Alpha Magnetic Spectrometer

A cosmic-ray observatory in space

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AMS-LIP team

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History of AMS

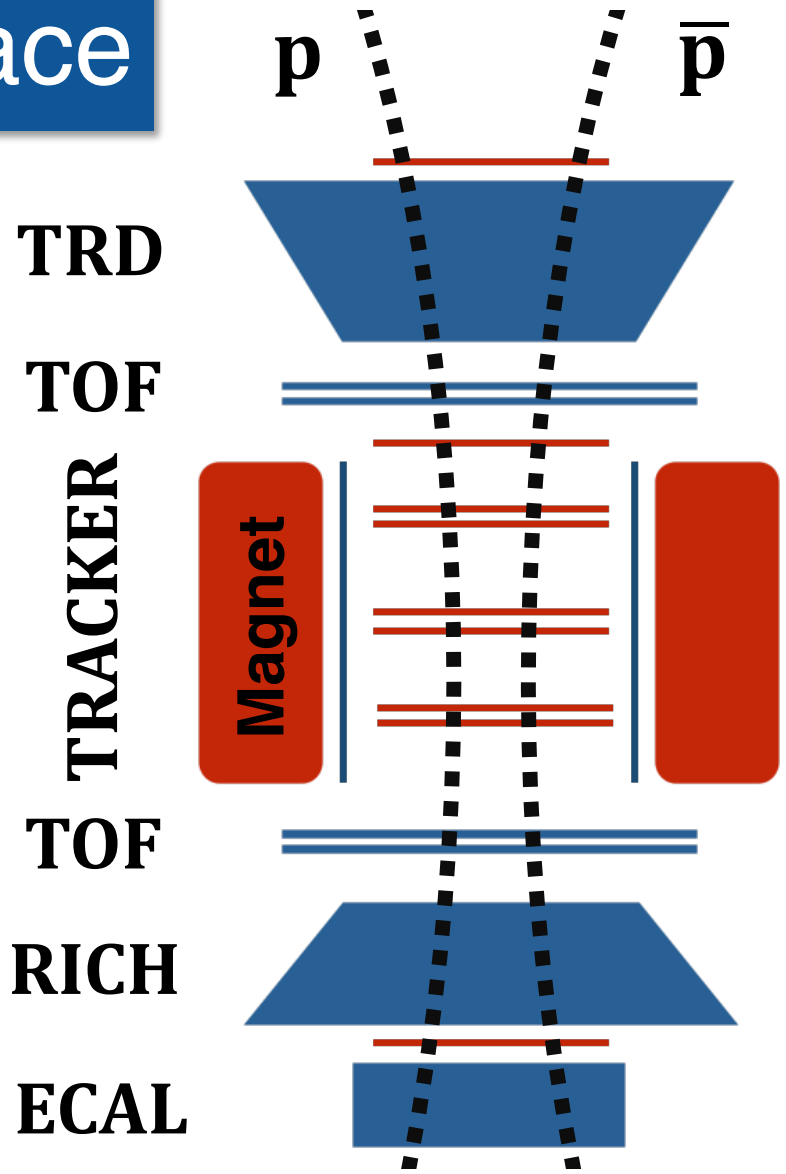
The **Alpha Magnetic Spectrometer** (AMS-02) is a state-of-the-art cosmic-ray detector designed to operate as an external module on the International Space Station (ISS).

Installed on the ISS in May of 2011, its main objective is the search for antimatter and dark matter.

AMS has collected more than **135,000,000,000 events** up to this day, at a rate of about **45 million events per day**.

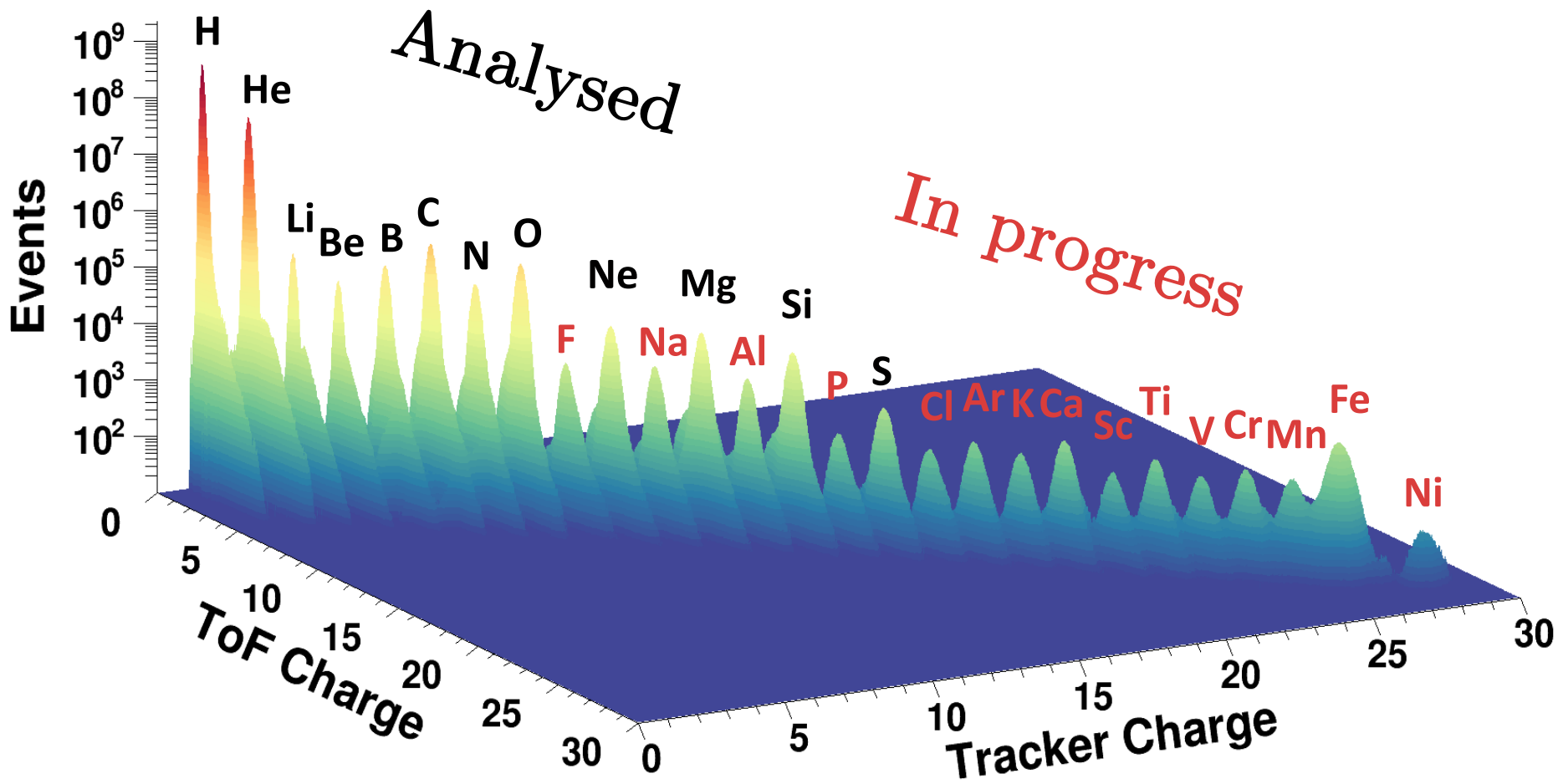
It will continue in space for the duration of ISS' lifetime.

AMS: A detector in space

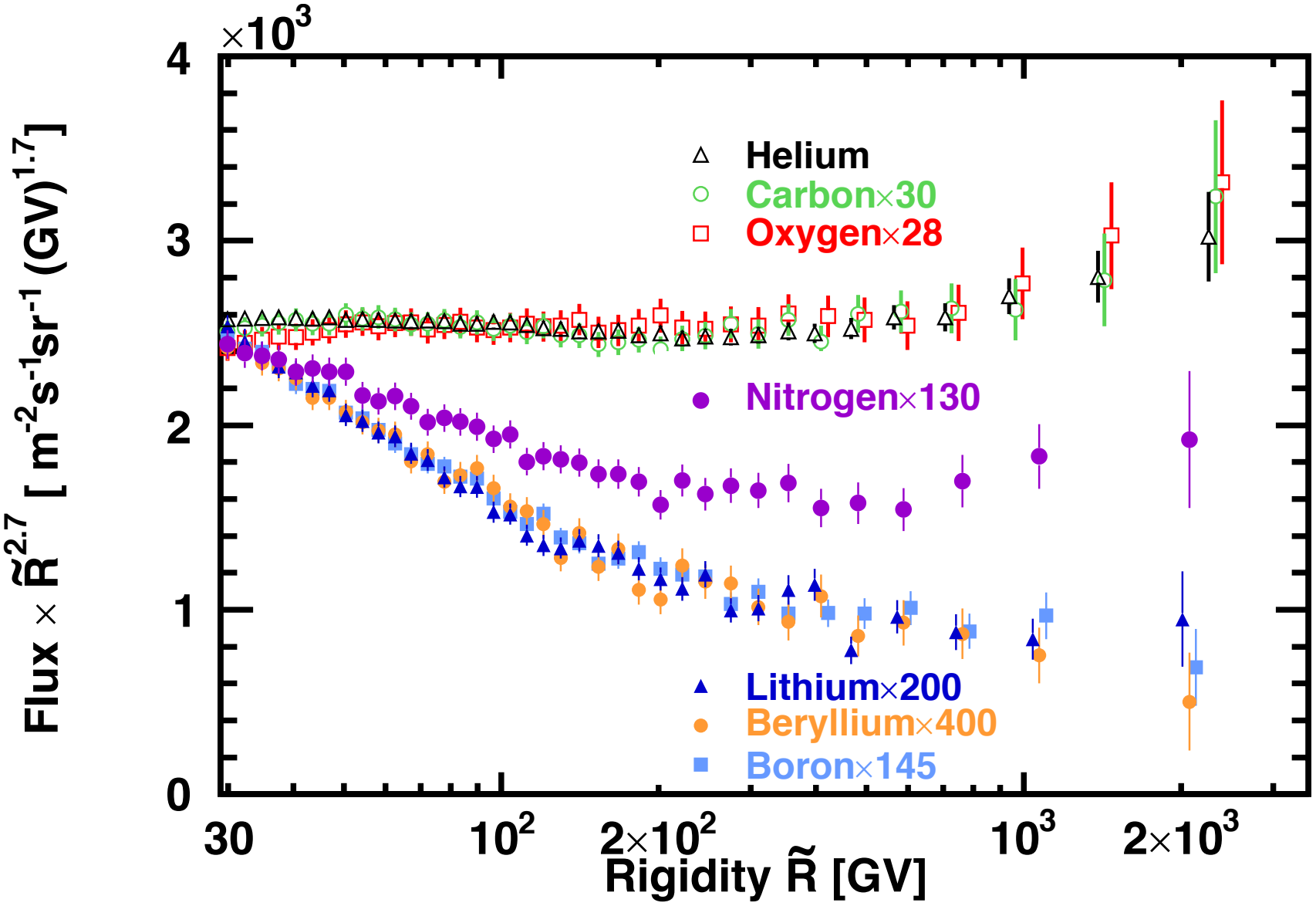


45 MILLION EVENTS PER DAY
153.000.000.000 EVENTS

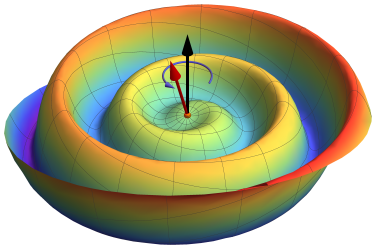
Analysis


Analysed
In progress
Events
10^9
10^8
10^7
10^6
10^5
10^4
10^3
10^2
0
H
He
Li
Be
B
C
N
O
F
Ne
Na
Mg
Al
Si
P
S
Cl
Ar
K
Ca
Sc
Ti
V
Cr
Mn
Fe
Ni
5
10
15
20
25
30
ToF Charge
0
5
10
15
20
25
30
Tracker Charge

Primary & Secondary CR



Low Energy Physics

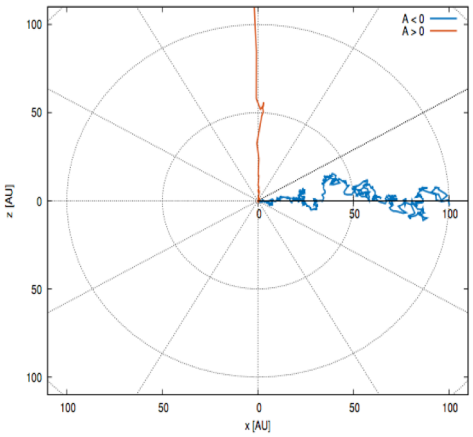


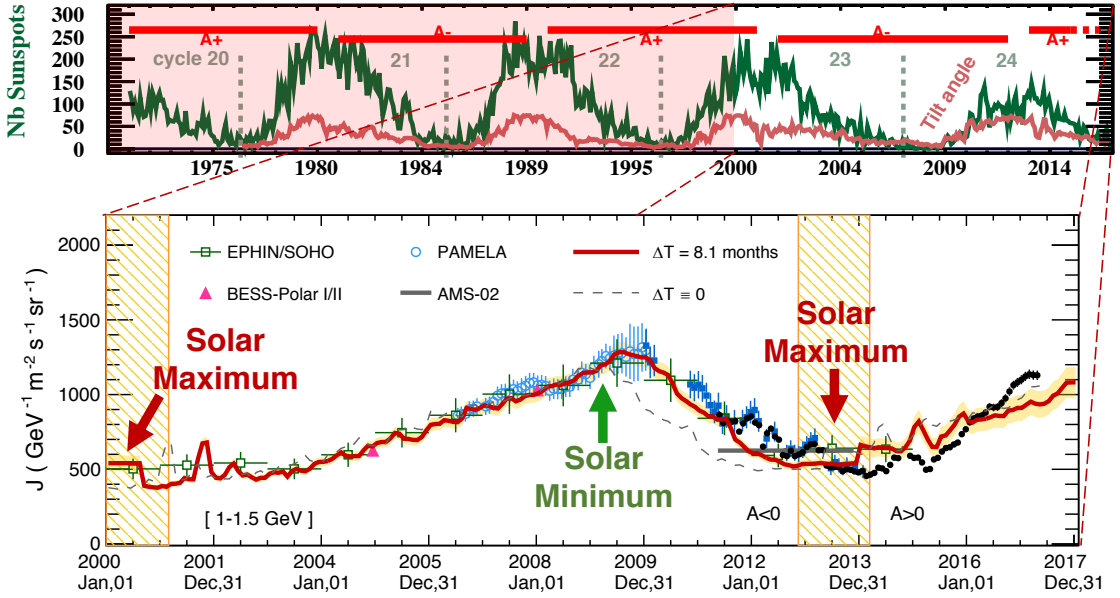
CR transport equation

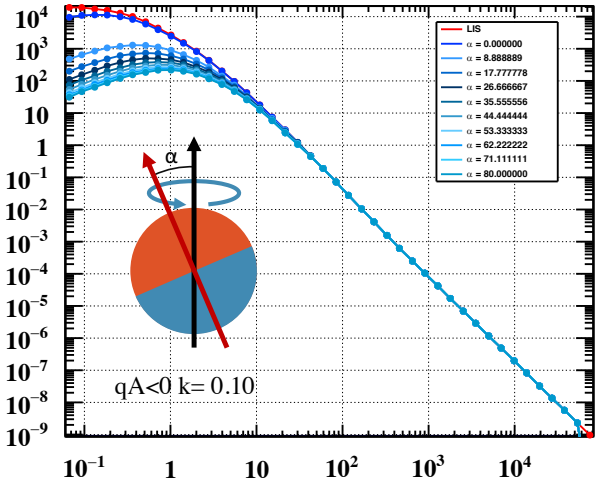
- Parker's equation

$$\frac{\partial f}{\partial t} = \underbrace{\nabla \cdot (\mathbf{K}_s \cdot \nabla f)}_{\text{diffusion}} - \underbrace{(\mathbf{V} + \langle \mathbf{v}_{dr} \rangle) \cdot \nabla f}_{\text{convection and drift}} + \underbrace{\frac{1}{3} (\nabla \cdot \mathbf{V}) \frac{\partial f}{\partial \ln P}}_{\text{adiabatic energy loss}} + \underbrace{Q(r, P, t)}_{\text{source/LIS}}$$

- Solar wind & heliospheric magnetic field
- Numerical & Stochastic resolution of the equation
  - 1D, 2D, Stochastic, Force-Field, ...





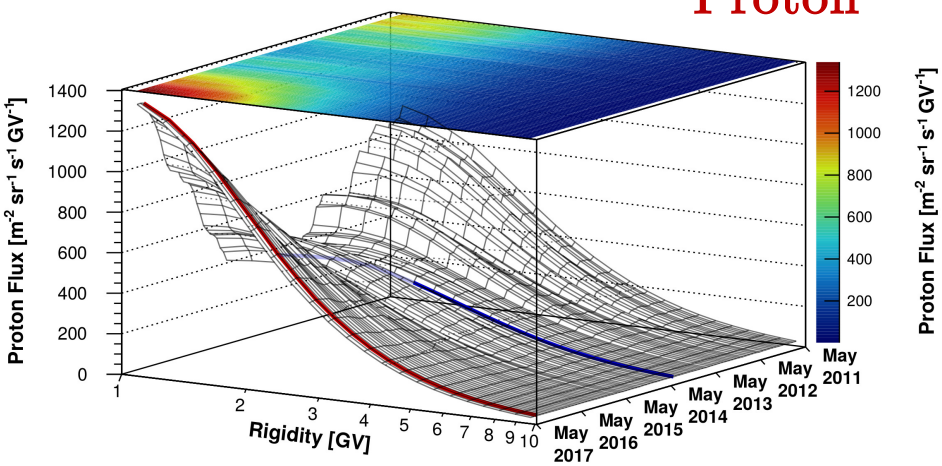


Low Energy Physics

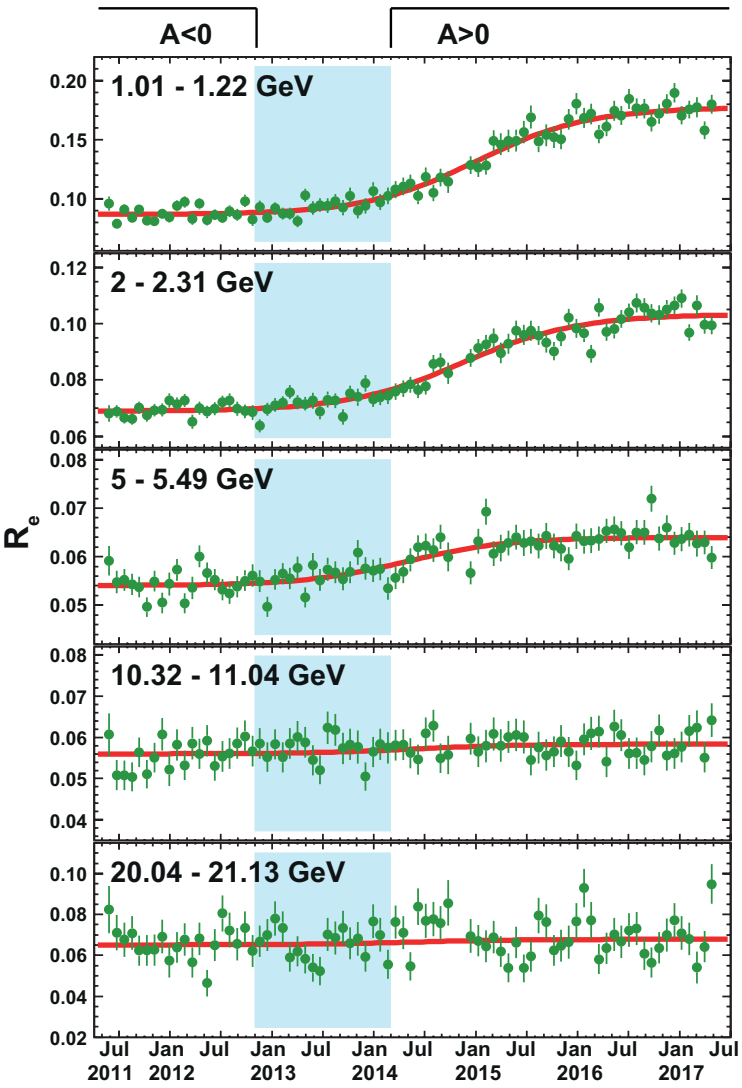
Physics channels

- Time-resolved CR fluxes
  - Daily (solar events)
  - Bartel (solar rotation)
  - Yearly (solar activity cycle, solar magnetic reversal)
- Flux ratios (p/He, e^+/e^-, $^3He/^4He$,...)
- Long-term observations
  - Neutron monitors
  - Satellites (Voyager, Parker probes, balloon, ...)

Proton



Positron-electron ratio



Low Energy Physics

Cosmic rays as probes

- Propagation models
  - Diffusion (velocity effects)
  - Charge sign effects
- Parametrizations & correlation with solar observables
- Forbush decrease & solar events
- Decoupling solar effects from CR flux

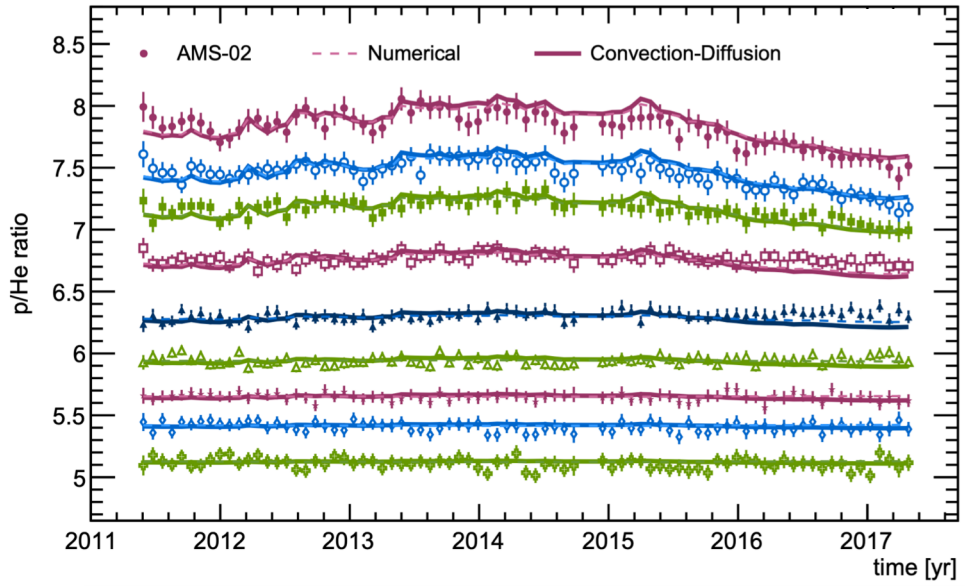
$$K_\perp = 0.02 K_\parallel$$

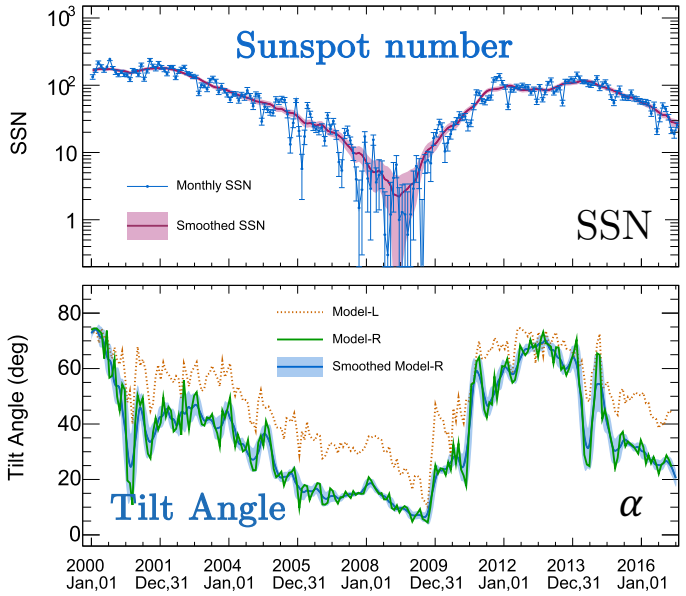
$$K_\parallel = k_0(t) \frac{A}{3B} \beta \, (P/1\,\mathrm{GV})$$

$$\mathrm{SSN} = \mathrm{SSN}(t)$$

Parametrization of diffusion parameter

Proton-helium ratio

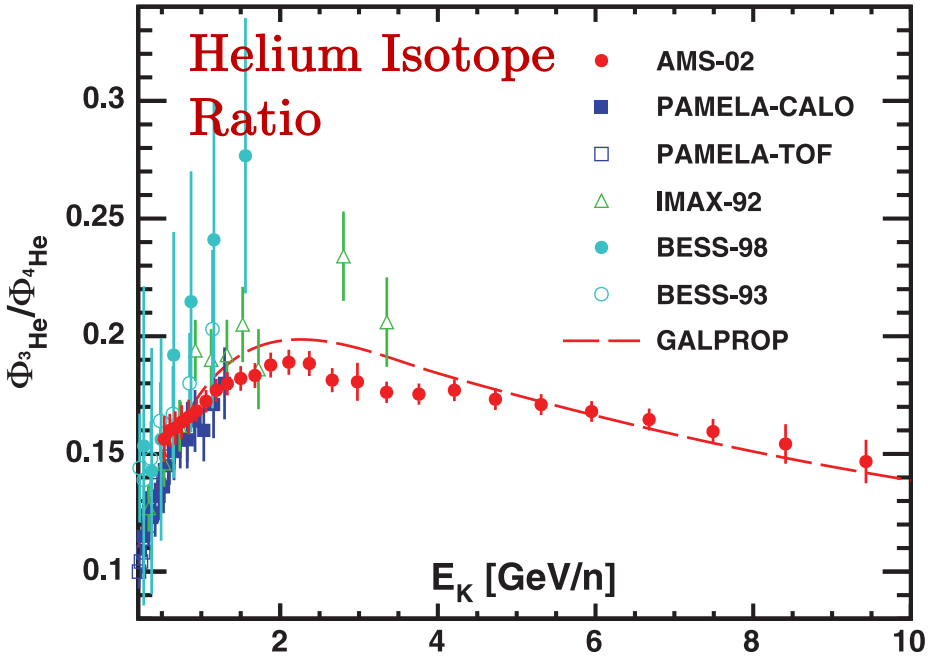




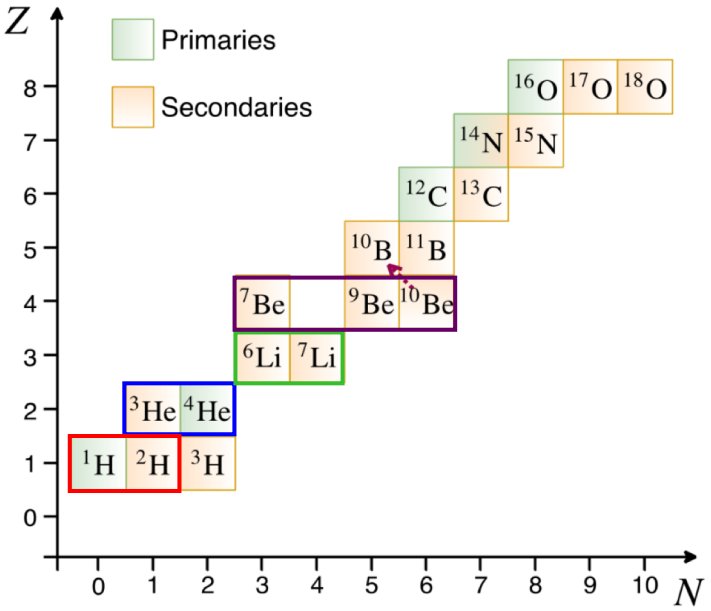
Isotopic separation

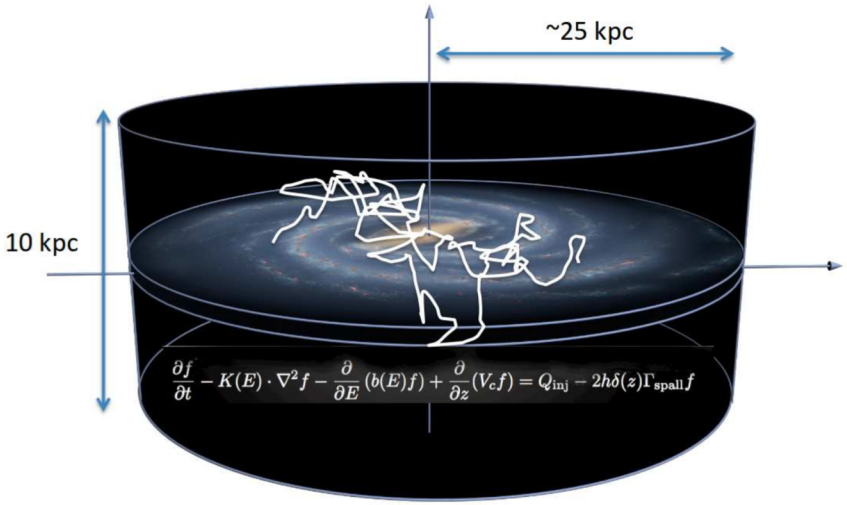
Cosmic rays as probes

- Light stable isotopes (D, ^{2}H, ^{3}He, ...)
  - CR propagation information
- Light radioactive isotopes (^{10}Be, ...)
- Secondary/Primary ratios
- Solar modulation physics
  - Velocity effect on diffusion
  - Drift velocities



Isotopes in light CR





Isotopic separation

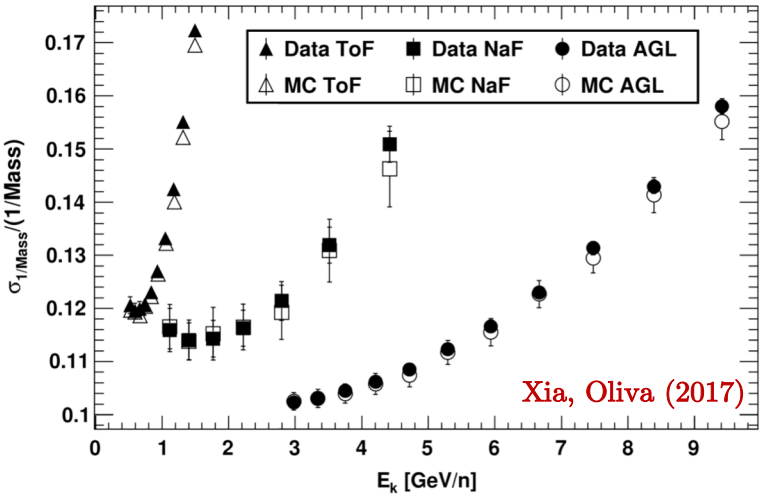
Detector physics

- Mass resolution
  - Rigidity & Velocity resolution
- Likelihood estimators
  - Folded rigidity template
  - Velocity resolution modelization

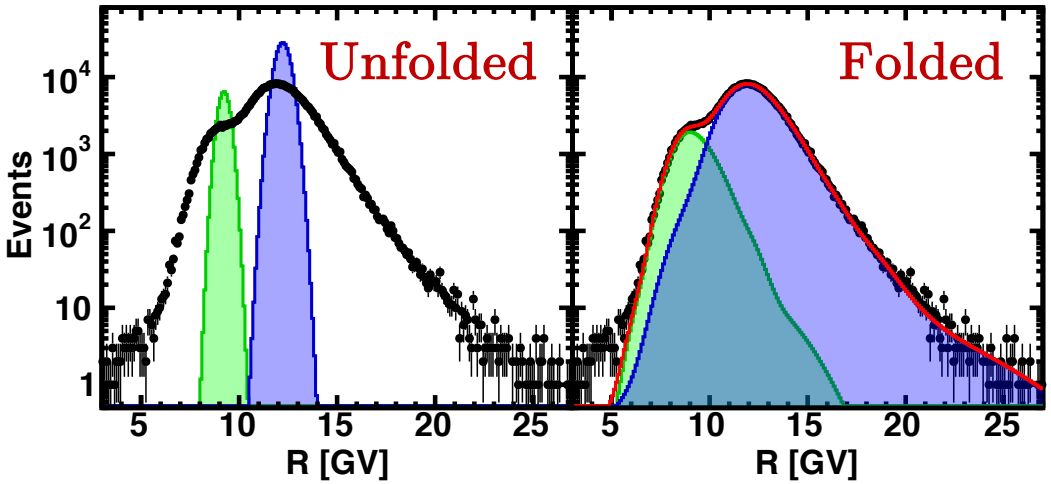
Mass resolution

$$\frac{\sigma_m}{m} = \left(\frac{\sigma_R}{R}\right) \oplus \left(\frac{\sigma_\beta}{\beta}\right)$$

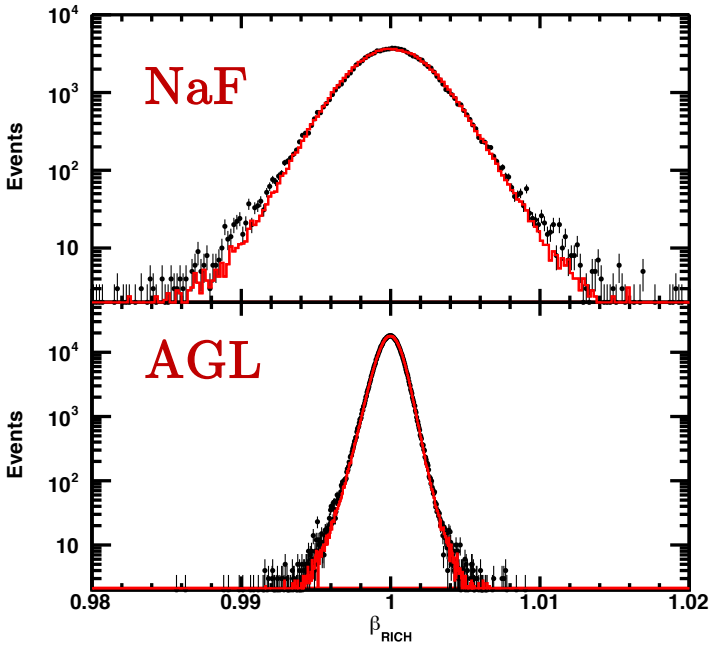
Mass resolution



Helium Isotopes $0.9863 < \beta_{AGL} < 0.9864$



Helium - RICH

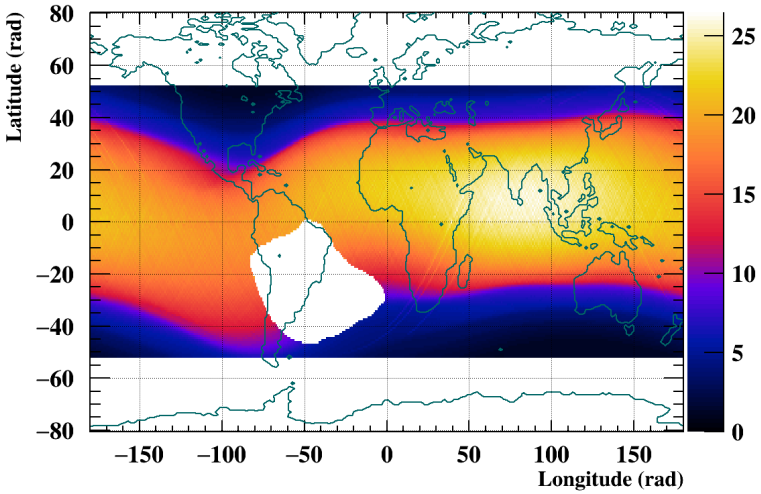


Isotopic separation

Innovative methods

- Geomagnetic Cutoff Estimator
  - Using earth's magnetic field
  - Building β pdf's from slices of rigidity
- Machine learning algorithms
  - BDT, MLP, ...
  - Classifier distribution as template
  - Classification techniques
  - Selection of physical variables

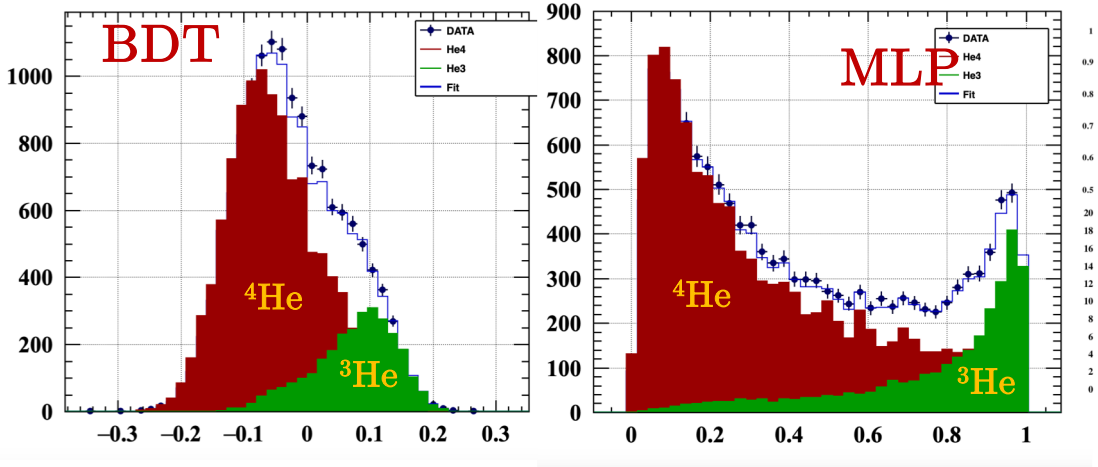
Geomagnetic Cutoff

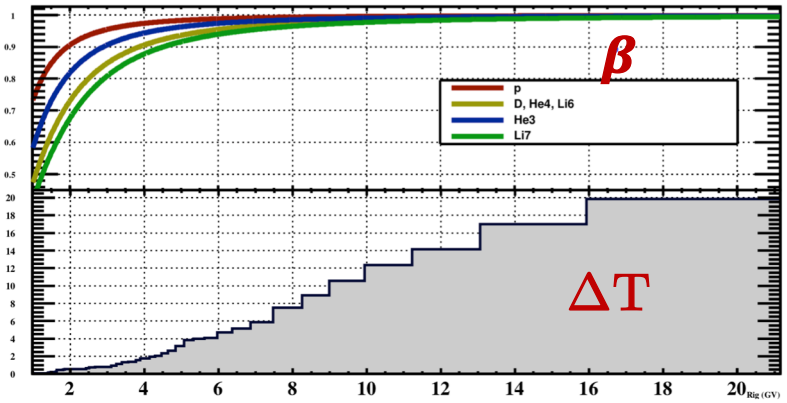


$P_{\mathrm{Cutoff}}(\varphi, \theta)$

$P(\mathrm{GV})$

Helium





Rig

Conclusions

- **Cosmic-ray physics is multidisciplinary...**
  - Particle Physics
  - Detector physics
  - Cosmic-ray transport
    - Plasma physics, Diffusion, ...
  - Computational physics
  - Advanced Statistics
  - Data analysis
  - Machine learning

- **There is more to be done in...**
  - Detector studies (RICH, Tracker, ECAL, ...)
  - Observation of solar events on daily flux
  - Selection of higher charge events
  - Machine learning classifiers
  - Geomagnetic field as a velocity selector
  - Velocity resolution model

Our doors are always open…

Questions?

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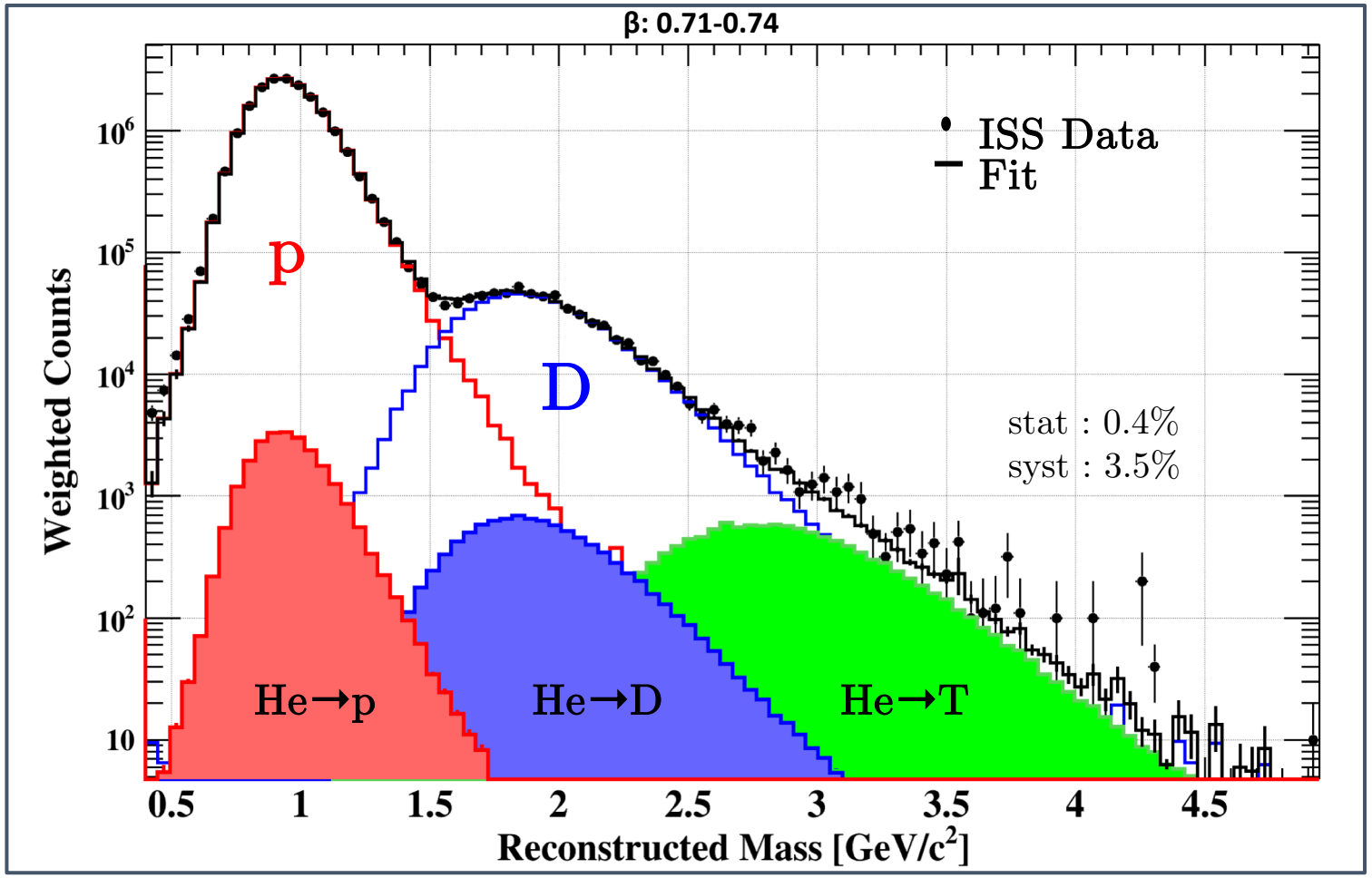
LIP

TÉCNICO LISBOA

Backup


β: 0.71-0.74
ISS Data
Fit
p
D
stat : 0.4%
syst : 3.5%
He→p
He→D
He→T
Weighted Counts
Reconstructed Mass [GeV/c²]
10⁶
10⁵
10⁴
10³
10²
10
0.5
1
1.5
2
2.5
3
3.5
4
4.5