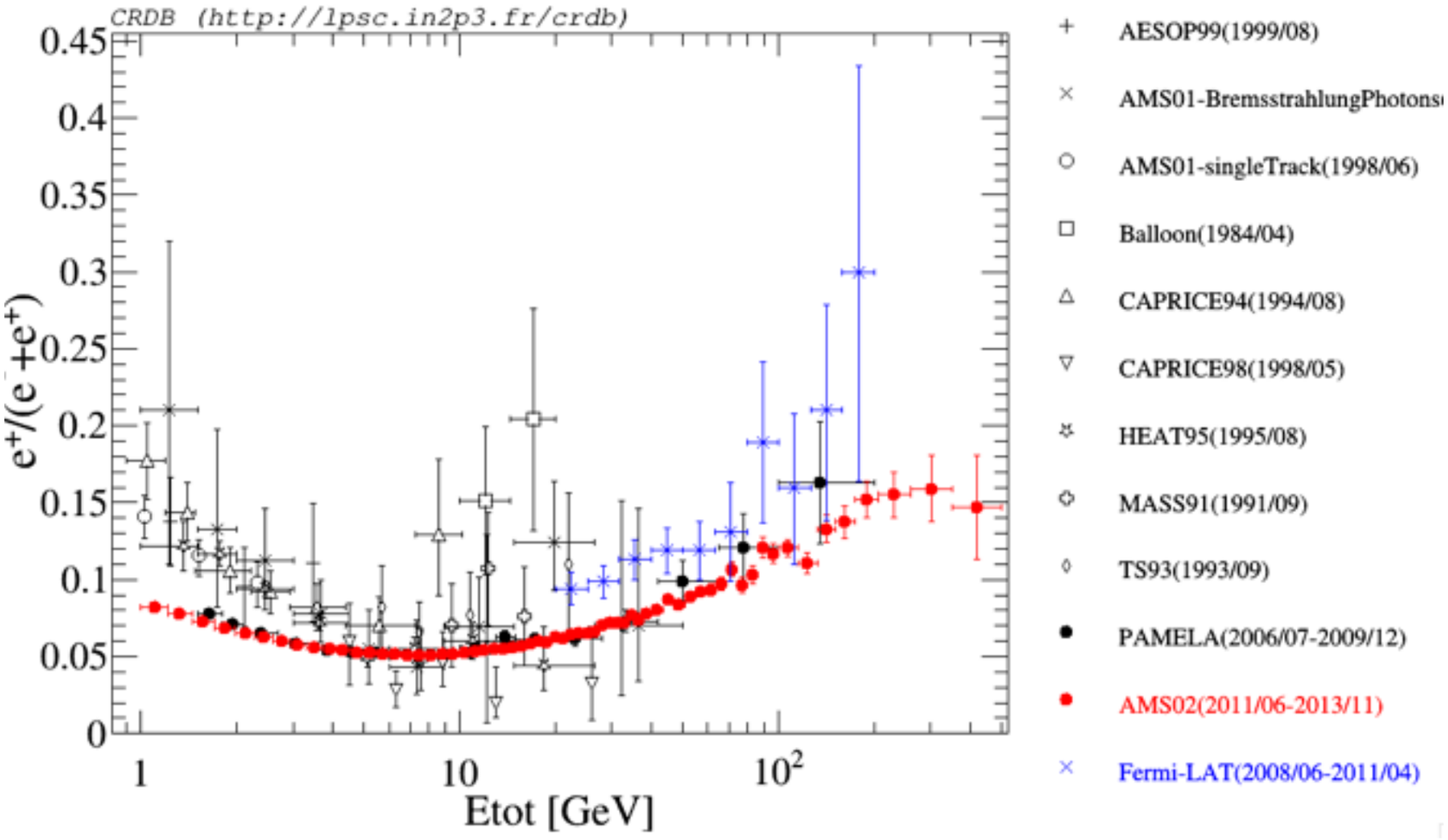


e^- and e^+ measurements: e^+ fraction

- Latest Fermi-LAT and AMS-02 data confirm Pamela findings
- Turnover of positron fraction at ~300 GeV?
  → Clues about the origin of the primary contribution of positrons







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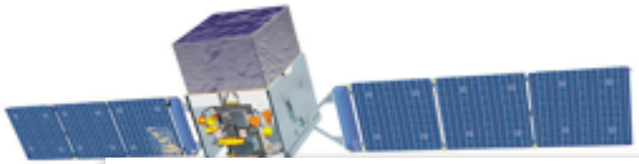
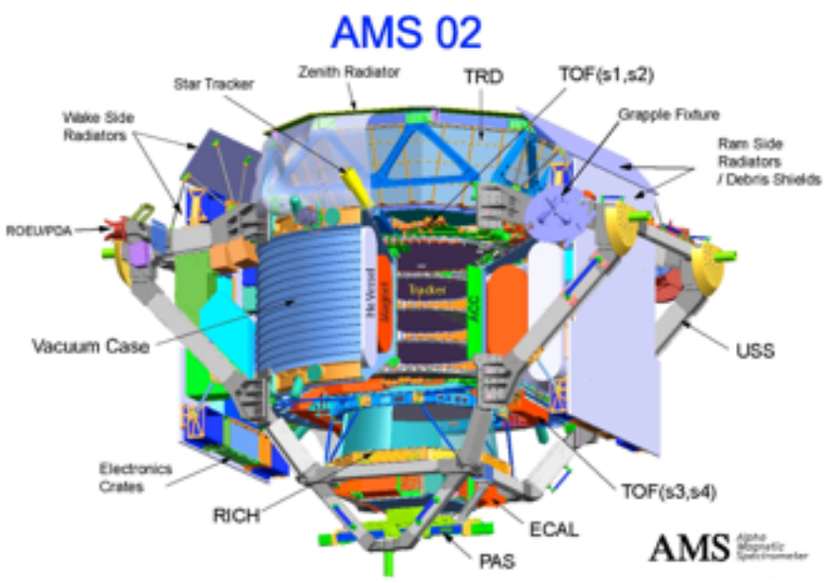
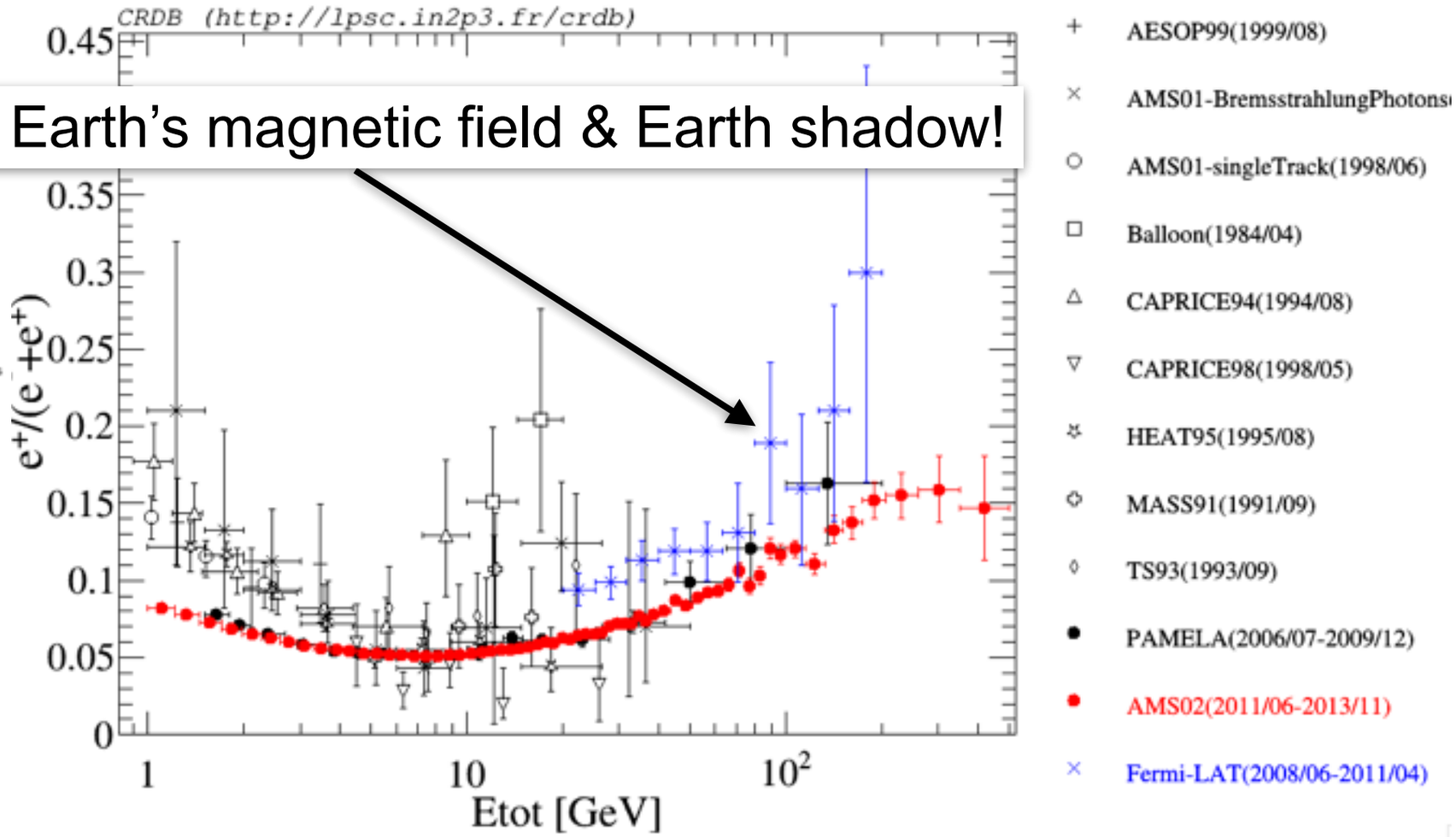


Measurement using Earth's magnetic field & Earth shadow!

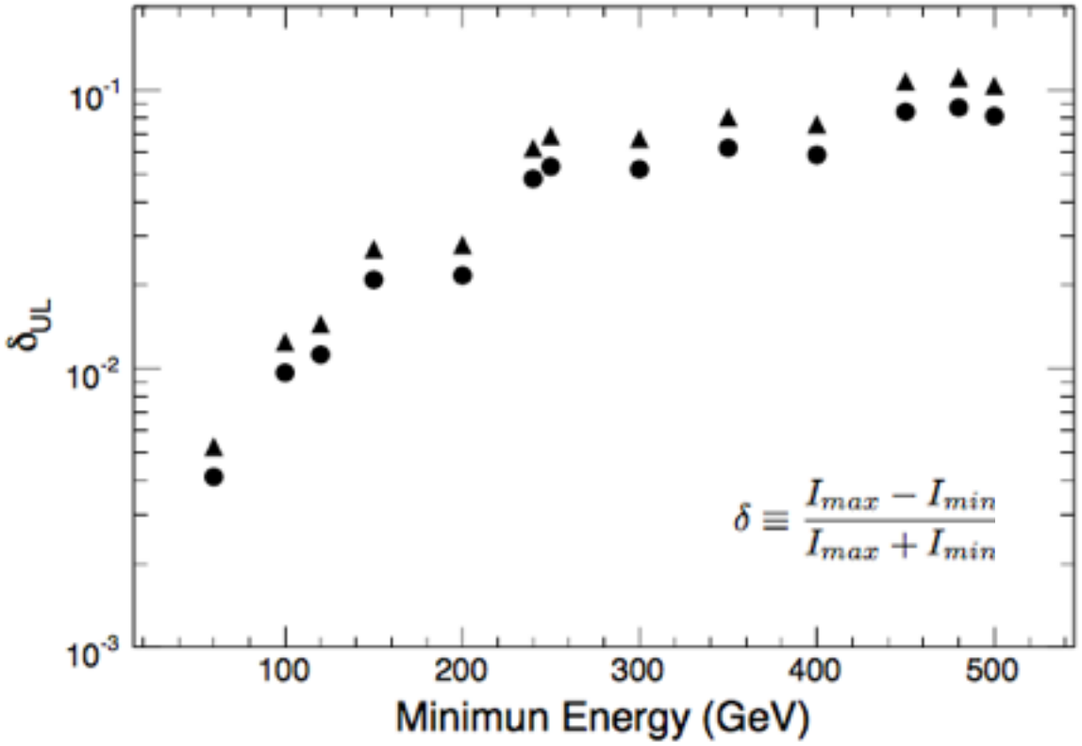




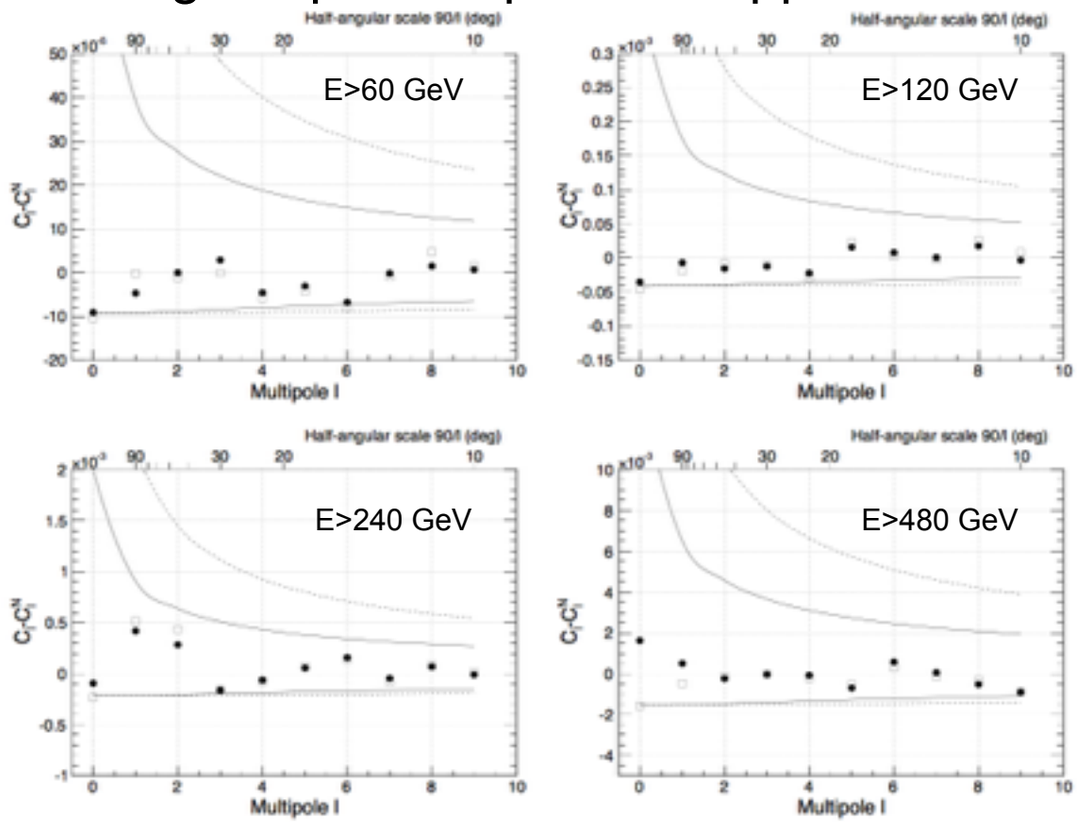
e^- and e^+ measurements: anisotropy

- Identification of CR sources by means of direction?
  Disentangling dark matter scenarios from astrophysical sources?
- Single source → dipole
- Several sources → multipole anisotropy

Upper limits on dipole anisotropy



Angular power spectrum upper limits



Fermi-LAT Collaboration PRD 2010

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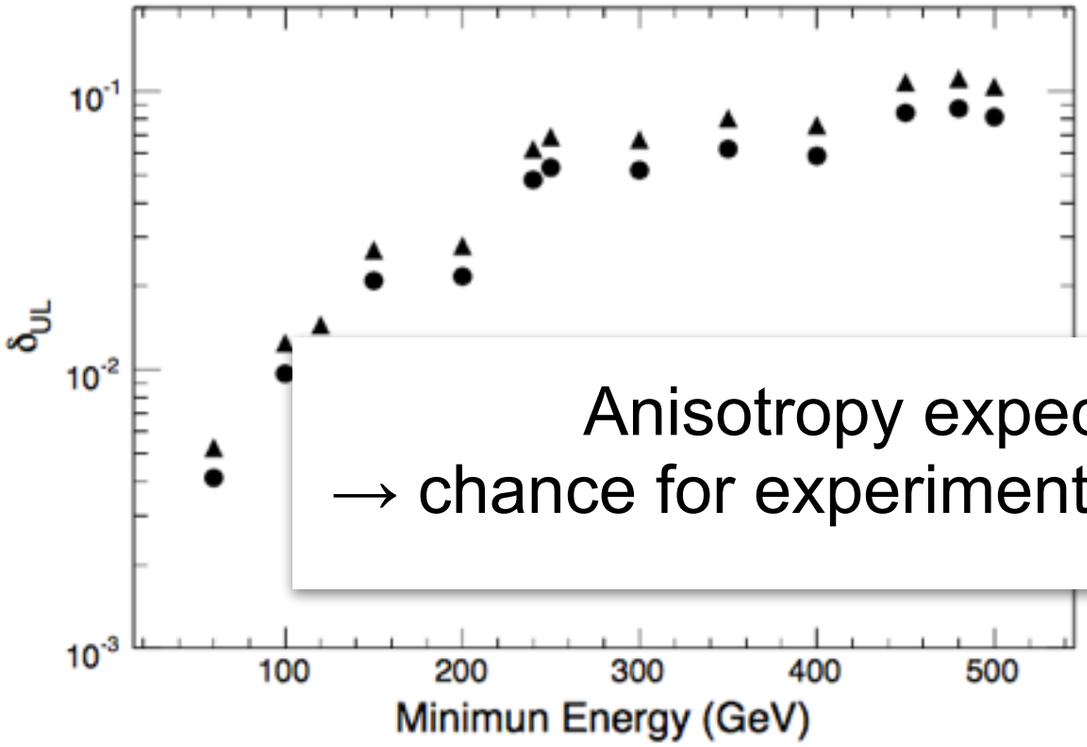

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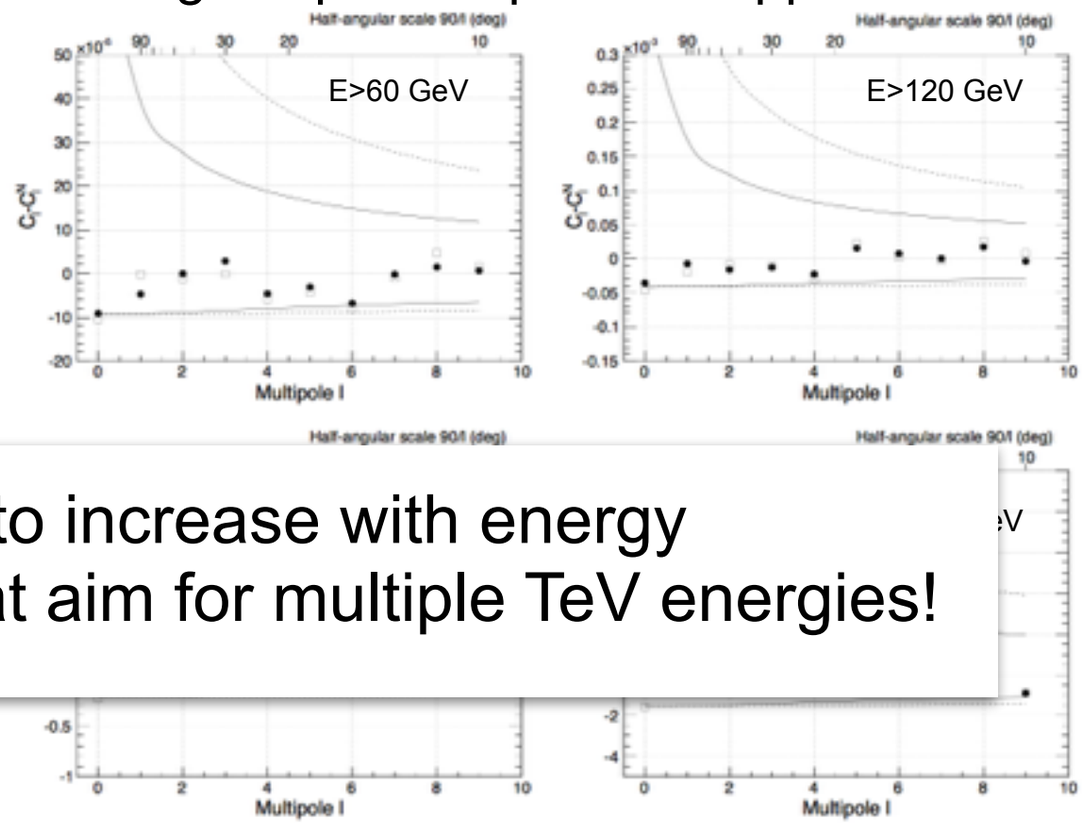

Anisotropy expected to increase with energy
→ chance for experiments that aim for multiple TeV energies!

Fermi-LAT Collaboration PRD 2010

And on the theory side?

- Dark matter scenario needs elimination of competing explanations by astrophysical sources
  → extremely difficult for the case of spectrum and positron fraction
  → might be feasible with future anisotropy measurements
- Spectrum beyond ~1 TeV completely unpredictable, dominated by one or several nearby sources
- Understanding the local accelerators:
  - Connection to gamma-ray observations?
  - Role of escape?

Conclusion

- It is an intriguing property of CR research that questions cannot be answered by isolated measurements but the picture as a whole is needed
- CR electrons make for an especially fascinating species with the potential to add significantly to the overall image
- Need of complementary measurements for verification
  – especially true for high-statistics measurements!
- With new/improved experiments taking data/coming soon, measurements at highest energies & anisotropy come into reach and we face extremely exciting times ahead