AMS -02
& Research Activity in Italy

B.Bertucci

Università di Perugia & INFN sezione di Perugia

AMS-02 in Italy

Research institutes:

6 Universities / INFN Sections
& ASI Science Data Center

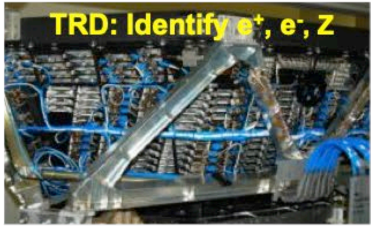
+ infrastructures

- computing → CNAF
- space qualification → SERMS

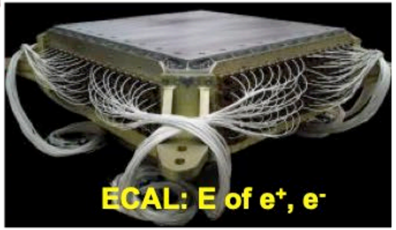
agenzia spaziale italiana

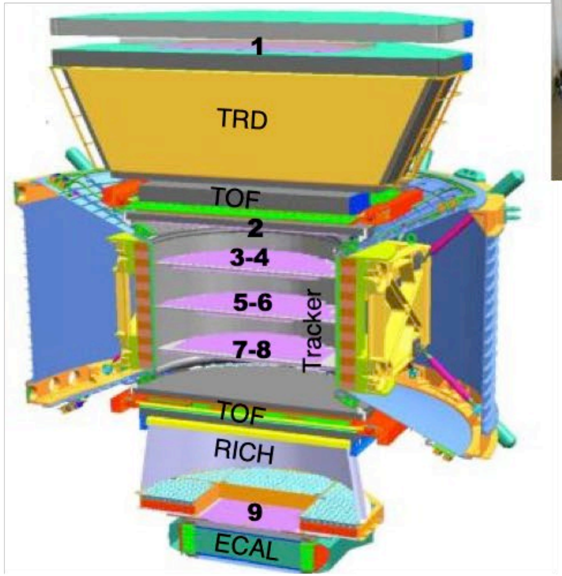
INFN Istituto Nazionale di Fisica Nucleare

Italy & AMS-02 detectors

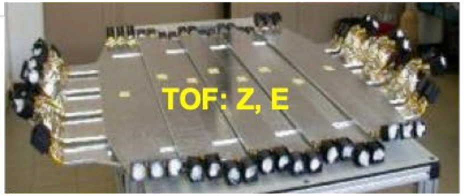



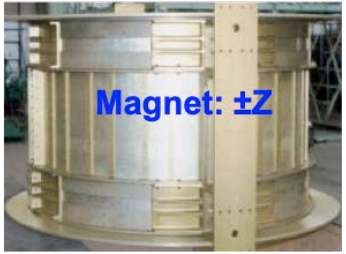




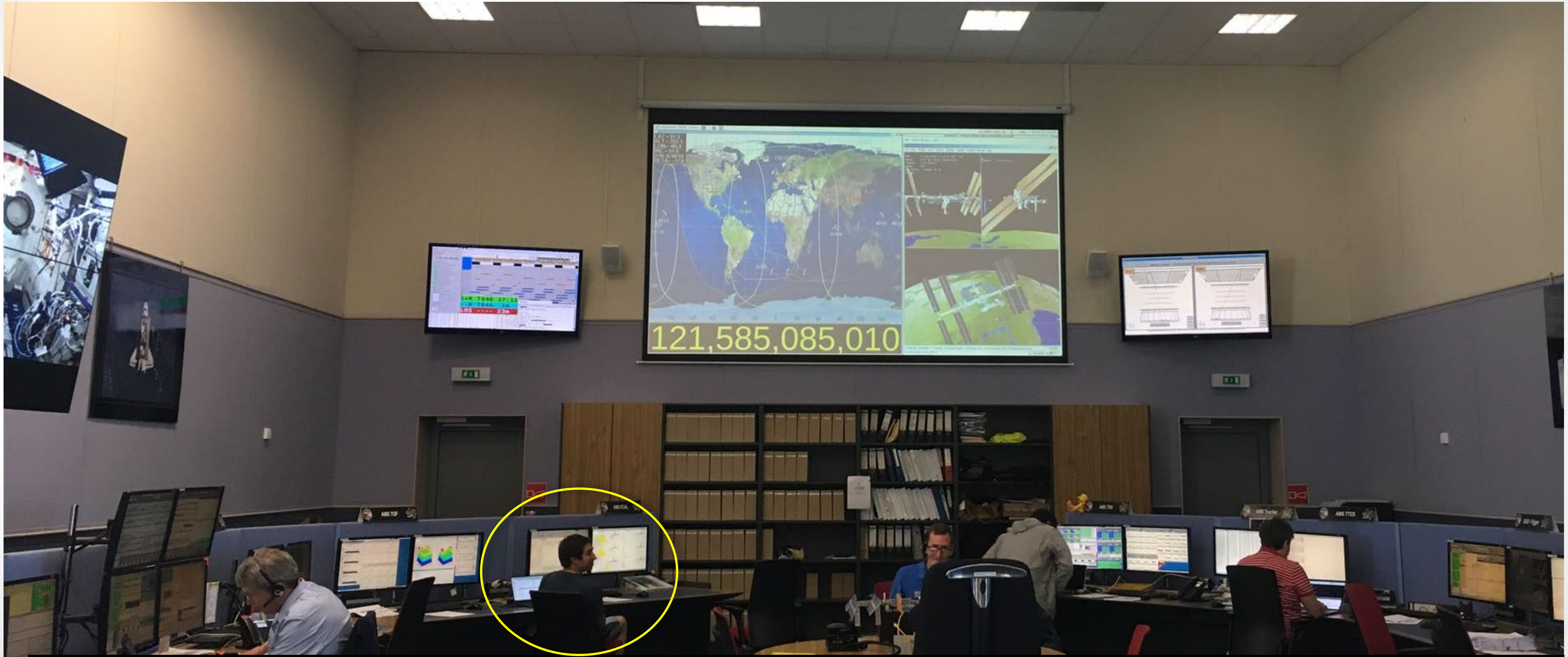


Particles and nuclei are defined by redundant measurements of their charge (Z) , energy (E), Rigidity (R)





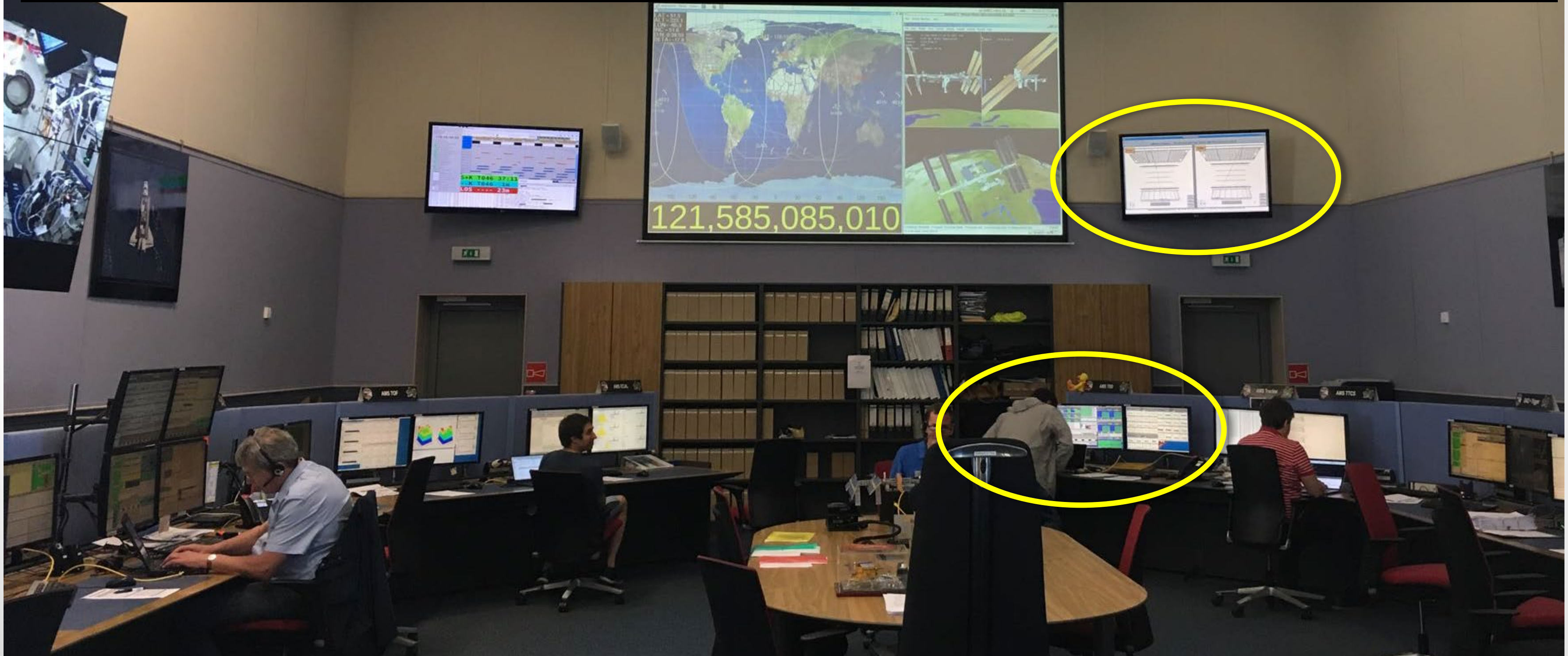
Operations & Monitoring



Italy @ POCC: ≈ 700 shifts/year [Italy] + Tracker expert on call [PG/TN]

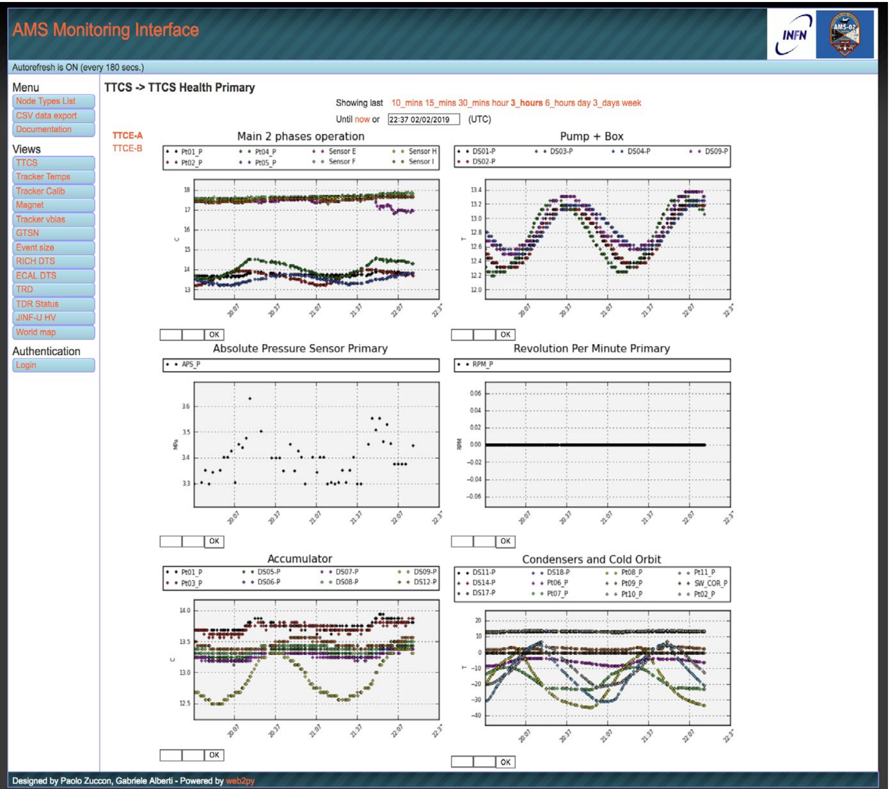
Operations & Monitoring

Fast production of incoming data (1 minute root files) for event display & Tracker monitoring [PG]

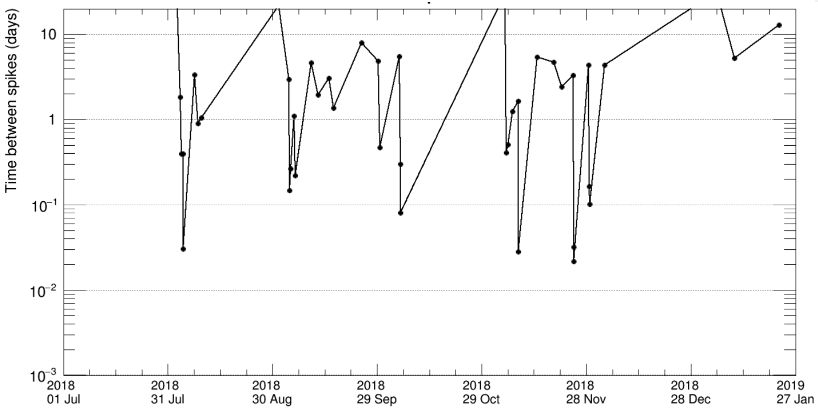


Monitoring & Alert [Pg]

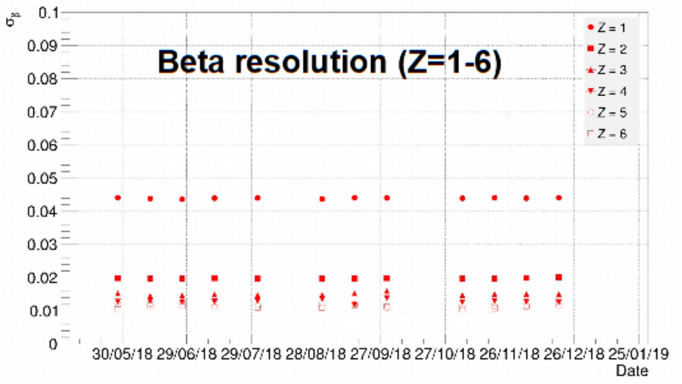
AMI : to access health data

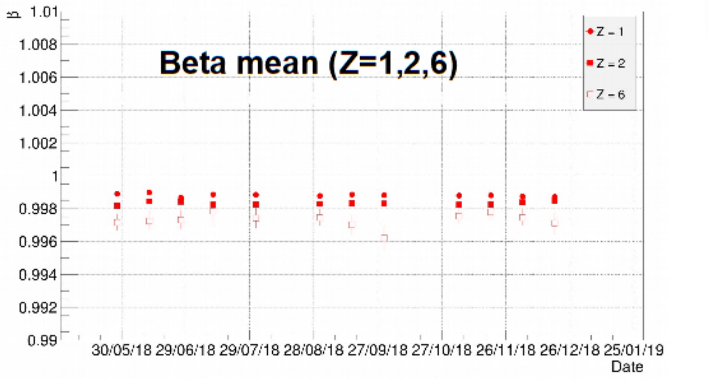


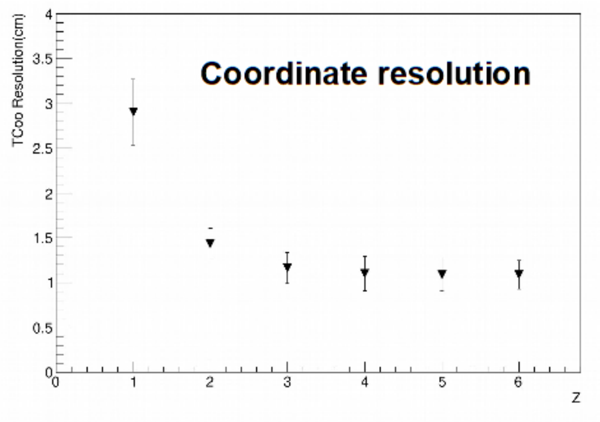
TTCS spike alert : for prompt alert on anomalous pump RPM

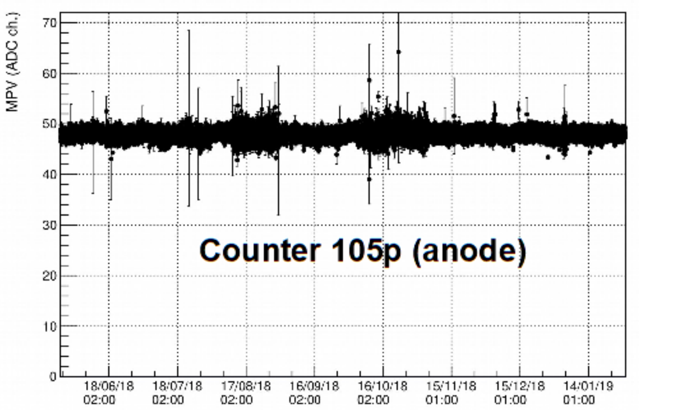


Calibration & Stability: TOF detector [L.Quadrani, A.Contin Bo]



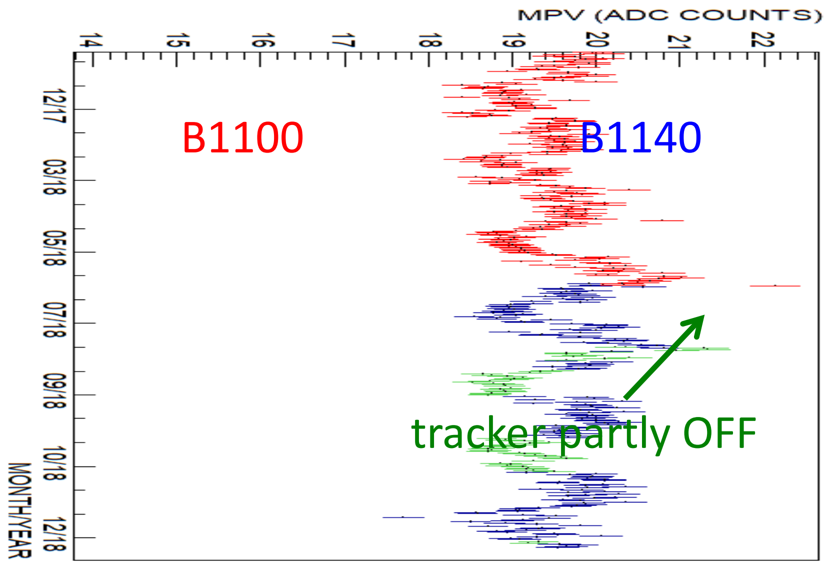


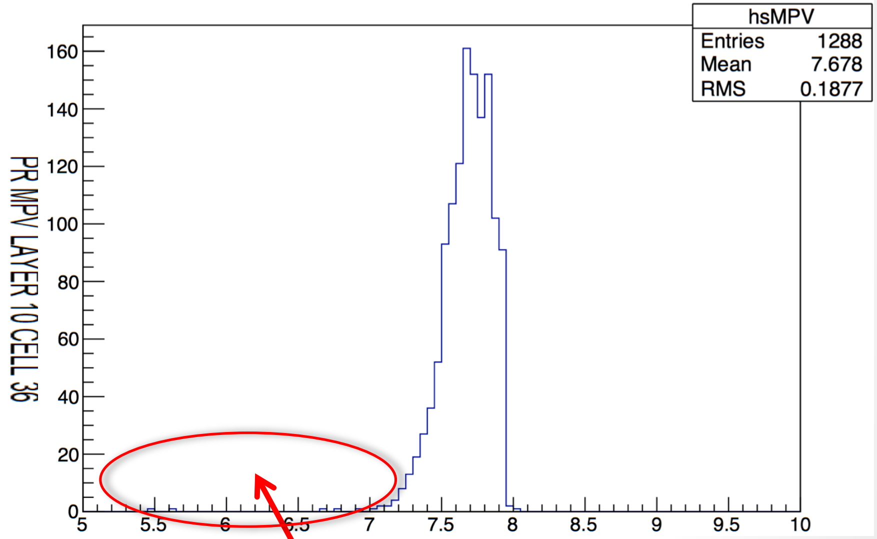




Calibration & Stability: ECAL [S.Di Falco, M.Incagli Pi]

Signal from MIP Protons is used to daily monitor ECAL response at the cell level and equalize it over time/detector.



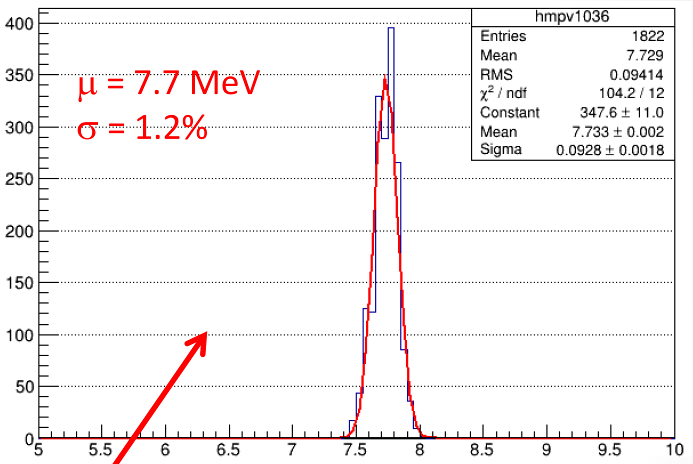


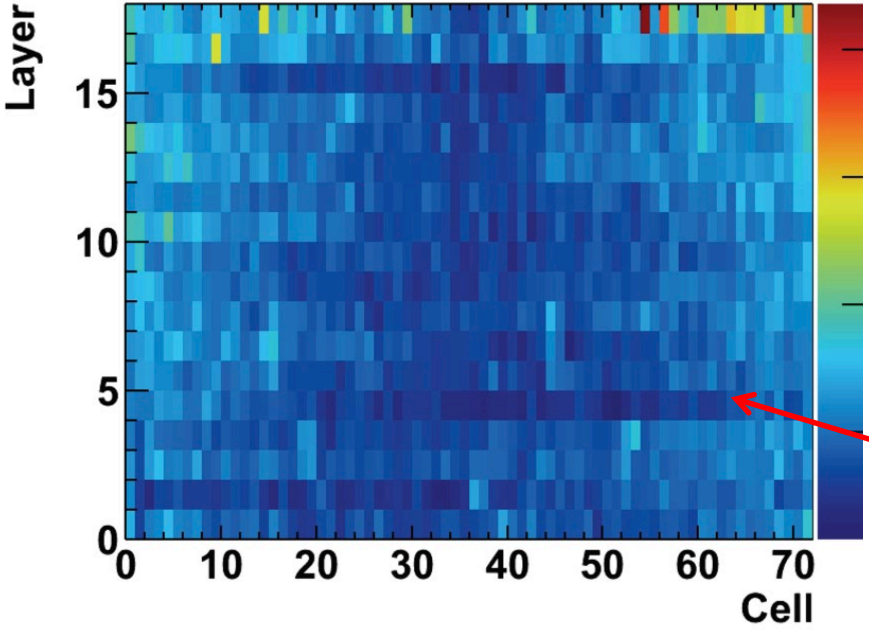
MIP proton/He selection for equalization updated to cope with different tracker conditions

When Proton MIP signal is close to *zero suppression threshold*, Helium events are used for equalization.

Calibration & Stability: ECAL [S.Di Falco, M.Incagli Pi]

After equalization stability in time for the single cell is within 1-1.5 %, within the whole calorimeter the cell response is equalized within ≈2.4%

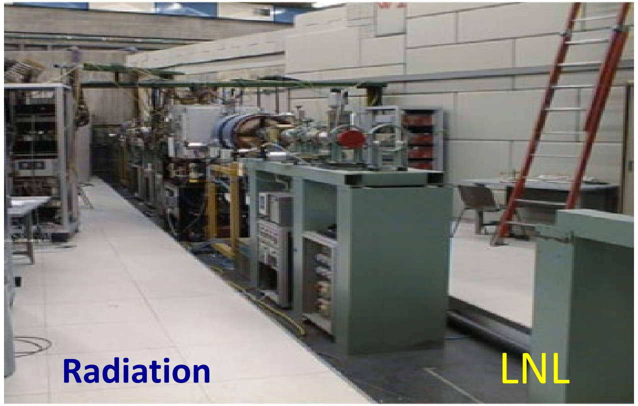


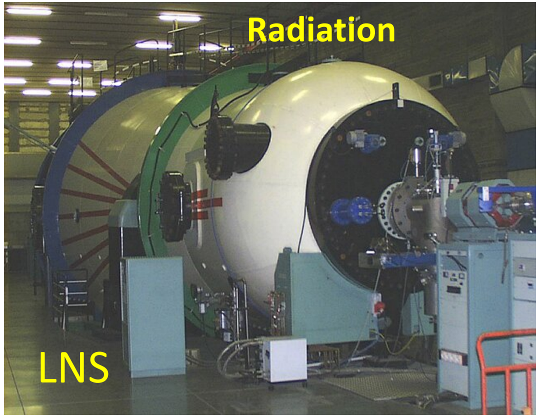


- Stability (=width of the MPV distribution for the cell over time) in the period 2011-2017 for one cell
- Stability (=RMS/Mean) of the response for all calorimeter cells

AMS-02 pre-flight space qualification

Different italian facilities available for testing electronic components, magnet vacuum case and assembled sub-detectors

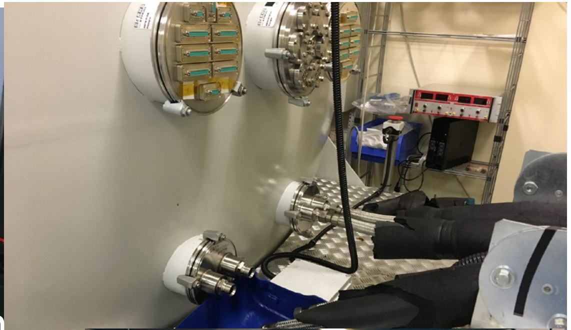


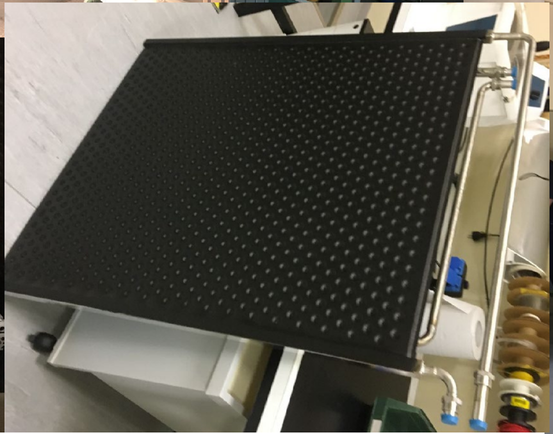


UTTPS space qualification @ SERMS

[G.Ambrosi, L. Mussolin, M.Gaggiotti, G.Scolieri, M.Caprai & B.Bertucci]

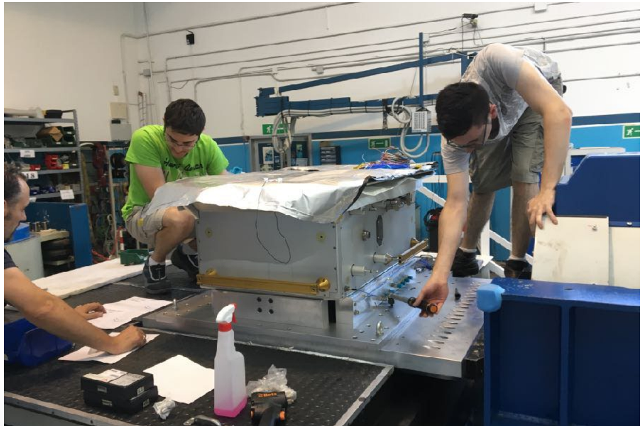
Winter-Spring 2018: Refurbishment of the facility for the UTTPS test

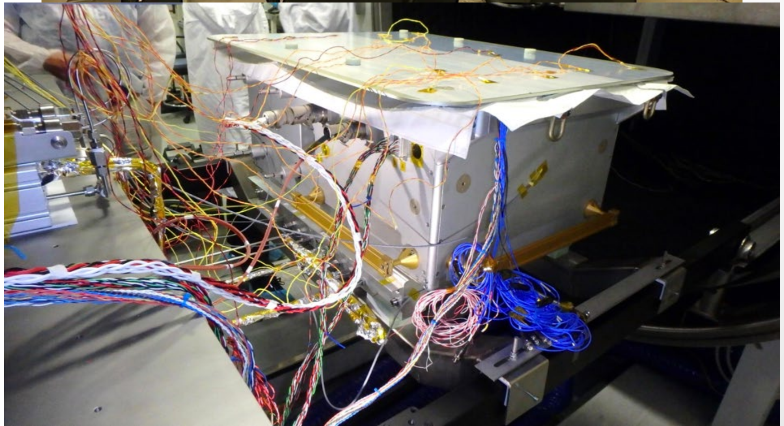




UTTPS space qualification @ SERMS

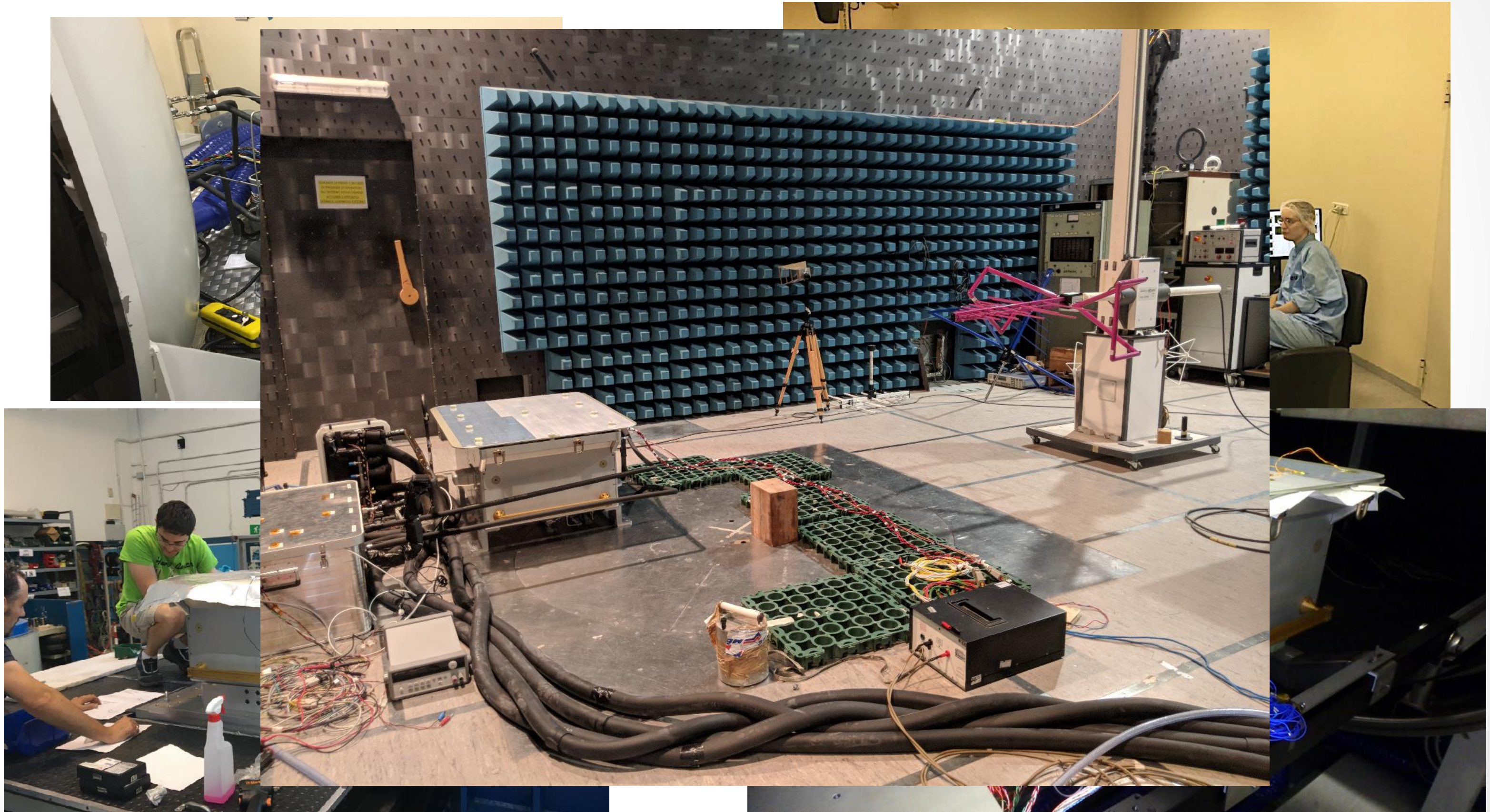
Summer 2018: vibration, TVT, EMI tests of UTTPS QM





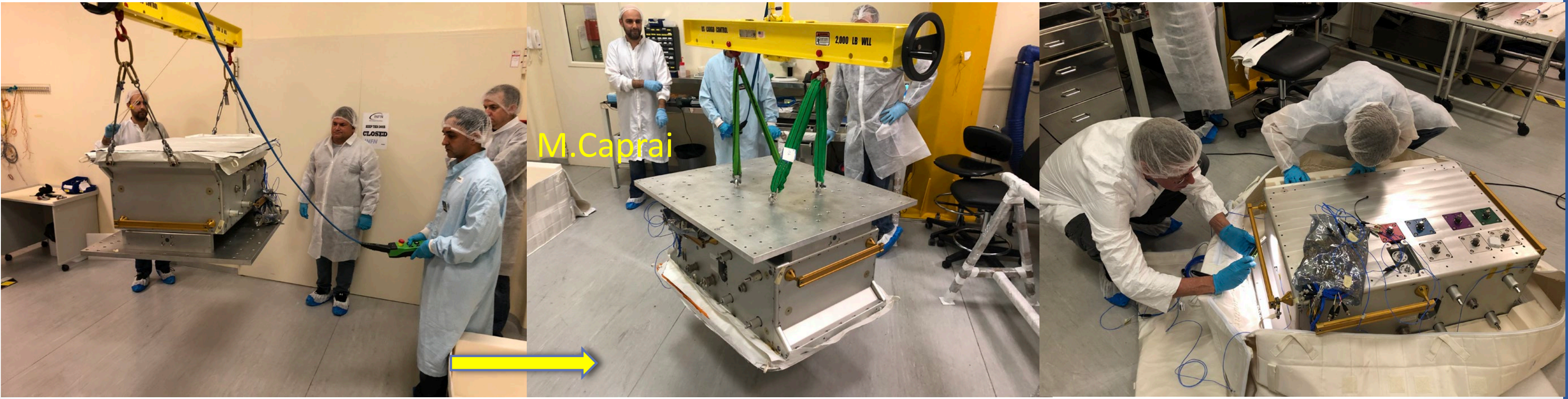
UTTPS space qualification @ SERMS

Summer 2018: vibration, TVT, EMI tests of UTTPS QM



UTTPS space qualification @ SERMS

Fall 2018: UTTPS QM



Upside down !!!!

UTTPS space qualification @ SERMS

Fall 2018: UTTPS QM

Physics & Data analysis

HIGH ENERGY

Galactic Cosmic Rays, anti-particles

- $e^{\pm}$, p-bar [PG/ASI-SSDC]
- Li,Be,B,C,0 [PG]
- Ne-Si ongoing [PG]
- p anisotropy [MiB] ongoing
- deuterons [Tn] ongoing
- anti-deuterons [PG] ongoing

LOW ENERGY

Time dependencies of CR fluxes:

- e^{+}/e^{-} monthly fluxes [Pg]
- p,He monthly fluxes : done and *to be updated* [Pg/ASI, Mib]
- C,0 monthly fluxes : ongoing [Pg/ASI]
- p,He daily fluxes : ongoing [Mib/Pg/ASI]

MODELS & PHENOMENOLOGY of CRs

- Magnetosphere & the geomagnetic cutoff [Mib]
- using AMS measurements to improve the understanding of the cosmo [Bo, Mib, Pg/ASI , Rm1]

Physics & Data analysis

HIGH ENERGY

Galactic Cosmic Rays, anti-particles

- $e^{\pm}$, p-bar [PG/ASI-SSDC]
- Li,Be,B,C,0 [PG]
- Ne-Si ongoing [PG]
- p anisotropy [MiB] ongoing
- deuterons [Tn] ongoing
- anti-deuterons [PG] ongoing

LOW ENERGY

Time dependencies of CR fluxes:

- e^{+}/e^{-} monthly fluxes [Pg]
- p,He monthly fluxes : done and *to be updated* [Pg/ASI, Mib]
- C,0 monthly fluxes : ongoing [Pg/ASI]
- p,He daily fluxes : ongoing [Mib/Pg/ASI]

MODELS & PHENOMENOLOGY of CRs

- Magnetosphere & the geomagnetic cutoff [Mib]
- using AMS measurements to improve the understanding of the cosmo [Bo, Mib, Pg/ASI , Rm1]

$e^+ + e^-$: MC free approach for e/p separation

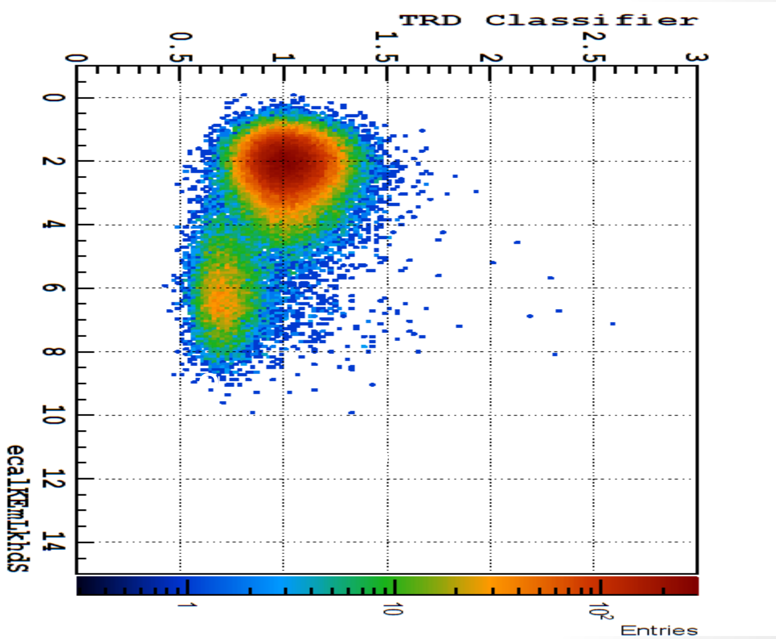
[B.Bertucci, **M.Crispoltoni, V.Di Felice**, **M.Duranti**, V.Vagelli (PG/ASI-SSDC)
& F.Nozzoli (Tn)]

Template fit based on new ECAL estimators

analytical (~ gaussian) templates with parameters extracted **directly from the data**;

MC independent / **complementary to other analyses.**

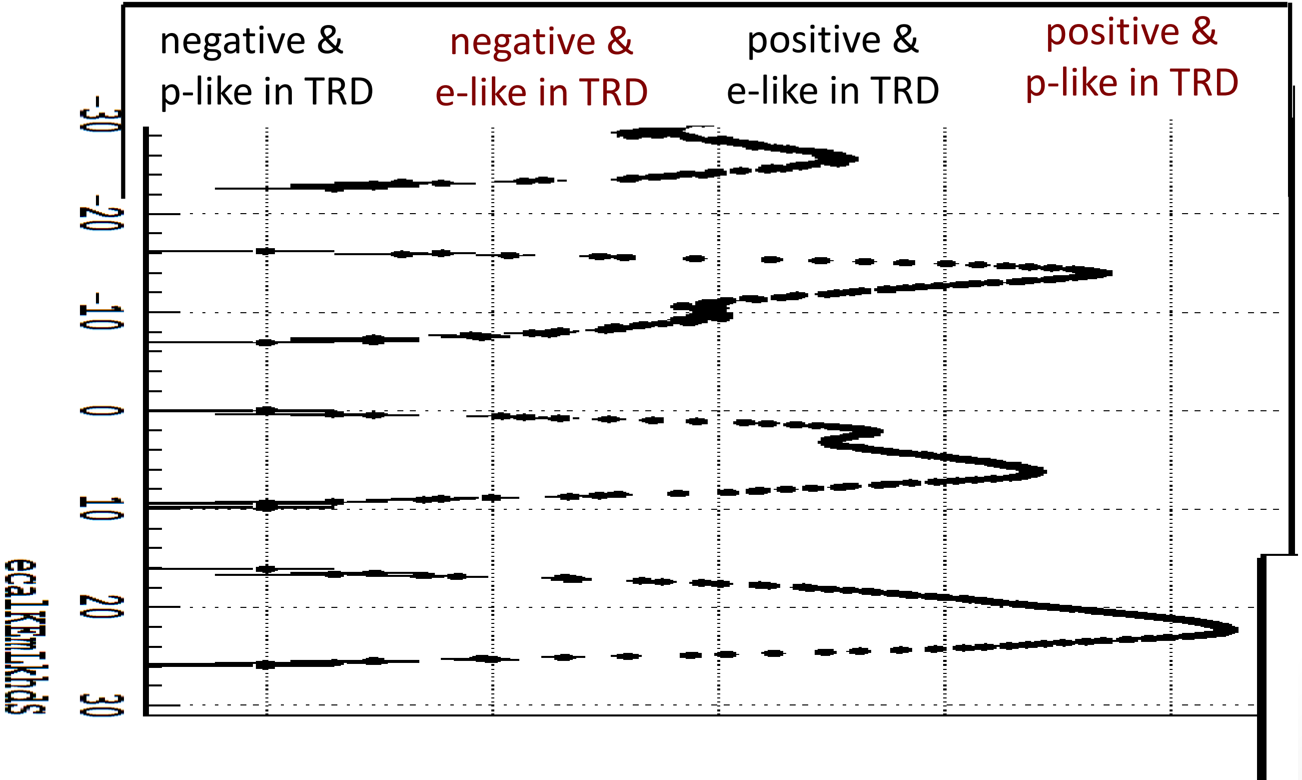
TRD classifier and charge sign used only to constraint background and signal templates



$e^+ + e^-$: MC free approach for e/p separation

Simultaneous fit to "signal" and "background" using positive TRD proton-like and negative TRD electron like samples to build p and e templates respectively

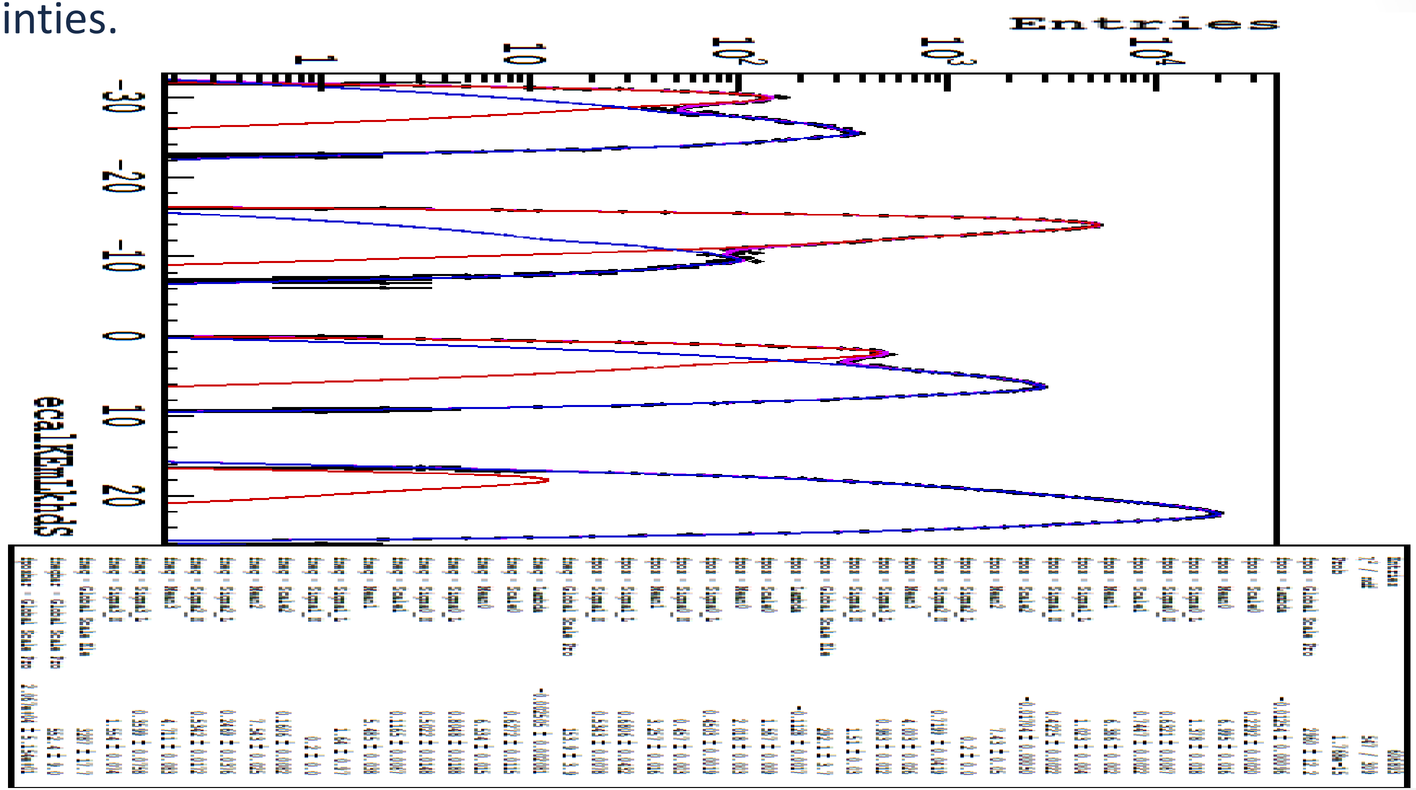
30 GeV



$e^{+} + e^{-}$: MC free approach for e/p separation

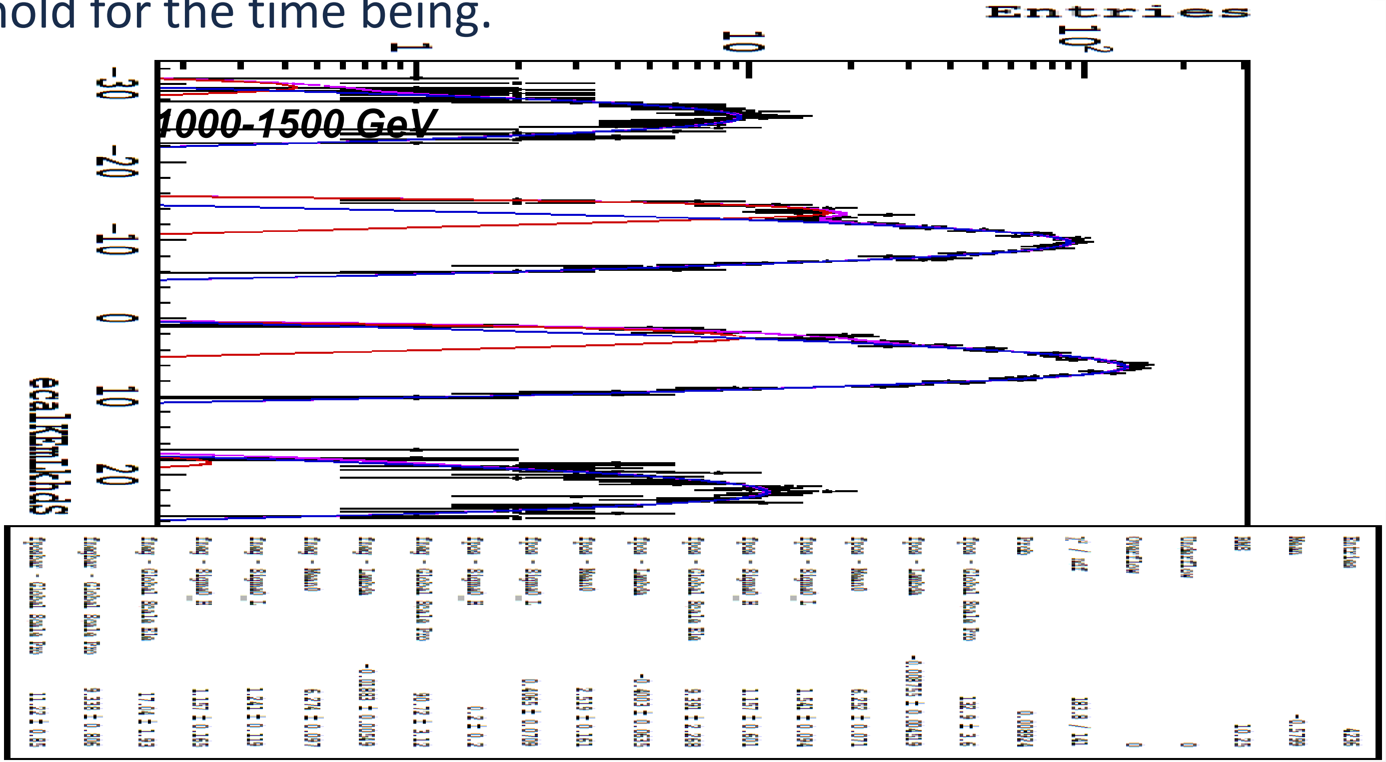
Pros : MC independent

Cons: A large number of parameters in the fit which leads to higher statistical uncertainties.



$e^+ + e^-$: MC free approach for e/p separation

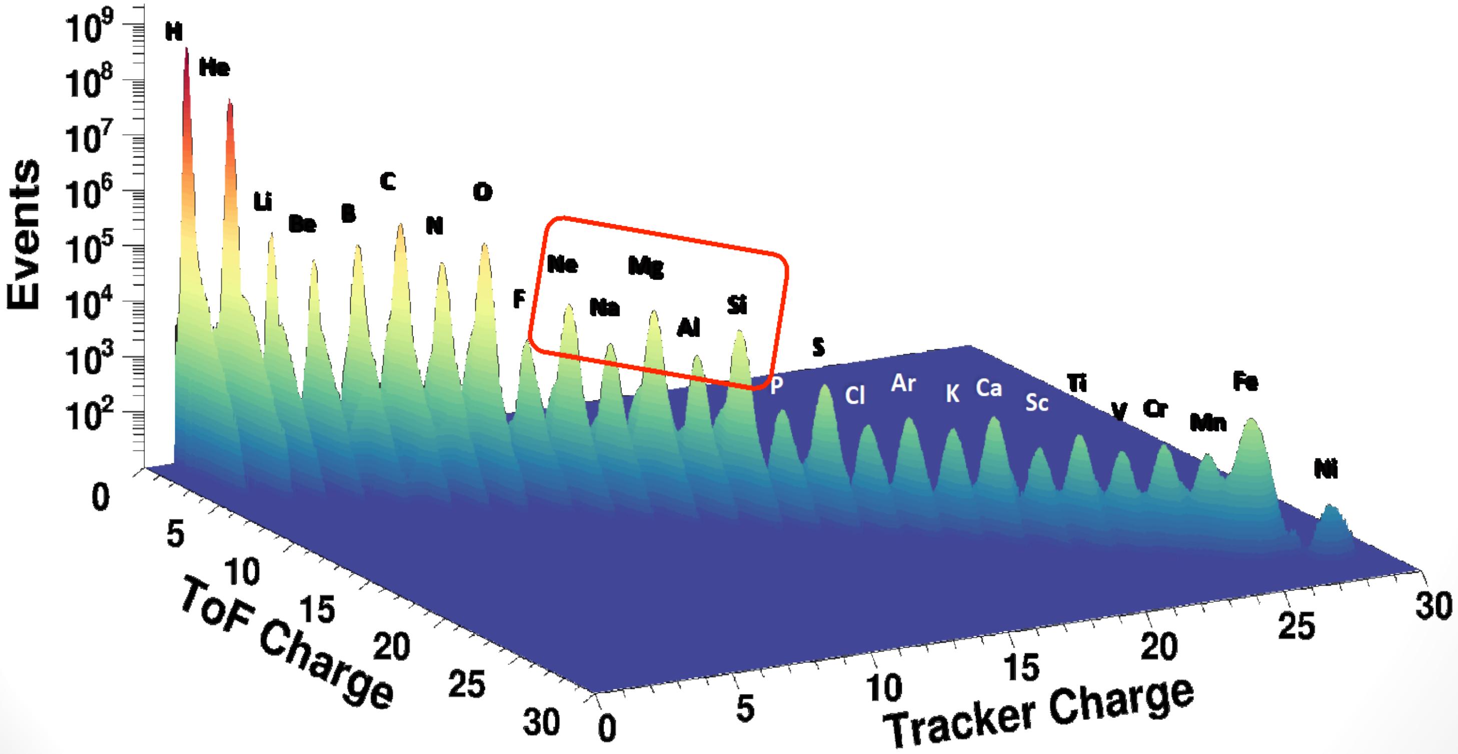
- ✓ As of today we can “trust” results up to ≈1.5 TeV
- ✓ It could be used for future updates of $e^{\pm}$ measurements
- ✓ on-hold for the time being.



Nuclei : fluxes from Ne to Si [Pg]

PhD Student: **Jian Tian** (CSC fellow at PG, now permanently @ CERN)

Tutors B.Bertucci, *V.Formato*



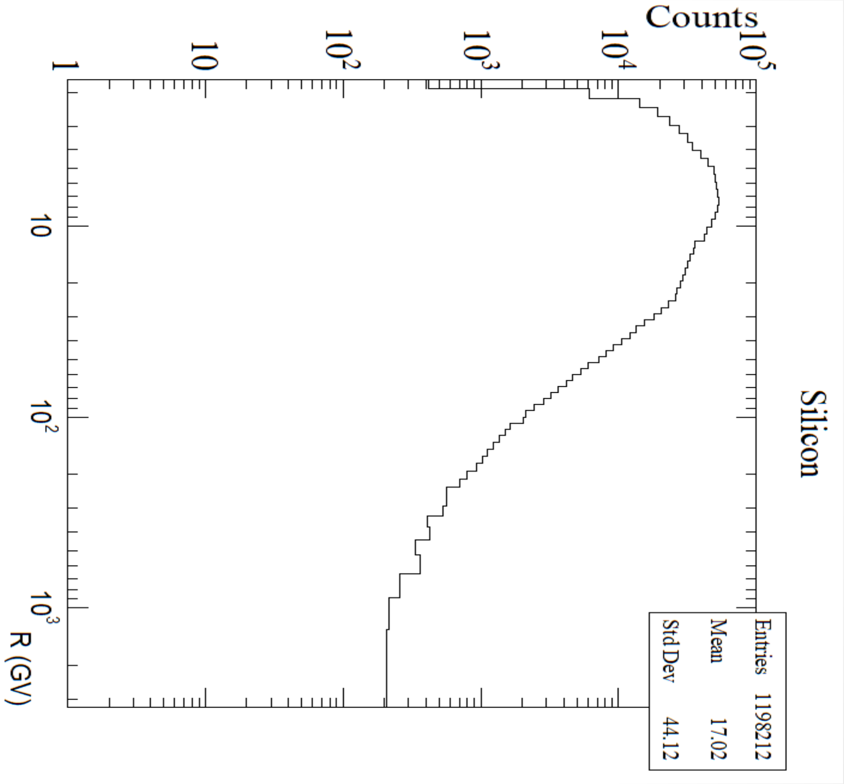
Nuclei : fluxes from Ne to Si

Starting point:

-selection and tools from Li/Be/B/C/O analysis (Donnini, Formato)

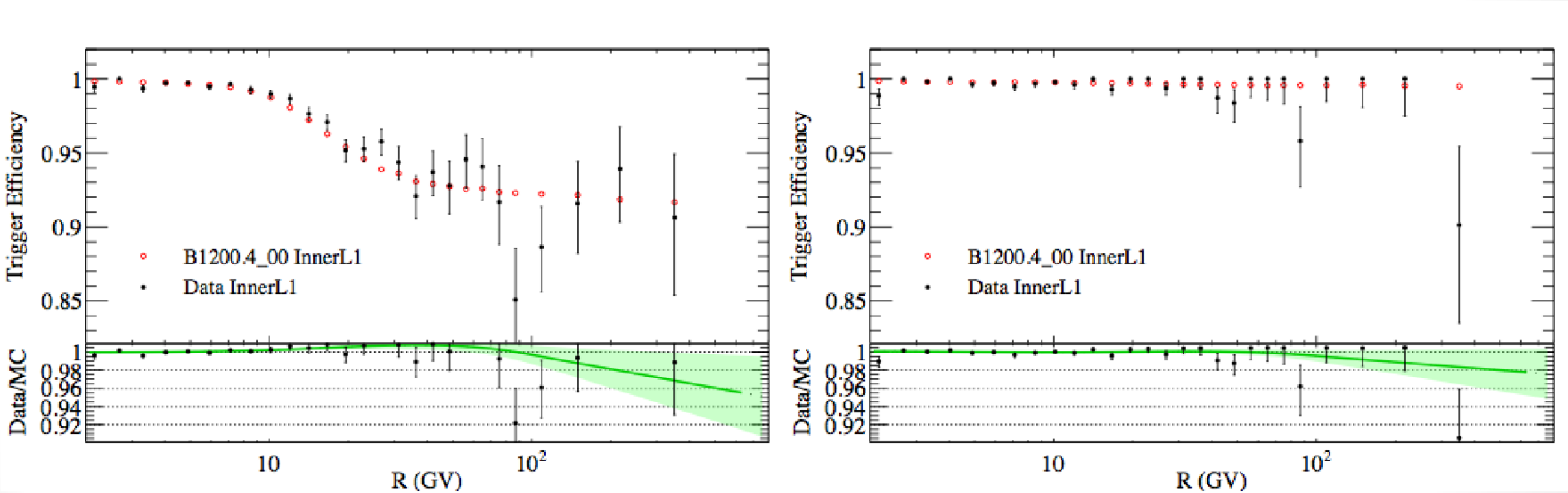
-initial effort focused on Si to test and improve the current selections.

Currently we have ~1.2M silicon nuclei in the Inner+L1 geometry using 84 months of pass7 data along with the new charge reconstruction by Hu Liu.



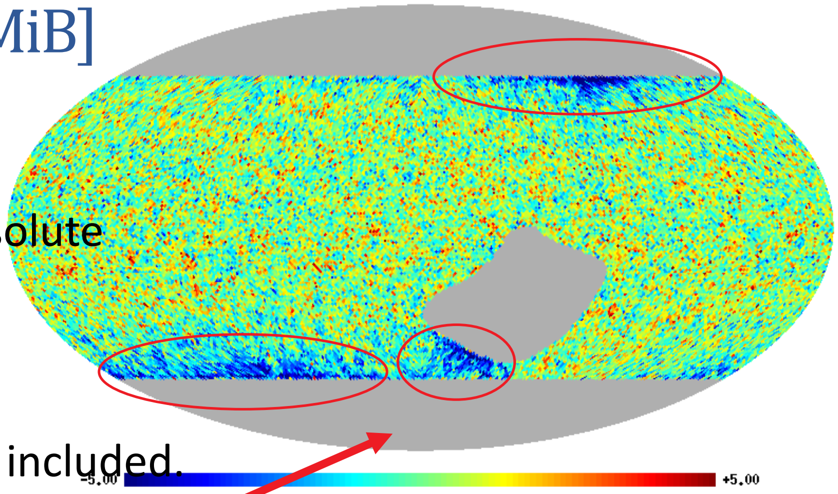
Nuclei : Silicon

Currently estimating all efficiencies and acceptance corrections



Work ongoing: Some of the efficiencies require a different handling w.r.t. the Carbon analysis (e.g. L1 pickup, Tracking efficiency)

p anisotropy [G. Lavacca, MiB]



STATUS:

Development of the code for the proton absolute anisotropy studies completed:

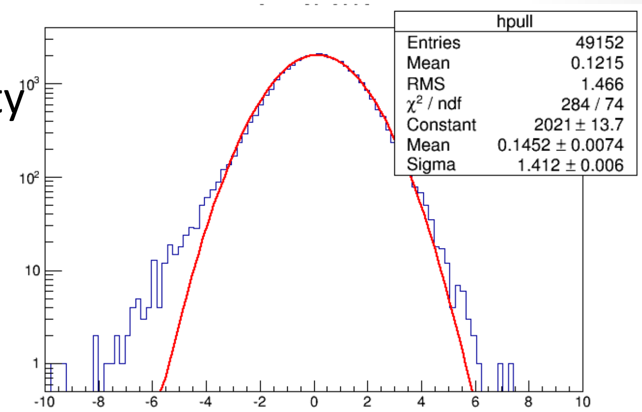
- Full-span analysis on pass6 data (5.5 years, ~9.1x10 protons R>18GV).
- Trigger efficiency and live-time corrections included.

ON-GOING:

Inclusion of the other efficiency corrections and rigidity scale effects.

To be done:

- Proton absolute anisotropy at the magnetosphere border.
- Migration to pass7.

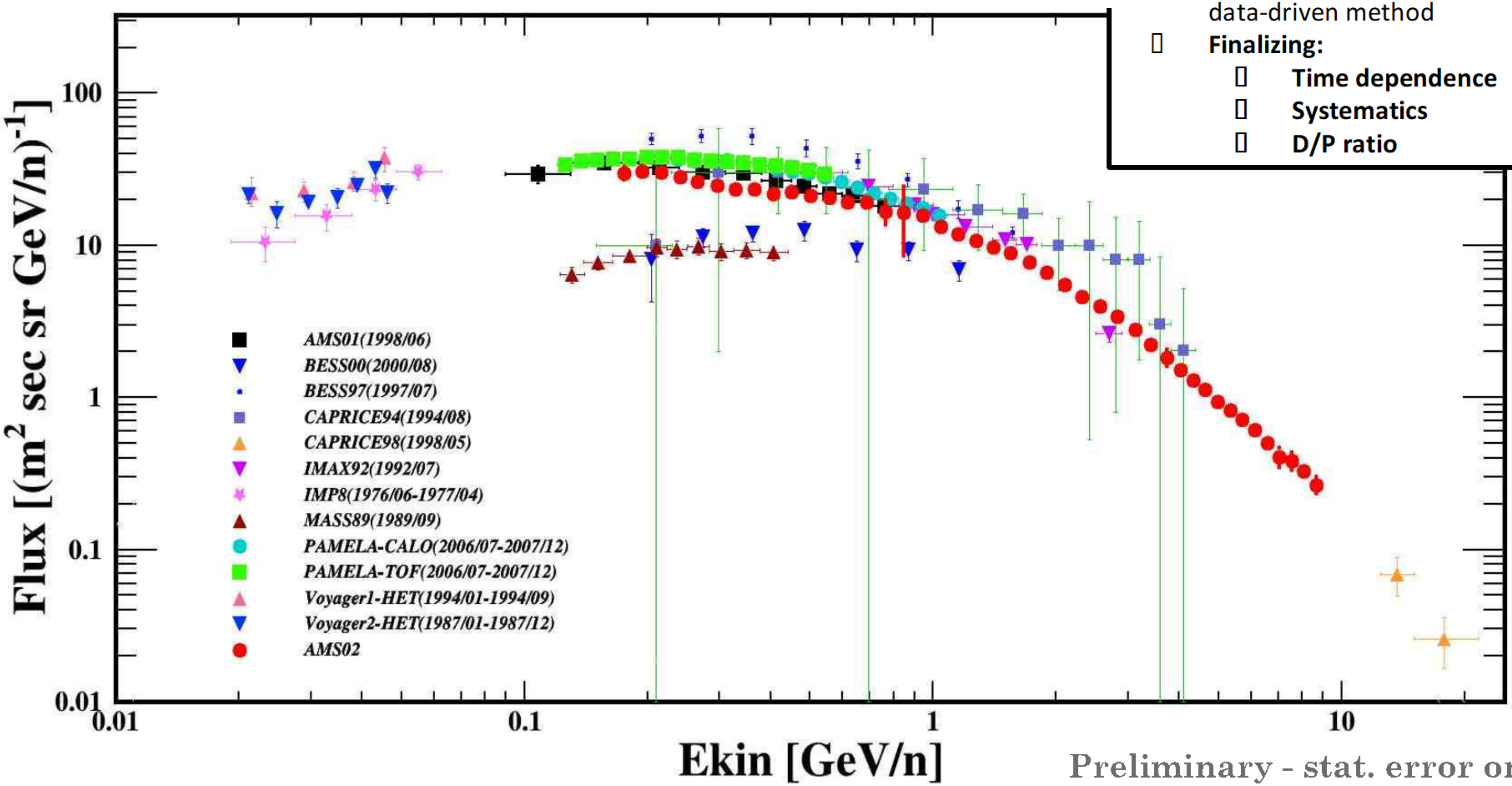


Pull distribution for protons in **GTOD** R>18GV

B.Bertucci - AMS General Meeting 07/02/19

Deuterium – *see report from Dimiccoli [Tn]*

- We calculated **D flux** with **Tof, RICH Naf & Agl**
- Acceptance from data-driven method
- **Finalizing:**
  - **Time dependence**
  - **Systematics**
  - **D/P ratio**



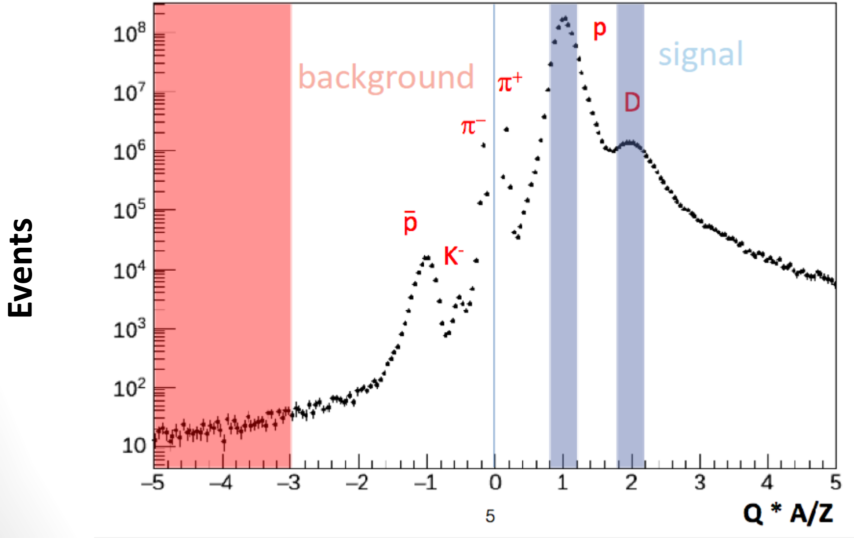
Preliminary - stat. error only

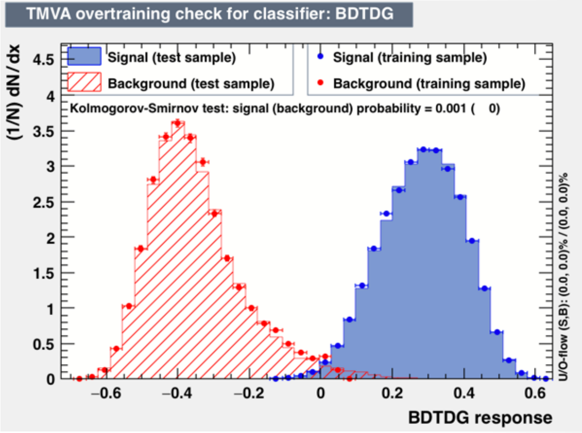
Antideuterium (V.Formato + M.Duranti , Pg)

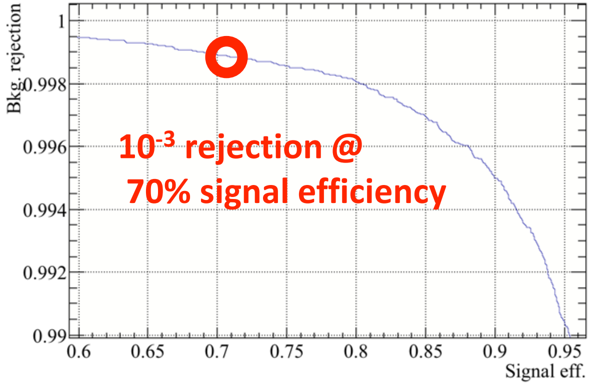
Background suppression is the key for anti-d identification:

→ mass mis-reconscruction due to either wrong β or R

→ working on a statistical estimator [BDT] of the mass reconstruction quality based on Tracker variables [*updating to pass 7*]

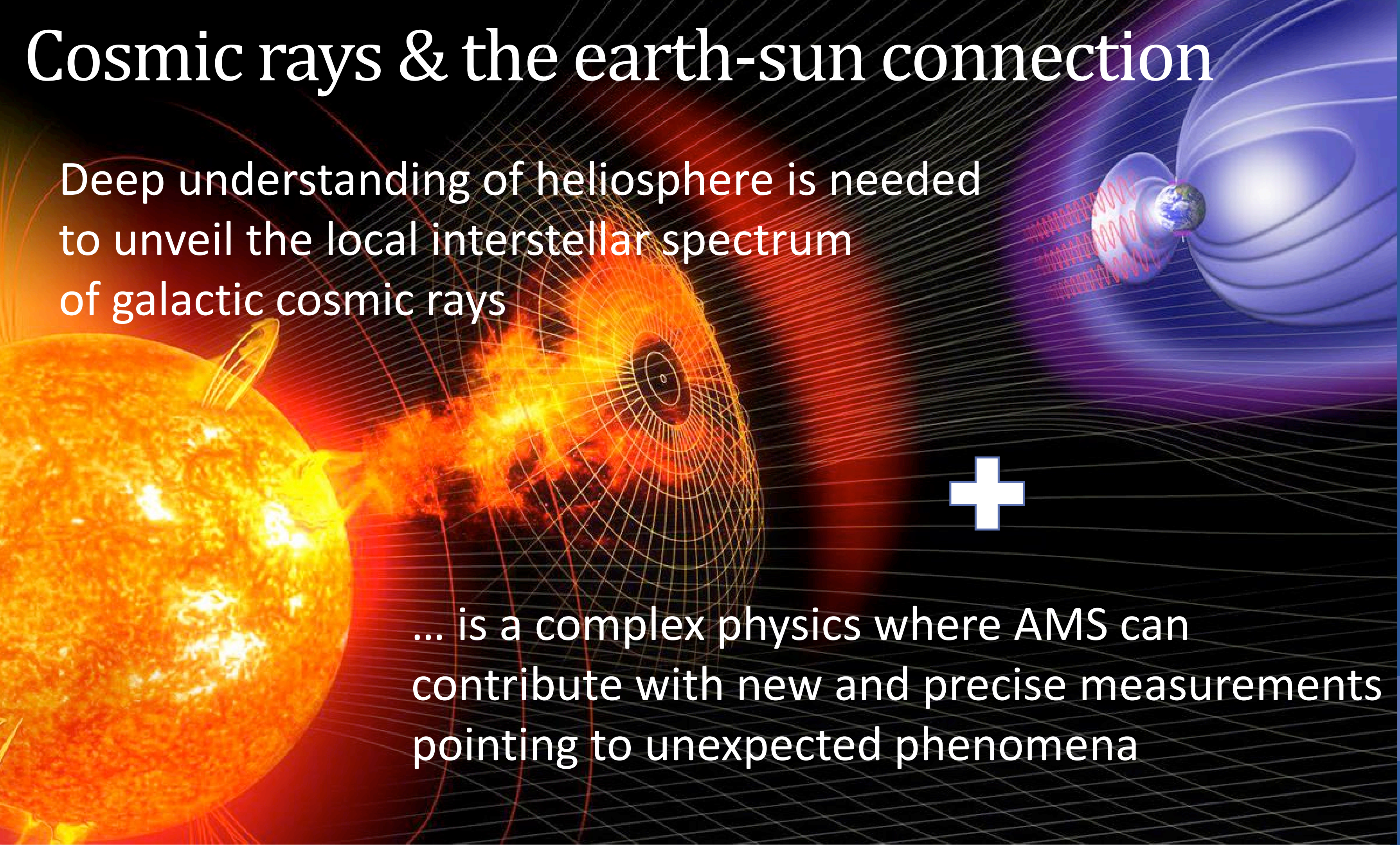






see report from A. Oliva

Cosmic rays & the earth-sun connection



Deep understanding of heliosphere is needed
to unveil the local interstellar spectrum
of galactic cosmic rays

+

… is a complex physics where AMS can
contribute with new and precise measurements
pointing to unexpected phenomena

Unveiling the GCR spectrum [Bo,Mib]

Thanks to AMS-02 high precision data we can constrain CR production, propagation and the galactic physics for the first time

AMS-02 published data are fitted in the combined framework of GALPROP and HelMod (for Galactic propagation and Heliosphere propagation, respectively) **with a single universal model**, capable of reproducing primary and secondary spectra at the same time

All GALPROP Local Interstellar Spectra predictions (p, He, C, O, B/C, Li, Be, B) are obtained using the very same set of parameters, i.e. a single AMS-02 driven cosmic ray model

(ApJ **840**:115 No 2, 2017; ApJ **854**:94 No 2, 2018; ApJ **858**:61 No 1, 2018; *forthcoming paper on secondaries*)

MCMC approach to find GALPROP parameters

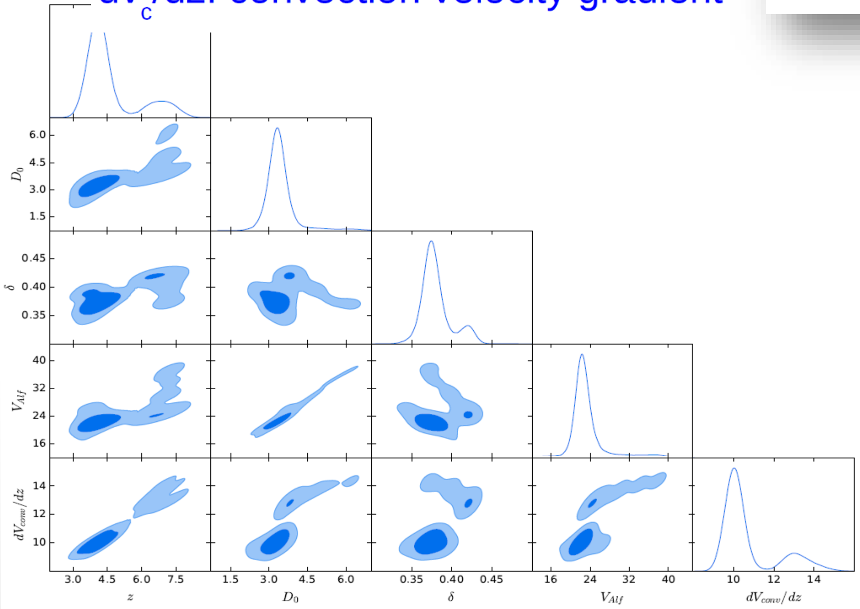
z_h: half size of the Halo

D_0: diffusion coefficient

δ : diffusion coefficient index

V_{alf} : Alfvén velocity

dv_c/dz: convection velocity gradient



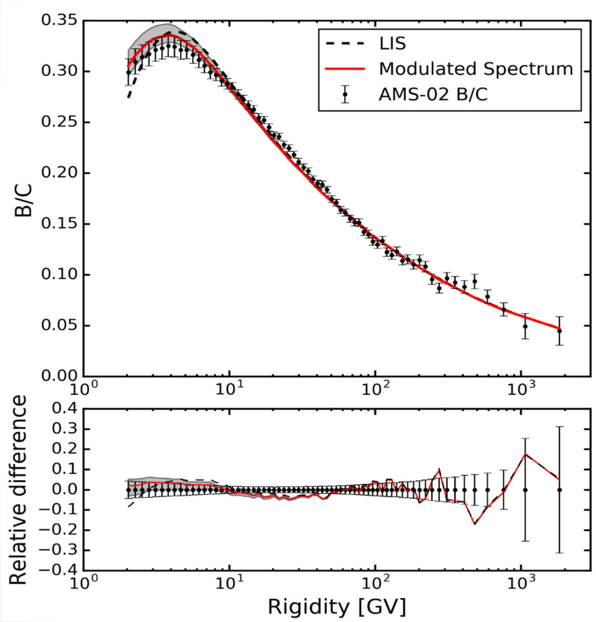
Best-fit Propagation Parameters

N	Parameter		Best Value
1	z_h,	kpc	4.0 ± 0.7
2	D_0,	10^{28} cm^2 s^{-1}	4.3 ± 0.6
3	δ		0.415 ± 0.025
4	$V_{\rm Alf}$,	km s^{-1}	29 ± 3
5	$dV_{\rm conv}/dz$,	km s^{-1} kpc^{-1}	9.8 ± 0.7

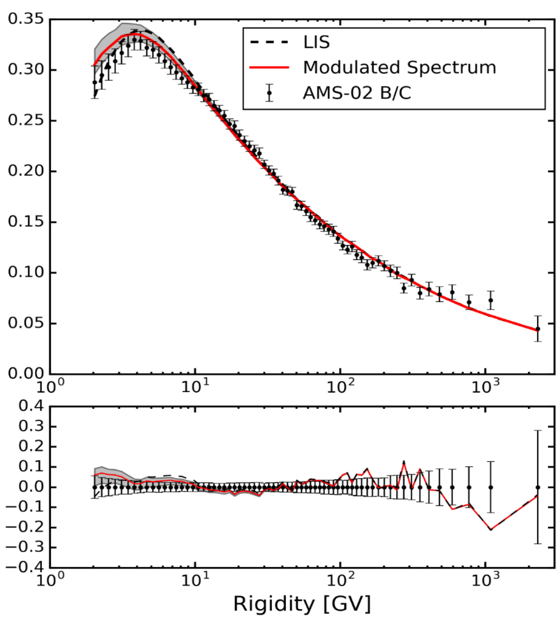
1. The Monte-Carlo-Markov-Chain interface to GALPROP v55 was **developed in Bologna**, embedding GALPROP framework into the MCMC scheme;

2. The experimental observables, used in the MCMC scan as constraints, include **all primary CRs AMS-02 data and B/C ratio**.

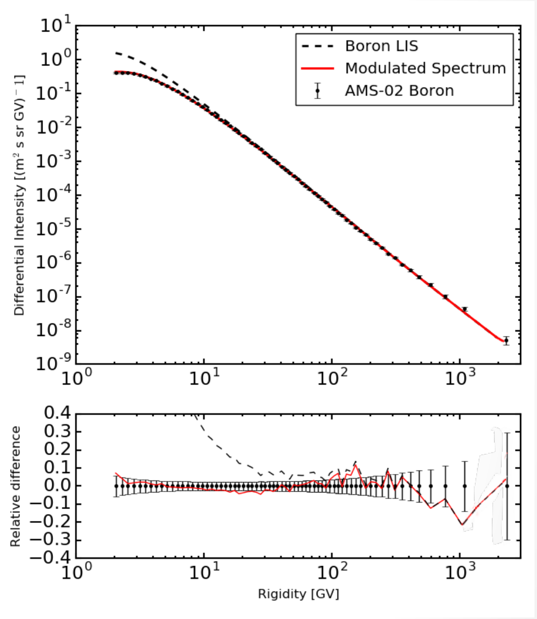
B/C ratio and B spectrum compared to AMS-02 data



PRL **117**, 231102 (2016)

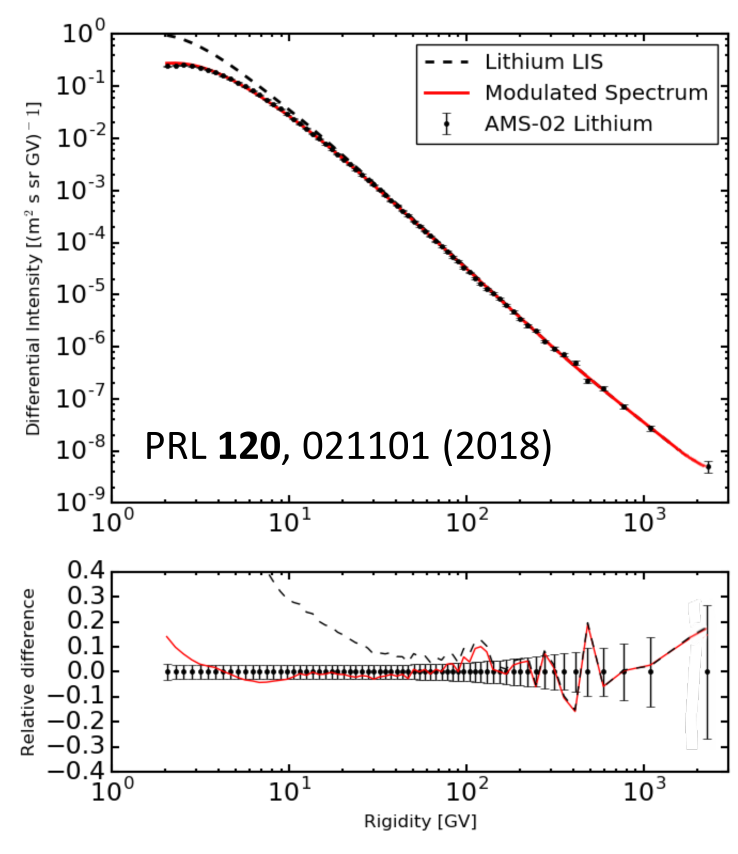


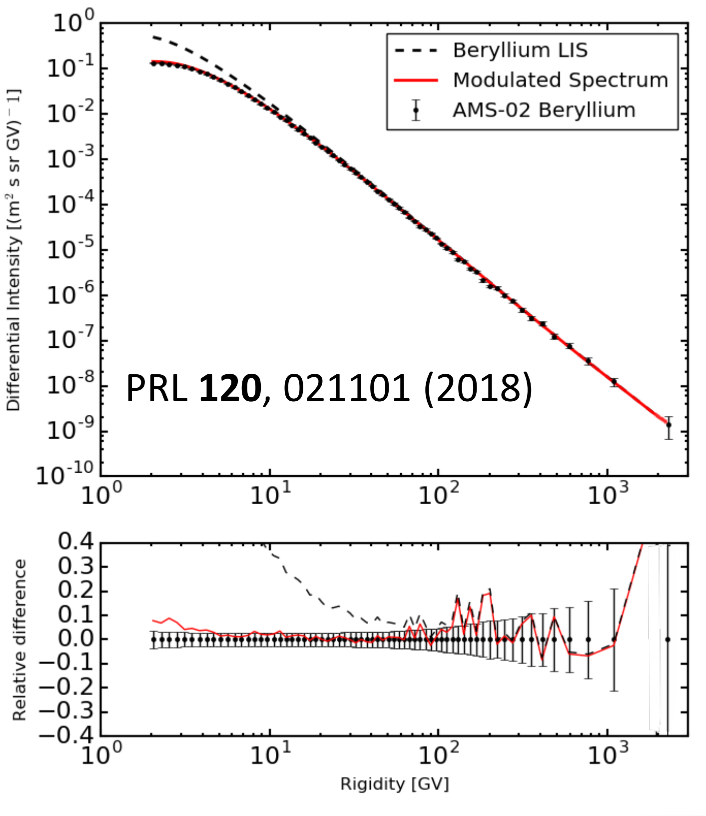
PRL **120**, 021101 (2018)



PRL **120**, 021101 (2018)

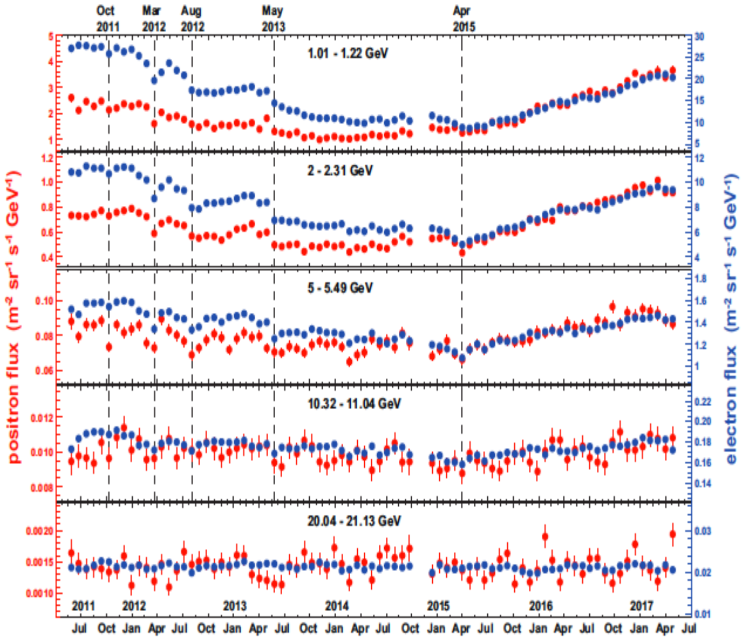
Li and Be spectrum compared to AMS-02 data

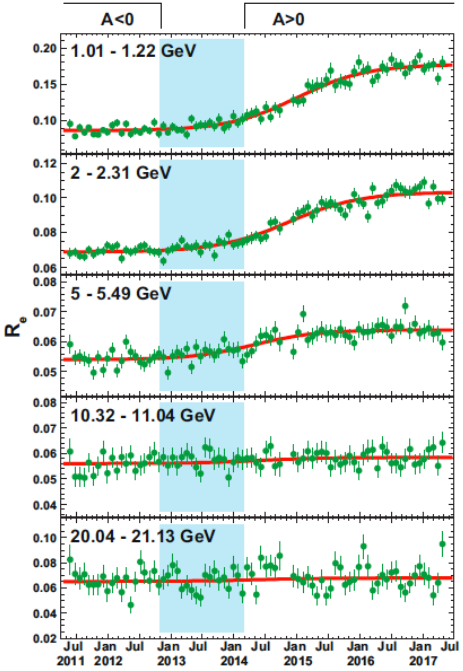




Charge sign dependence of solar modulation

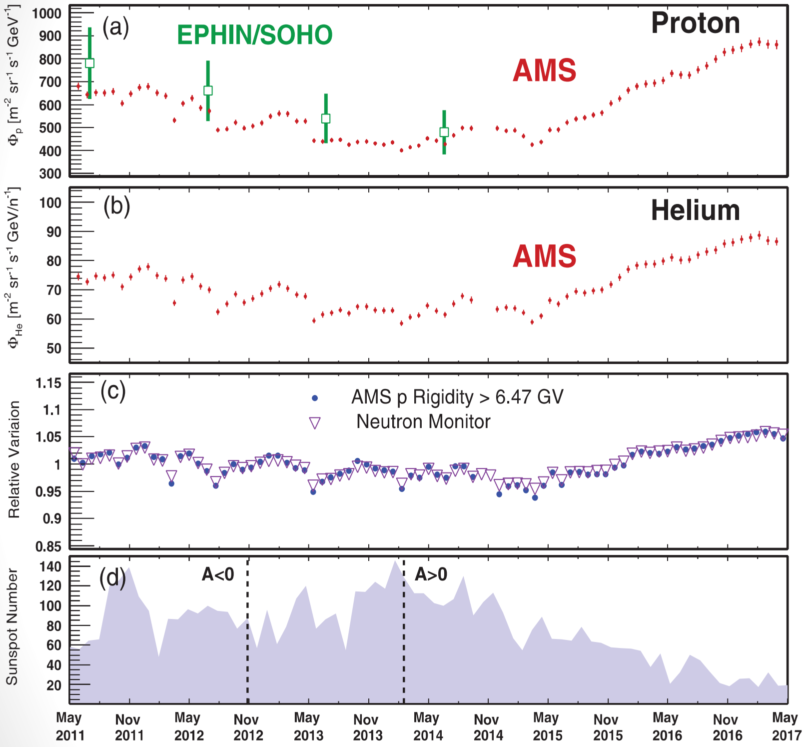
work started by M.Graziani in her PhD Thesis (Pg, 2016)
then Graziani (KIT) & Zimmermann (Aachen)



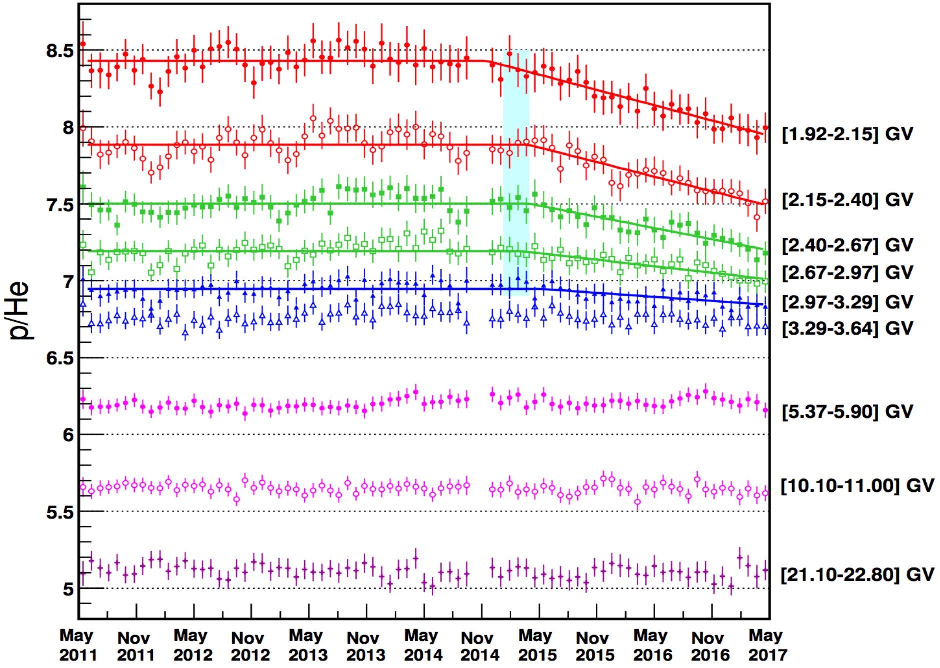


M.Aguilar et al , Phys. Rev. Lett. 121, 051102 (2018)

P & He : similarities & differences



Kuhl et al Sol.Phys 291 (2016)



M.Aguilar et al, Phys. Rev. Lett. 121, 051101 (2018)

[He: N.Tomassetti, PG / p: S. Della Torre MiB]

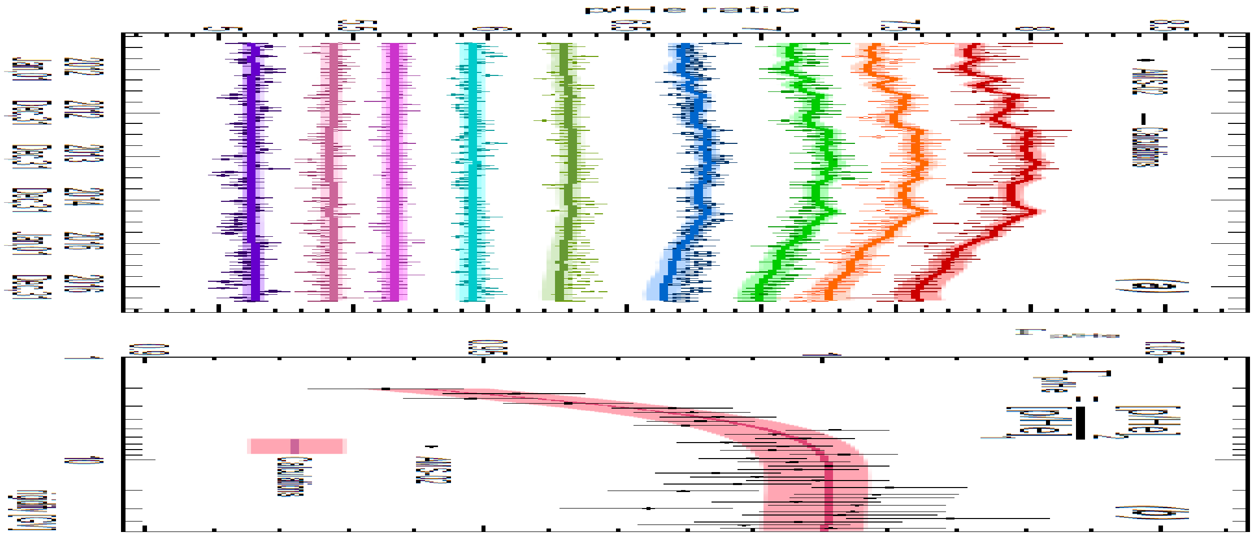
Testing Diffusion of Cosmic Rays in the Heliosphere with Proton and Helium Data from AMS

N. Tomassetti, F. Barão, B. Bertucci, E. Fiandrini, J. L. Figueiredo, J. B. Lousada, and M. Orcinha
Phys. Rev. Lett. **121**, 251104 – Published 18 December 2018

- The p/He time-dependence is *predicted* from a proton-driven model under the assumption of a β dependence of the diffusion coefficient K

$$K(R,t) = \beta \times k_0(t) \times R$$

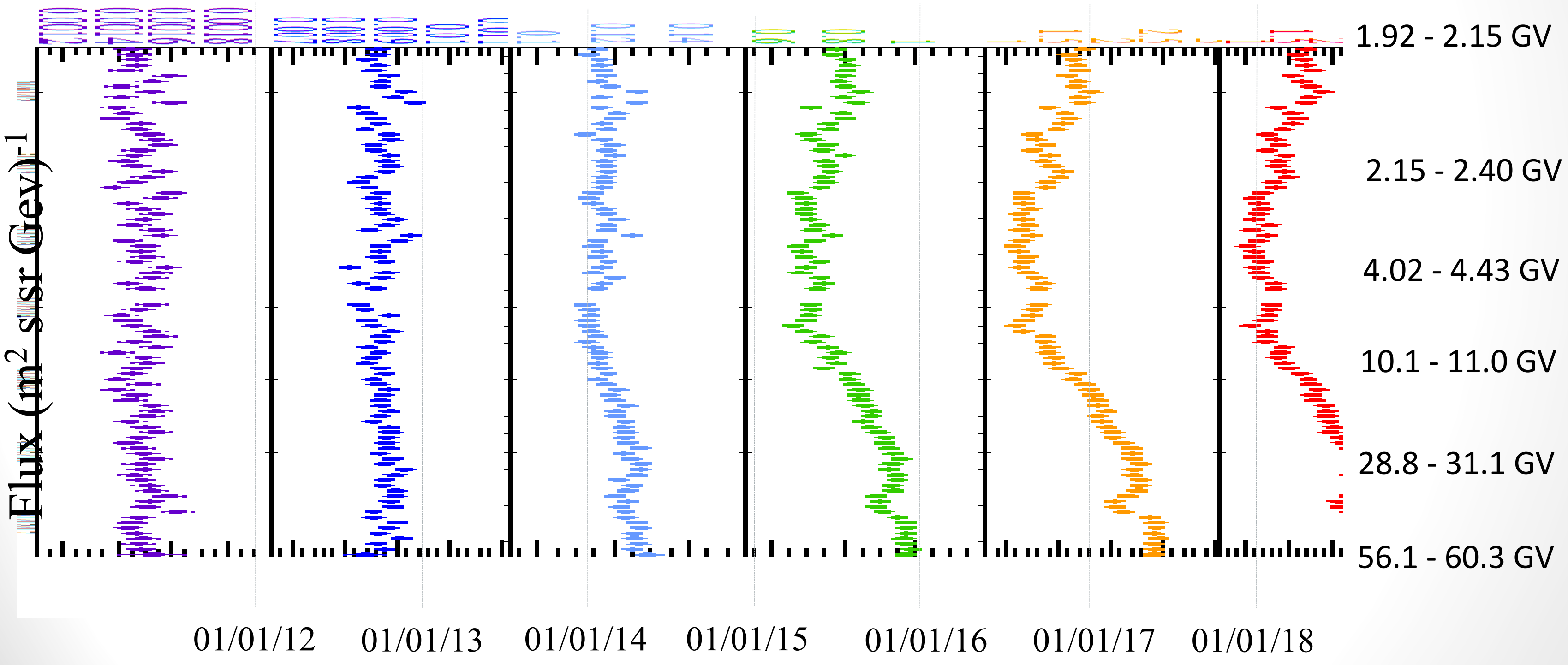
- The p/He structure is expected to disappear at relativistic rigidities



The p/He long-term behavior is a signature of *universality* of the CR mean free path $\lambda(R)$

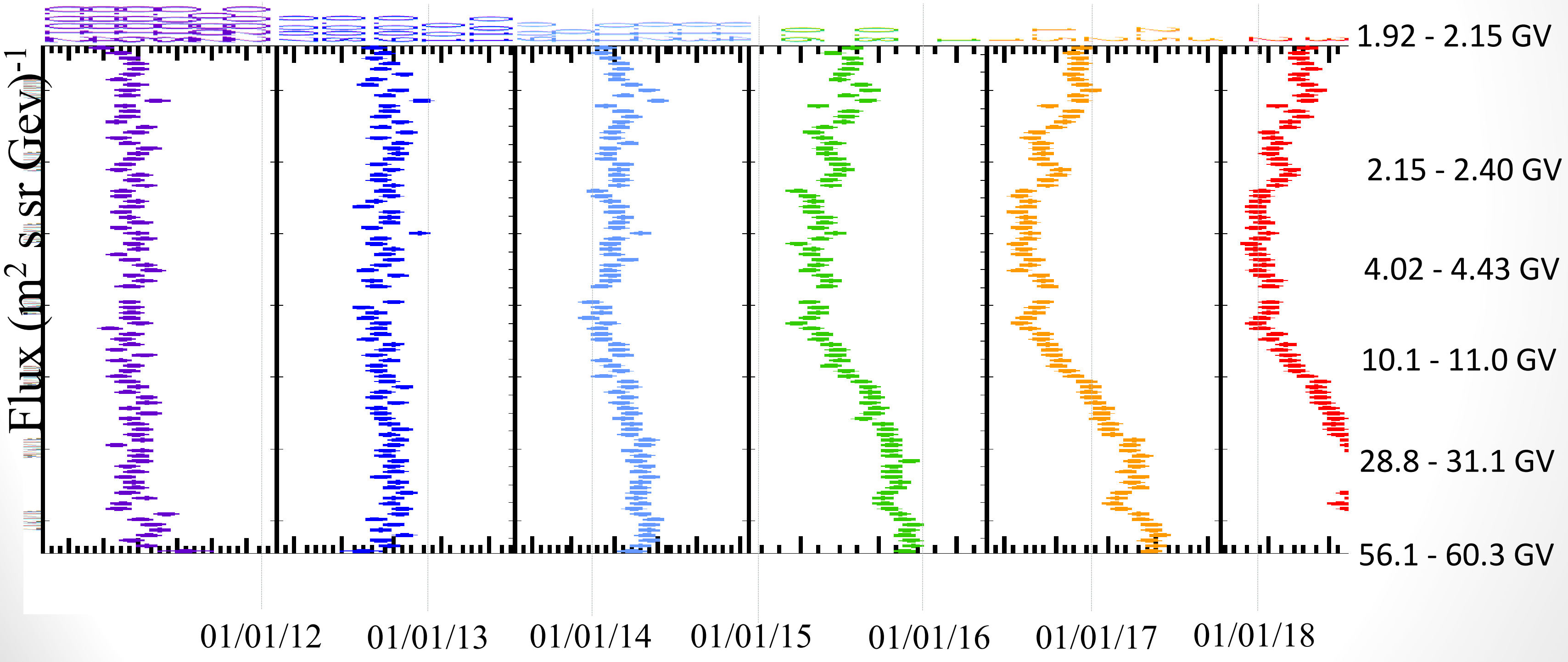
Carbon flux vs time [F.Donnini, B. Khiali PG/ASI-SSDC]

Data set PASS 7 , xx bartel rotations up to May 2018



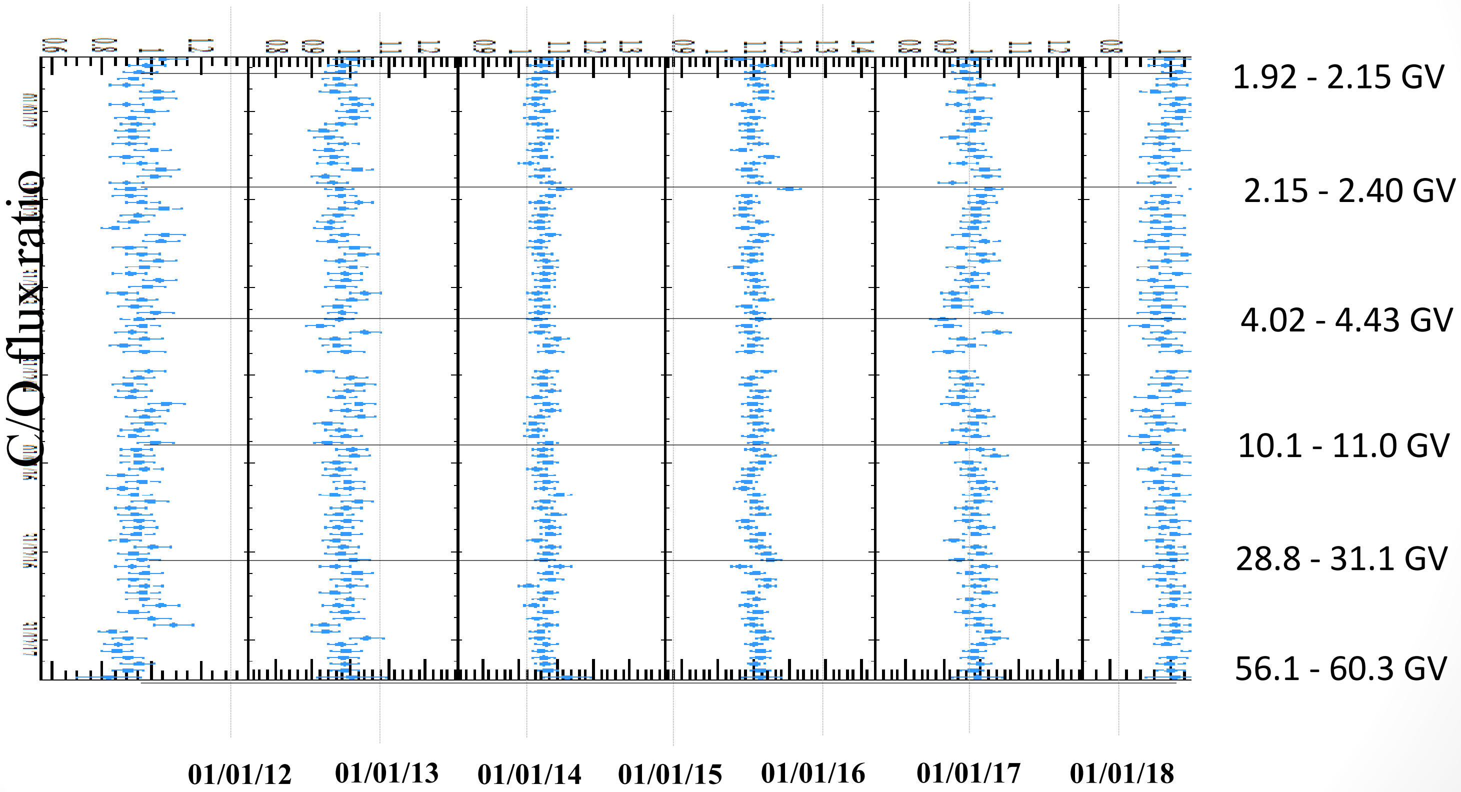
Oxygen flux vs time [F.Donnini, B. Khiali PG/ASI-SSDC]

Data set PASS 7 , xx bartel rotations up to May 2018



Carbon & Oxygen : flux ratio over time

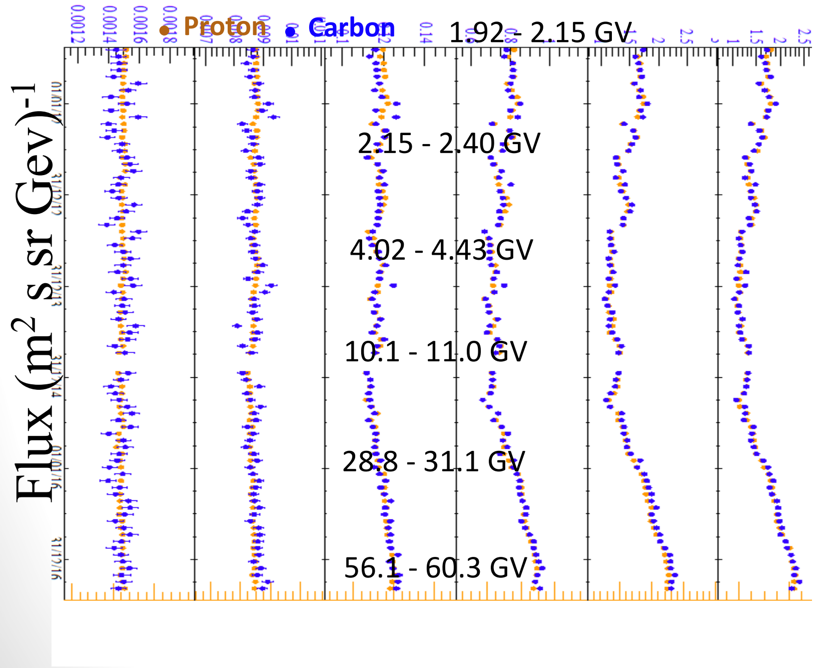
Within statistical uncertainties no trend in C/O flux ratio (ok, expected…)

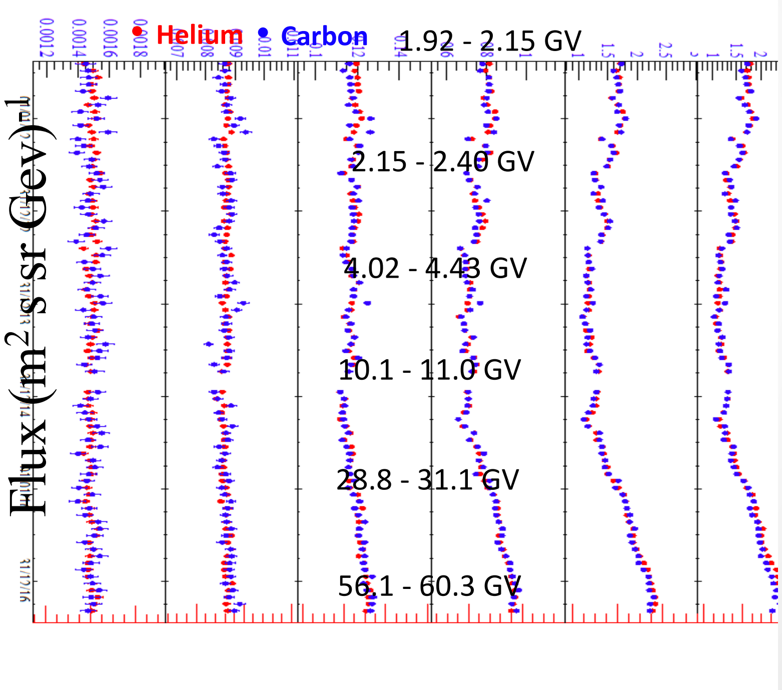


Carbon compared to p and He

Unexpectedly at low rigidities C & O) seems to behave as protons and not as helium

p/He fluxes to be extended with pass 7 data (i.e. adding 1 year wrt to published data) to confirm/discard this effect



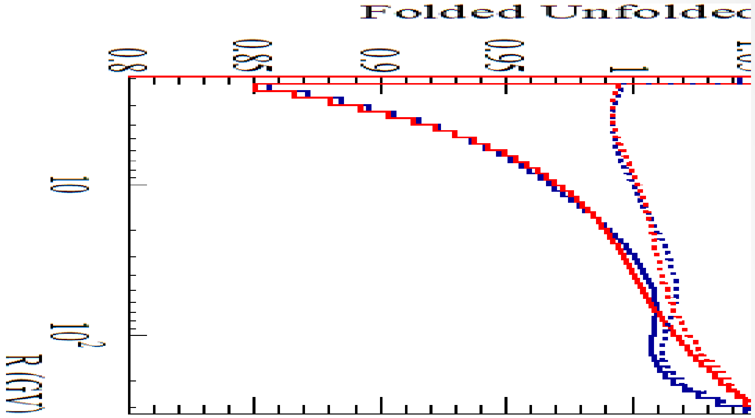


C & O fluxes in time : status and next steps

Data set PASS 7 + new charge reconstruction (by H.Liu) to improve Data/MC agreement

From 2011 up to May 2018, ready to include data up to Jan-2019 as soon as their production will be ready.

Whole analysis redone with the new rigidity estimate at the top of the instrument. Results in agreement with standard analysis except in the very first bins, cause under investigation.

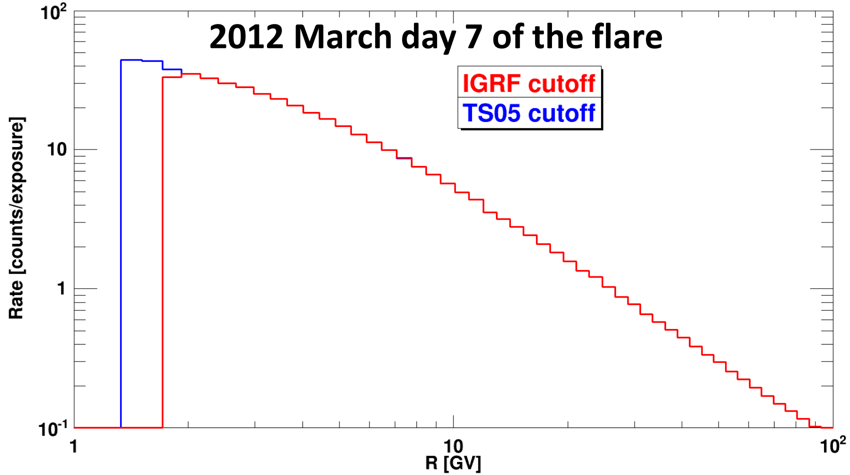


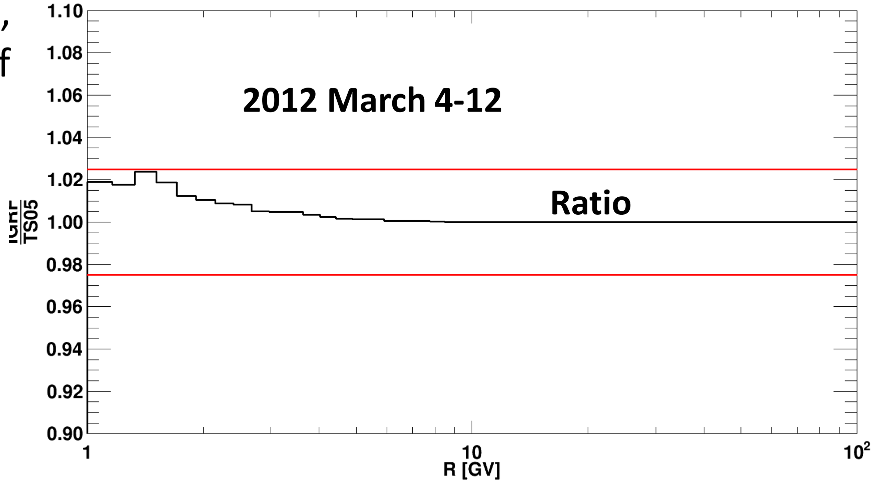
→ Extension of p/He analysis to pass7 [V.Di Felice, PG/ASI-SSDC + MiB]

Time dependent effects: solar flares [MiB]

AMS-02 protons: pass6 - standard selection – FullSpan;
Periods: solar flares;
Backtracing: performed using both IGRF and TS05 models

Integrating over whole solar flare period (9 days, March 4 → 12), the RATE differences (IGRF cutoff vs TS05 cutoff) are lower than 2.5 %.

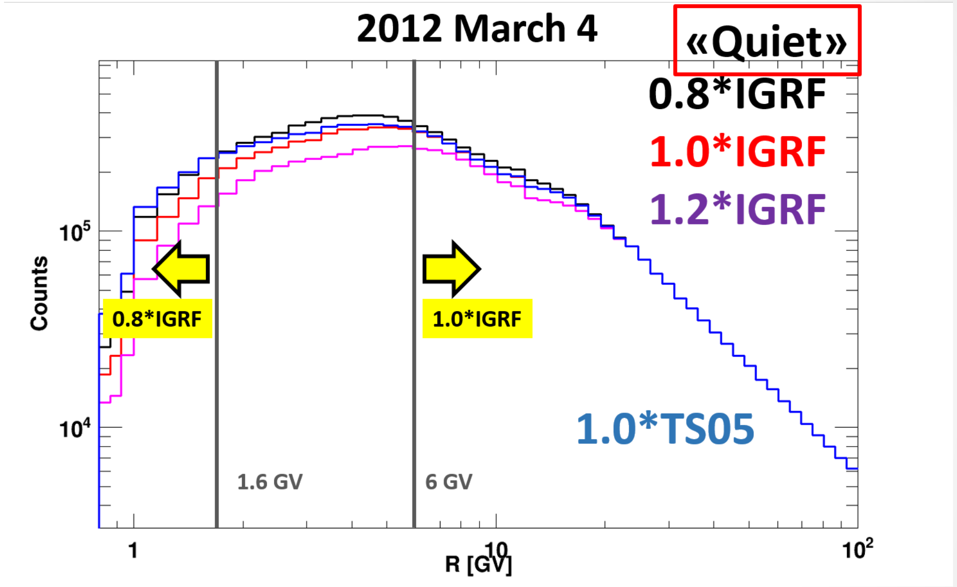




IGRF can not be used to perform a solar event analysis & daily flux during disturbed periods

Time dependent effects: solar flares [MiB]

To increase the statistics at low energy it can be useful to adopt different Safety Factor for different rigidity regions, an example is shown in the figure.
The differences on rates with different Safety Factors are negligible (inside 1%).



Aspecific analysis is being carried during two Bartel rotations (in high solar activity March 2012 and in low solar activity June 2016) in order to evaluate this possibility.

Radiation & Human Space Exploration

More than 20 years studying radiation & its effects inside the astronauts habitat

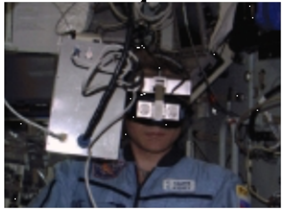
MIR

ISS

Sileye 1 (1995 – 1997)

Sergey Avdeev tiene il detector SilEye1 mentre indossa il supporto di legno a caschetto

Sileye 2 (1997 – 2000)



Sergey Avdeev 'indossa' SilEye2 (sulla sua destra) e lo stimolatore luminoso

Alteino

Alteino nel modulo Russo della ISS

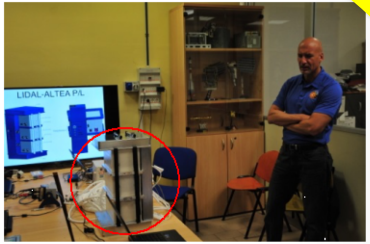
(2002 – 2010)

ALTEA

L'astronauta Paolo Nespoli fotografa ALTEA nella configurazione XYZ prima di posizionarlo

(2006 – 2012)

LIDAL

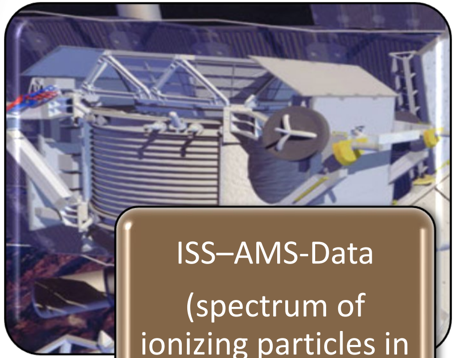


L'astronauta Luca Parmitano durante la familiarizzazione con LIDAL (nel cerchio rosso)

(programmato per partire nel 2019

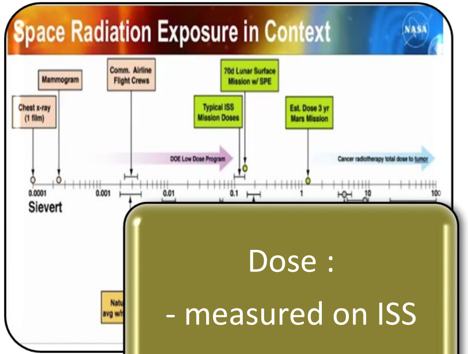
(2019 – ?)

From ISS to MARS ….[Rm1, Pg/ASI-SSDC]



ISS–AMS-Data

(spectrum of ionizing particles in space since 2011)



Dose :

- measured on ISS

- expected

Biological Damage

(effects on livings things)

→ AMS total fluxes as input of ISS experiments (same environment !)

→ Daily fluxes (solar flares & quiet periods !)

Conclusion

Italy was major partner in the construction of AMS on the ISS and is maintaining its full involvement:

- in the operation of the detectors & upgrade of the TTCS
- data analysis
- exploitation of the precise AMS measurements in different physics contexts.