

# *Galactic Cosmic-Rays (GCR) with AMS-02: pheno/data analysis*

*[LAPP/LAPTh/LPSC collaboration]*



## *I – Context*

- 1. GCRs*
- 2. AMS-02*

## *II – Project*

- 1. Pheno/data analysis*
- 2. Post-doc profile*
- 3. E-Teams involved*

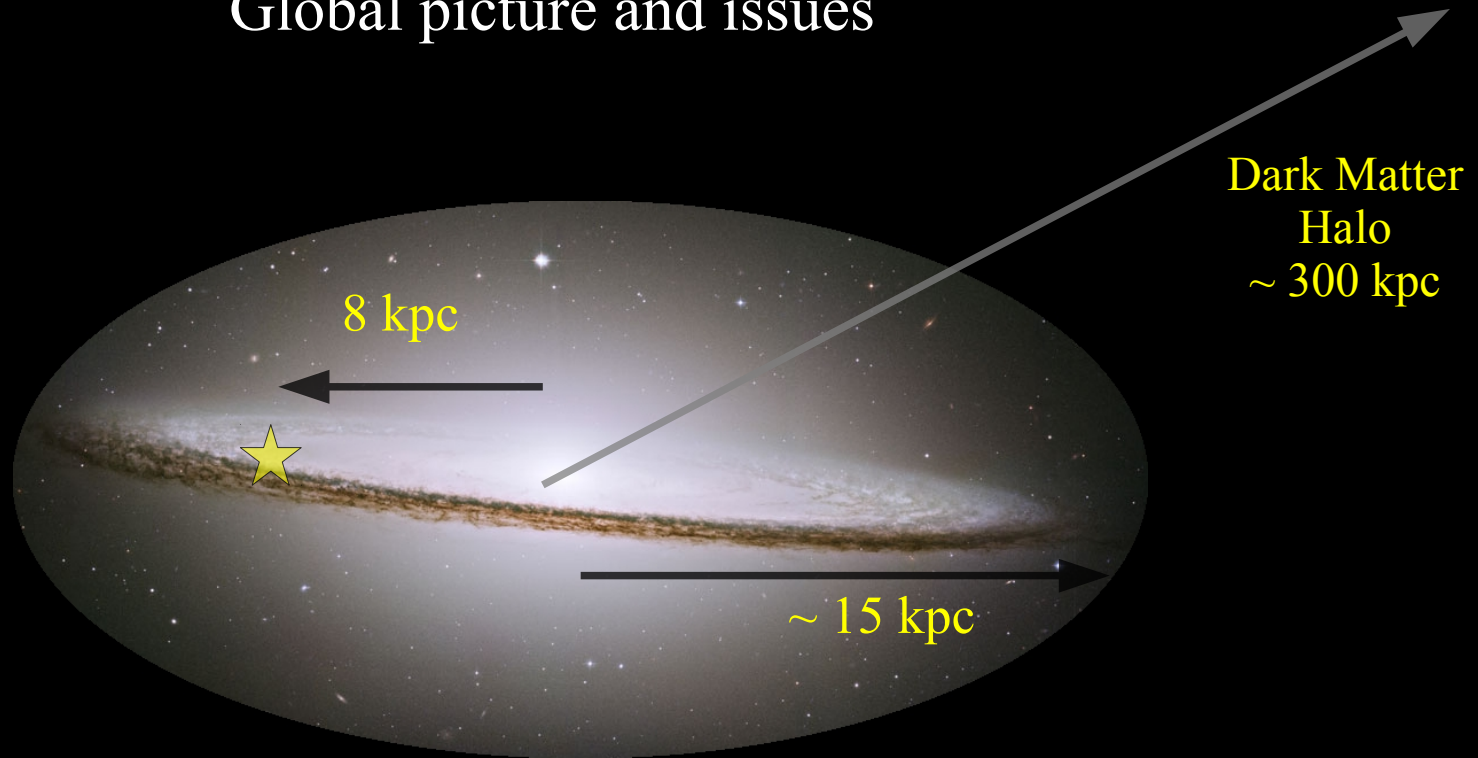


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**ENIGMASS**  
11/10/2012

# *CR propagation: neutral and charged particles (I)*

## Global picture and issues



- Cosmic-Ray (CR) origin
- CR transport
- Dark Matter (DM) searches

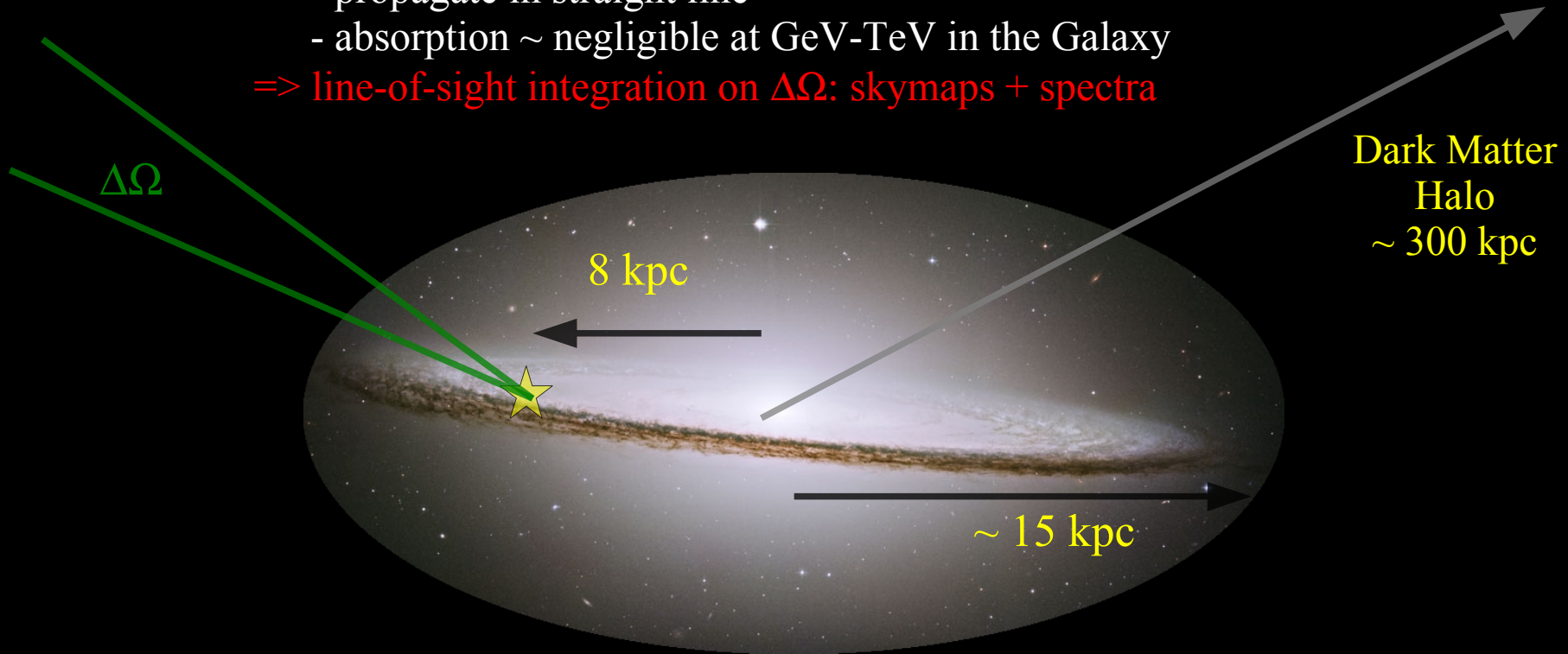
# *CR propagation: neutral and charged particles (II)*

## Neutral particles:

- propagate in straight line
  - absorption  $\sim$  negligible at GeV-TeV in the Galaxy
- $\Rightarrow$  line-of-sight integration on  $\Delta\Omega$ : skymaps + spectra

CLUMPY

<http://lpsc.in2p3.fr/clumpy/>



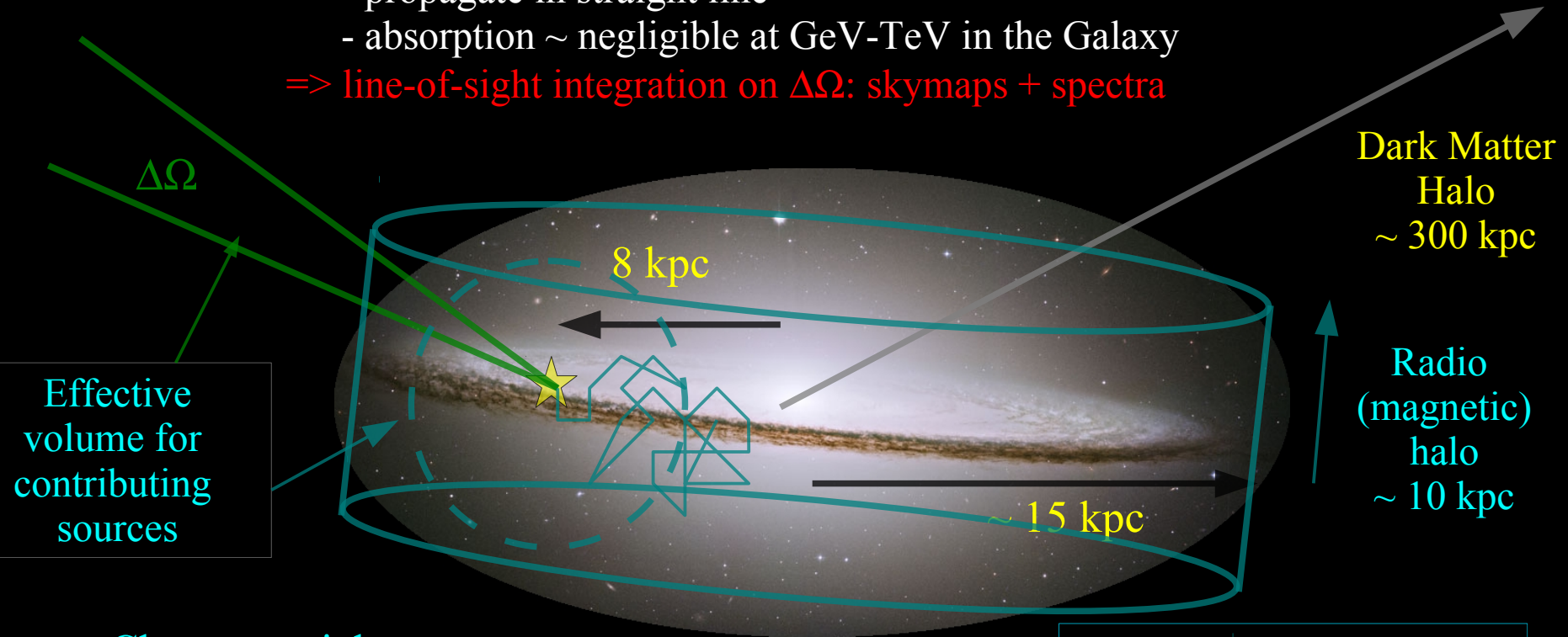
# CR propagation: neutral and charged particles (III)

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CLUMPY

<http://lpsc.in2p3.fr/clumpy/>



Effective volume for contributing sources

Dark Matter Halo  
 $\sim 300$  kpc

Radio (magnetic) halo  
 $\sim 10$  kpc

## Charge particles:

- Diffusion in  $\delta\mathbf{B}$ , E losses, nuclear interactions
- $\Rightarrow$  diffusion equation  $\Rightarrow$  TOA spectra (+ space-time granularity @ high E)

USINE

<http://lpsc.in2p3.fr/usine/>

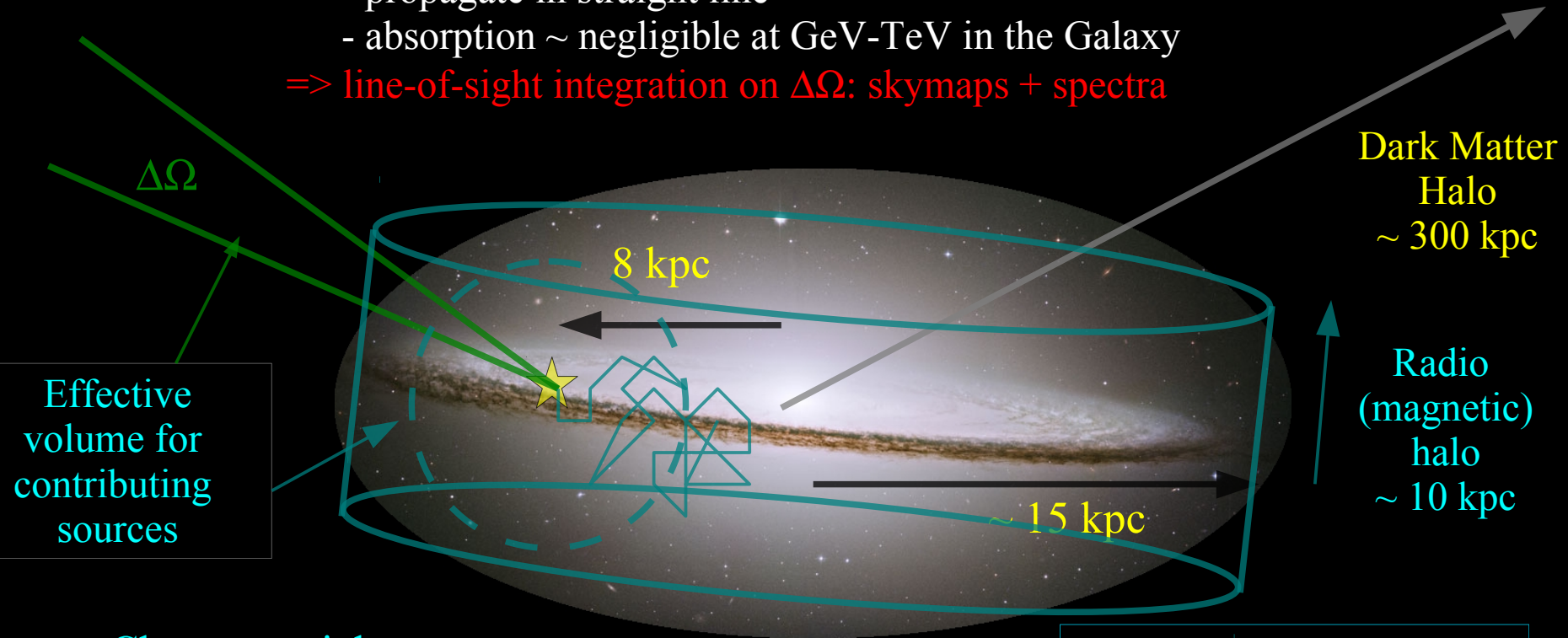
# CR propagation: neutral and charged particles (IV)

## Neutral particles:

- propagate in straight line
  - absorption  $\sim$  negligible at GeV-TeV in the Galaxy
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CLUMPY

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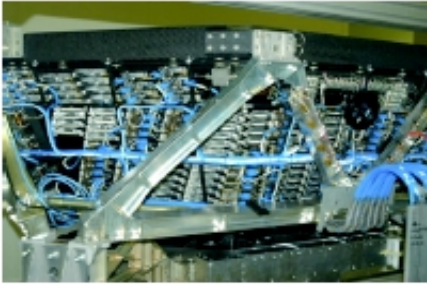
USINE

<http://lpsc.in2p3.fr/usine/>

$\Rightarrow$  background for DM detection:  $p$  (CR) + H (ISM)  $\rightarrow$   $p\bar{p}$ ,  $e^+$ ,  $\gamma$ ...  
(same transport for DM or astrophysically-induced species)

# AMS-02 on ISS: 19<sup>th</sup> of May 2011

**TRD**  
Electrons



Particles are identified by their mass, charge and energy.

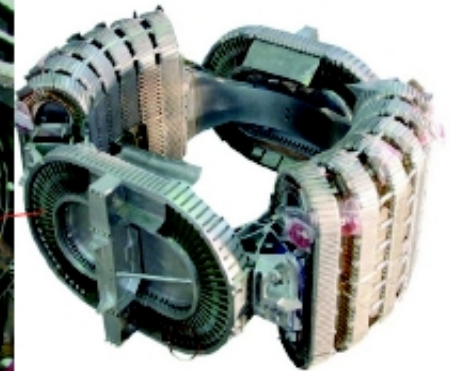
**TOF**  
Mass, Charge, Energy



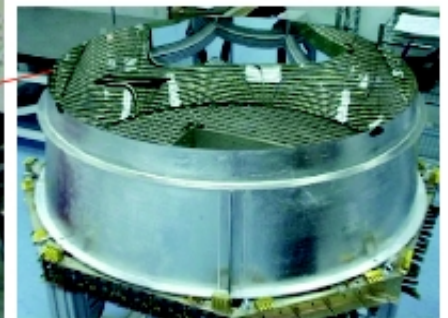
**Silicon Tracker**  
Mass, Charge, Energy



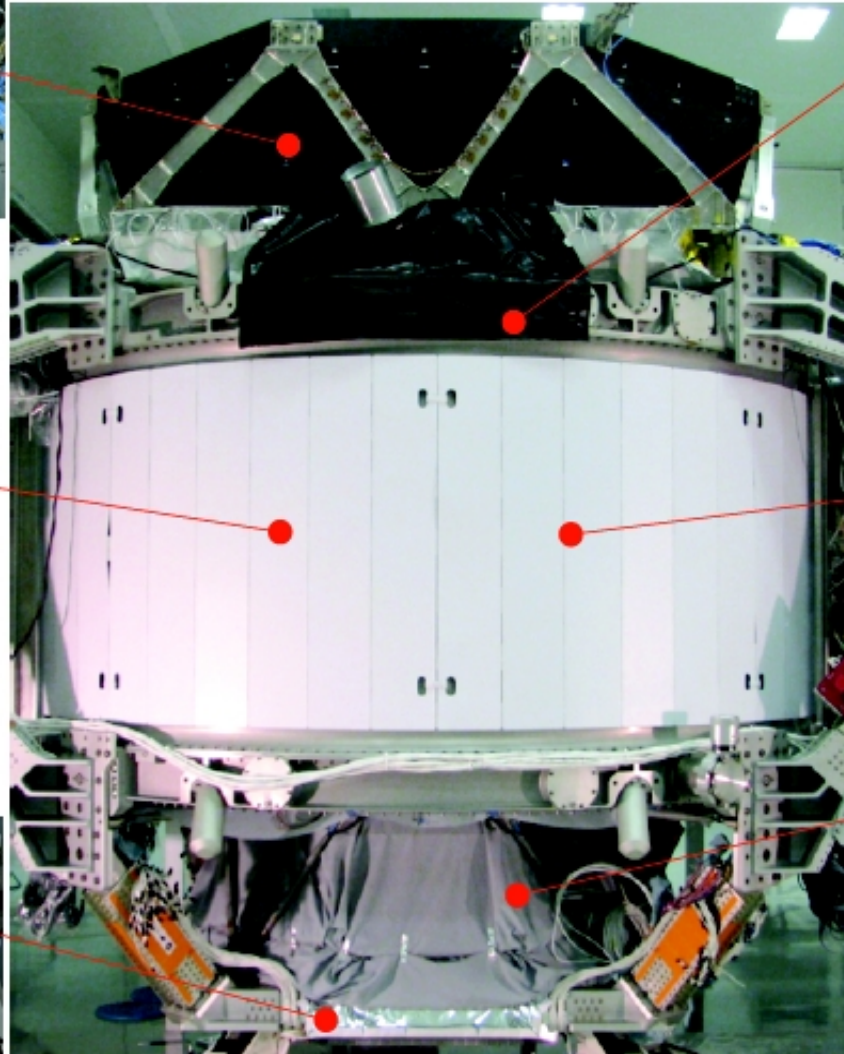
**Magnet**  
Mass,  $\pm$  Charge, Energy



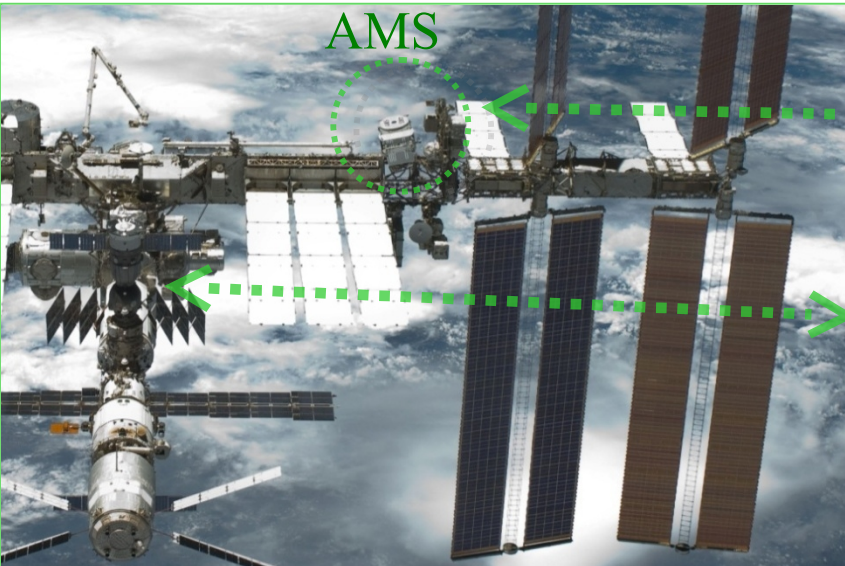
**RICH**  
Mass, Charge, Energy



**ECAL**  
Electrons, Gamma-rays



# AMS-02 data flow



Ku-Band  
High Rate (down):  
Events <10Mbit/s

S-Band  
Low Rate (up & down):  
Commanding: 1 Kbit/s  
Monitoring: 30 Kbit/s



# *AMS analysis: ongoing and future activities at LPSC*

## **- RICH detector characterisation**

- Aerogel index mapping using cosmic particles

## **- Flux reconstruction**

- Geomagnetic cutoff
- South-Atlantic Anomaly exclusion
- Exposure time calculation

## **- AMS- $\gamma$**

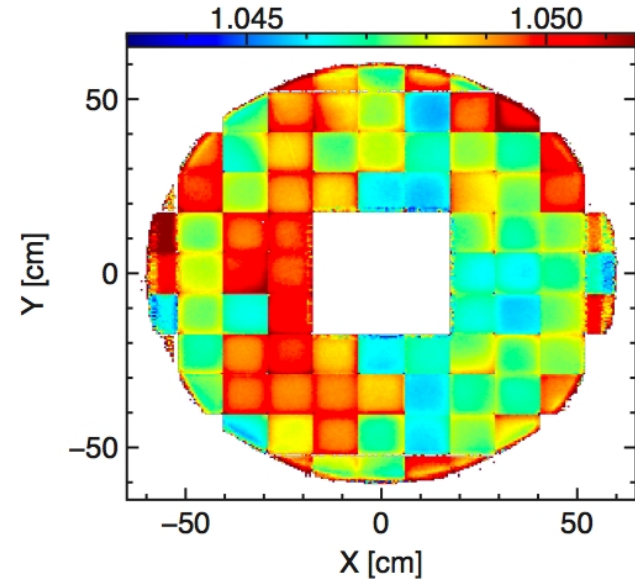
- Flux and  $\gamma$  map reconstruction

## **- Positron fraction**

- Solar modulation and geomagnetic cutoff effect

## **- Nuclear and isotopic fluxes/ratios**

- Charge reconstruction in the detector (RICH)
- Fragmentation in the detector
- Isotope identification with the geomagnetic field





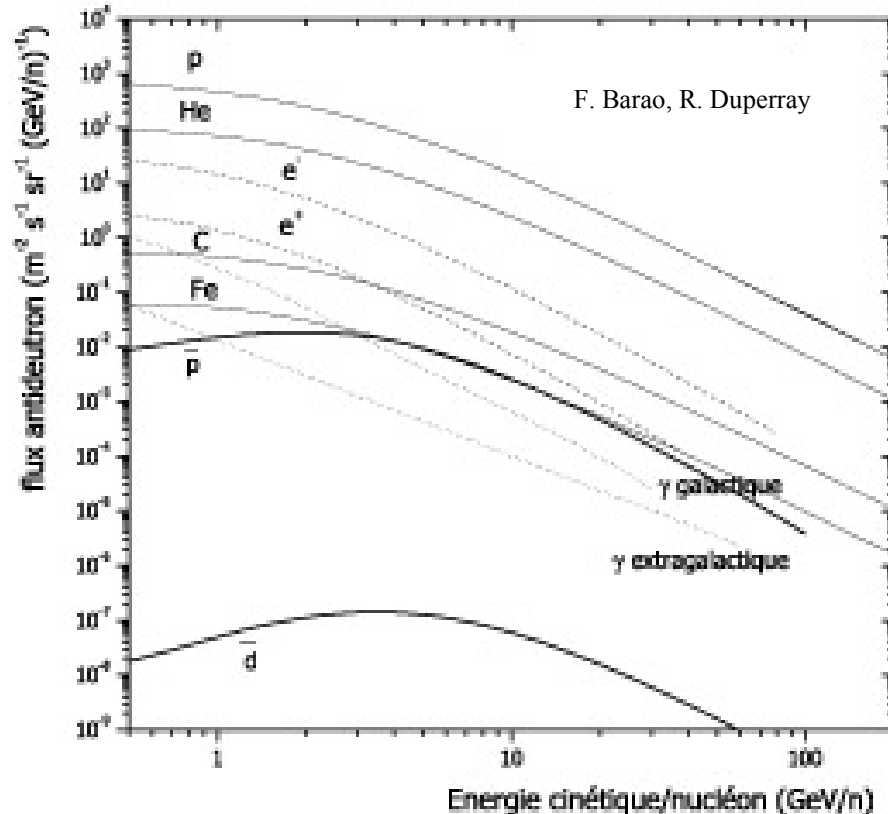
# AMS-02: new challenges



Exp.	#events/day	flight dates	Total #events
$N_{\text{HEAO-3}}$	$\sim 2.6 \cdot 10^4$ /day	[10/79-06/80]	$\Rightarrow 7 \cdot 10^6$ events ( $4 < Z < 30$ )
$N_{\text{PAMELA}}$	$\sim 2.2 \cdot 10^6$ /day	[07/06-...]	$\Rightarrow 5 \cdot 10^9$ events ( $Z < 6$ )
$N_{\text{AMS-02}}$	$\sim 4.6 \cdot 10^7$ /day	[04/11-...]	$\Rightarrow 2.4 \cdot 10^{10}$ events (all $Z$ )

**$\Rightarrow$  Huge increase of statistics accumulated since the discovery of CRs one century ago!**

# Galactic Cosmic-Ray composition



## GCR content

**Nuclei:** H, He, CNO, Fe...  
 - Light, heavy, VH and UH  
 - Stable,  $\beta$  and EC rad.  
**Electrons** [ $e/p \sim 1\%$  @ GeV]

Matter

**Anti-nuclei:** pbar, dbar...  
**Positrons** [ $e^+/e^- \sim 10\%$ ]

Anti-Matter

$\gamma$  and  $\nu$

Neutral

**=> AMS-02 able to measure all these species (but  $\nu$ )!**

### Objectives:

- $\bar{p}$ ,  $\bar{d}$ , and  $\gamma$  for dark matter searches (rare production)
- ( $^2\text{H}$ ,  $^3\text{He}$ , LiBeB, sub-Fe) +  $^{10}\text{Be}/\text{Be}$ , Be/B...to calibrate CR transport

The background features a large, stylized logo for 'Encompass'. The word 'Encompass' is written in a large, grey, sans-serif font. A thick, grey, wavy line forms a large, irregular shape that encircles the text. At the bottom center of this shape is a small, dark sphere with a bright highlight, resembling a planet or a ball. The entire graphic is set against a black background.

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*II – Project*

*1. Pheno/data analysis*

*2. Post-doc profile*

*3. E-Teams involved*

# *Objectives: data analysis and propagation*

## - LPSC team past/present efforts:

### **1. Experimental activity**

- detector calibration (for RICH)
- data analysis ( $e^+$ ,  $\gamma$ , nuclei)

### **2. Tools development for DM/propagation studies**

- CLUMPY: DM decay/annihilation in  $\gamma$ -rays
- USINE: charge particles propagation (still in progress)
- GreAT: statistical tools MCMC for USINE (thèse A. Putze)

### **2. CR phenomenology**

- B/C + radioactive nuclei (thèse A. Putze), light nuclei (thèse B. Coste)
- DM constraints ( $p\bar{p}$ ,  $d\bar{d}$ ,  $\gamma$ -rays)

## - LPSC team/post-doc objectives:

- element and isotope fluxes/ratios (+ fragmentation), AMS-02 potential with  $\gamma$ -rays
- better CR propagation models ('numerical' USINE), better ingredients

**=> Combines all CR measurements from AMS-02 to obtain best constraints  
(standard physics and DM indirect detection)**

### Post-doc profile:

- strong background in data analysis
- strong background in GCR physics

# Such a profile exists!

[one outstanding candidate - PhD in 2009]

Strongly recommended candidate:

- by **Roberto Battiston** [Professor, co-PI AMS-02, Univ. of Perugia]  
=> *In my opinion Nicola is among the few best experimental physicists in his age range*
- by **Fiorenza Donato** [assistant professor, Theoretical group, Univ. of Torino]  
=> *He developed analytical and numerical tools for CR propagation;*  
=> *has the autonomy of a senior researcher, extremely talented, and a hard worker.*

## - Experimental works:

- AMS-01 analysis
- AMS-02 tracker calibration

ApJ 724, 329 (2010), *Relative Composition and Energy Spectra of Light Nuclei in CRs: Results from AMS-01*  
ApJ 736, 105 (2011), *Isotopic Composition of Light Nuclei in Cosmic Rays: Results from AMS-01*

## - Theoretical/phenomenology works:

- CR propagation
- CR acceleration

Tomassetti & Donato, A&A 544, 12 (2012), *Secondary CR nuclei from SNRs and constraints on propagation parameters*  
Tomassetti, ApJL 752, 13 (2012), *Origin of the CR Spectral Hardening*  
Tomassetti, Ap&SS (2012), *Propagation of H and He CR isotopes in the Galaxy: astrophysical and nuclear uncertainties*

# *Such a profile exists!*

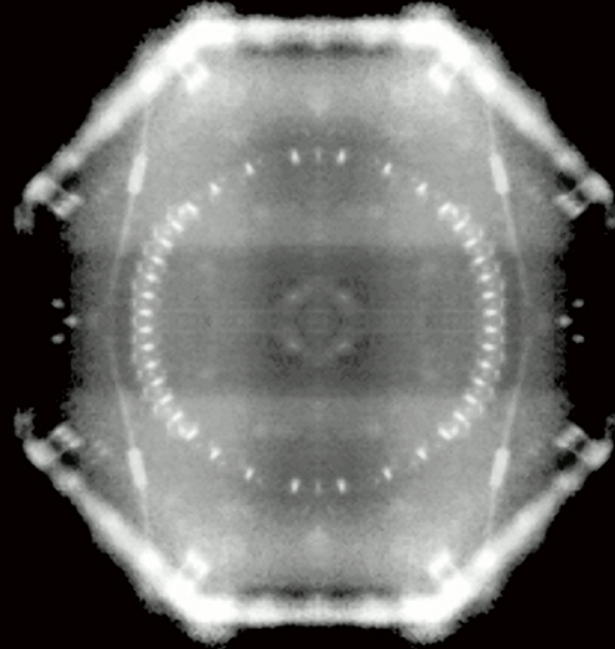
## - AMS Hadronic Tomography with Cosmic Rays

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<http://www.fisica.unipg.it/~tomassetti/research.html>



Exposure Time: May 20 2011 - May 20 2012  
Number of Protons: 3,676,863,217  
Number of Helium nuclei: 620,303,906  
Rigidity range: 2 GV - 2000 GV  
Tomographic plane: Z = +165 cm  
XY pixel size: 1 cm<sup>2</sup>



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Credit: AMS Collaboration 2012

+ 2012: AMS-02 Physics Potential for Gamma-Ray Studies (3 AMS-02 internal notes)

+ 2011: AMS Physics Potential with Charged CRs (applet simulations on-line)

=> window of opportunity to get this candidate will probably close soon

# Collaborations *LAPP/LAPTh/LPSC*

	<b>Laurent DEROME</b> AMS-02 group @ LPSC	<b>Sylvie ROSIER-LEES</b> AMS-France AMS-02 group @ LAPP	<b>Pierre SALATI</b> Astroparticle group @ LAPTh
<b>Team</b>	<ul style="list-style-type: none"> <li>- 1 ½ CNRS</li> <li>- 1 émérite</li> <li>- 1 ½ MdC/Prof.</li> <li>- 1 post-doc</li> </ul>	<ul style="list-style-type: none"> <li>- 5 CNRS</li> <li>- 2 émérites</li> <li>- 1 post-doc</li> <li>- 1 PhD</li> </ul>	<ul style="list-style-type: none"> <li>- 1 CNRS</li> <li>- 2 Prof.</li> <li>- 1 PhD</li> </ul>
<b>“Science”</b>	<ul style="list-style-type: none"> <li>- Nuclear fluxes (RICH)</li> <li>- Propagation + GreAT</li> <li>- Dark matter</li> </ul>	<ul style="list-style-type: none"> <li>- e- and e+ fluxes (ECAL)</li> <li>- Dark matter</li> </ul>	<ul style="list-style-type: none"> <li>- Propagation</li> <li>- Dark matter</li> </ul>
<b>Collaborations</b>	<p style="text-align: center;"> <span style="border: 1px solid red; padding: 5px; display: inline-block;">AMS-01 (1998) +02 (2011-XX) =&gt; <b>6 meetings since launch</b></span> <span style="margin-left: 100px; border: 1px solid red; padding: 5px; display: inline-block;">P. Brun, J. Pochon (PhD) A. Fiasson (Post-doc) =&gt; <b>several papers</b></span> </p> <p style="text-align: center;"> <span style="border: 1px solid red; padding: 5px; display: inline-block;">A. Barrau, L. Derome, D. Maurin, P. Salati, R. Taillet =&gt; <b>~ 15 papers (since 2001)</b></span> </p> <div style="border: 2px solid red; padding: 10px; margin-top: 20px; text-align: center;"> <p style="color: red; text-decoration: underline;">Recent common projects/collaborations</p> <ul style="list-style-type: none"> <li>- 5 meetings (since 2011) “<i>USINE and pheno</i>”</li> <li>- Failed ANR “<i>pheno+AMS data analysis</i>” (2011 + 2012)</li> <li>- ANR “<i>DMAstroLHC</i>” 2012 (PI: Bélanger)</li> </ul> </div>		

# Conclusions

## - A lot of exciting science with AMS-02

### 1. Data analysis:

- Standard astrophysics: isotopes and nuclei analysis
- Dark matter-related studies: anti-protons,  $\gamma$ -rays

### 2. CR phenomenology:

- Constraints on transport parameters
- Constrains on dark matter
- Numerical developments (propagation code USINE)

## - Strong synergy/complementarity LAPP/LAPTh/LPSC

1. Regular analysis meetings
2. Regular phenomenology meetings
3. Complementarity with ANR *DMAstroLHC*

## - Impressive post-doc candidate (in principle)

=> Perfect timing to have a post-doc @ LPSC!