

Galactic Cosmic-Ray Propagation in the AMS-02 Era

I – Science case

- 1. Galactic Cosmic Rays*
- 2. AMS-02*

II – Collaboration LAPP/LAPTh/LPSC

- 1. Teams and context*
- 2. Support asked for the project*

III – Conclusions

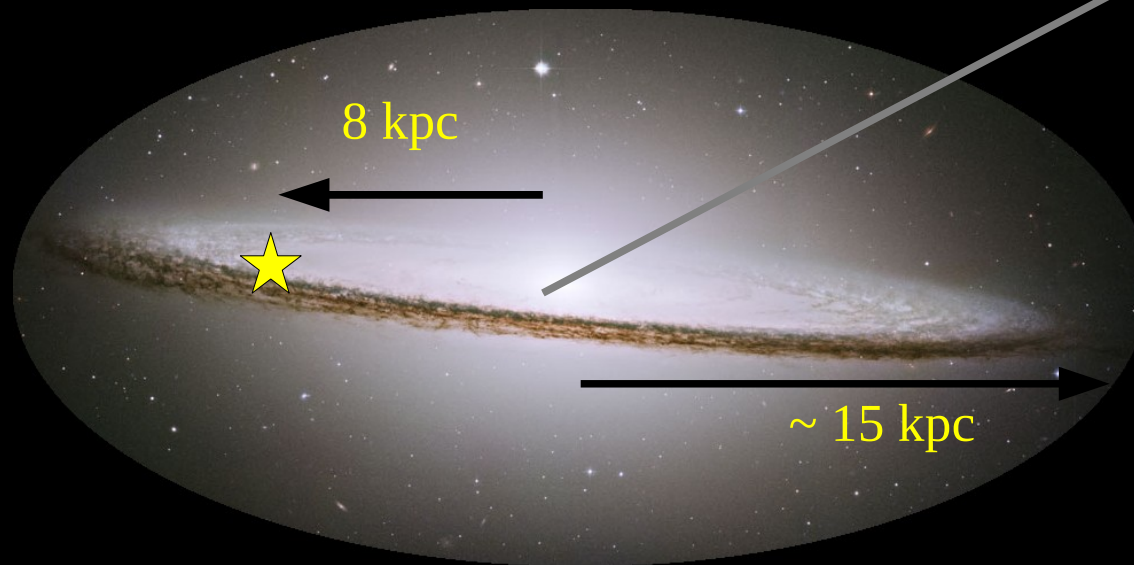
(a few slides are borrowed from L. Derome and S. Rosier)



Dark Matter annihilation products and flux

$$\chi + \chi \rightarrow f\bar{f}, W^+W^-, \dots \rightarrow \bar{p}, \bar{d}, e^+, \gamma, \nu$$

$$\frac{d\phi^i}{dE}(E, \vec{r}) \propto \int_V \mathcal{G}(\vec{r}, E; \vec{r}', E') \cdot \rho_{\text{DM}}^2(\vec{r}') \frac{dN_{\text{PP}}^i(E)}{dE} dV' dE'$$



Dark Matter
Halo
~ 300 kpc

=> background for detection are all possible astrophysical contributions!

p (CR) + H (ISM) → antiprotons, positrons, diffuse γ -rays...

$$\frac{d\phi^i}{dE}(E, \vec{r}) \propto \int_V \mathcal{G}(\vec{r}, E; \vec{r}', E') \cdot \frac{dN_{\text{CRs}}^p(E', \vec{r})}{dE} n_{\text{ISM}}(\vec{r}') v \sigma^{p+H \rightarrow i}(E') dV' dE'$$

=> same transport for DM or astrophysically-induced species i

Particle transport: neutral and charged particles

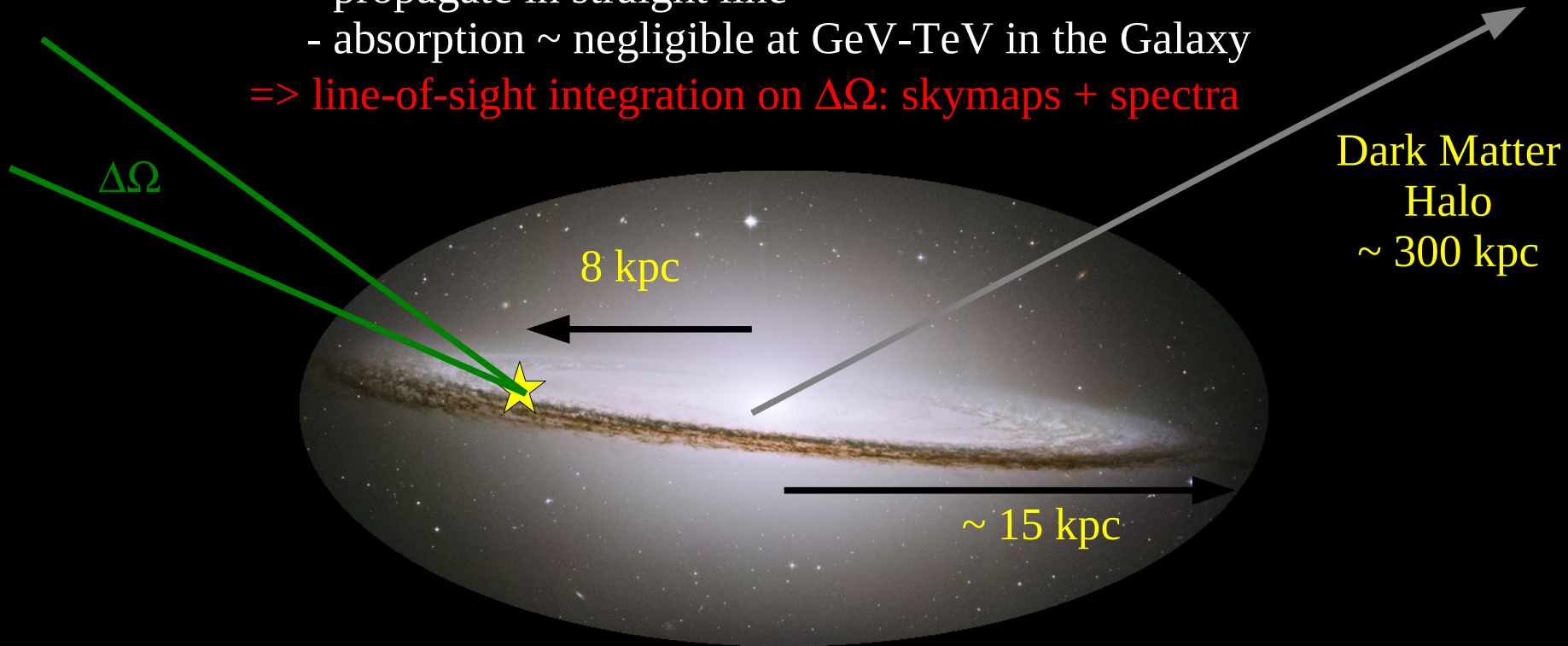
Neutral particles:

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

=> line-of-sight integration on $\Delta\Omega$: skymaps + spectra

CLUMPY

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



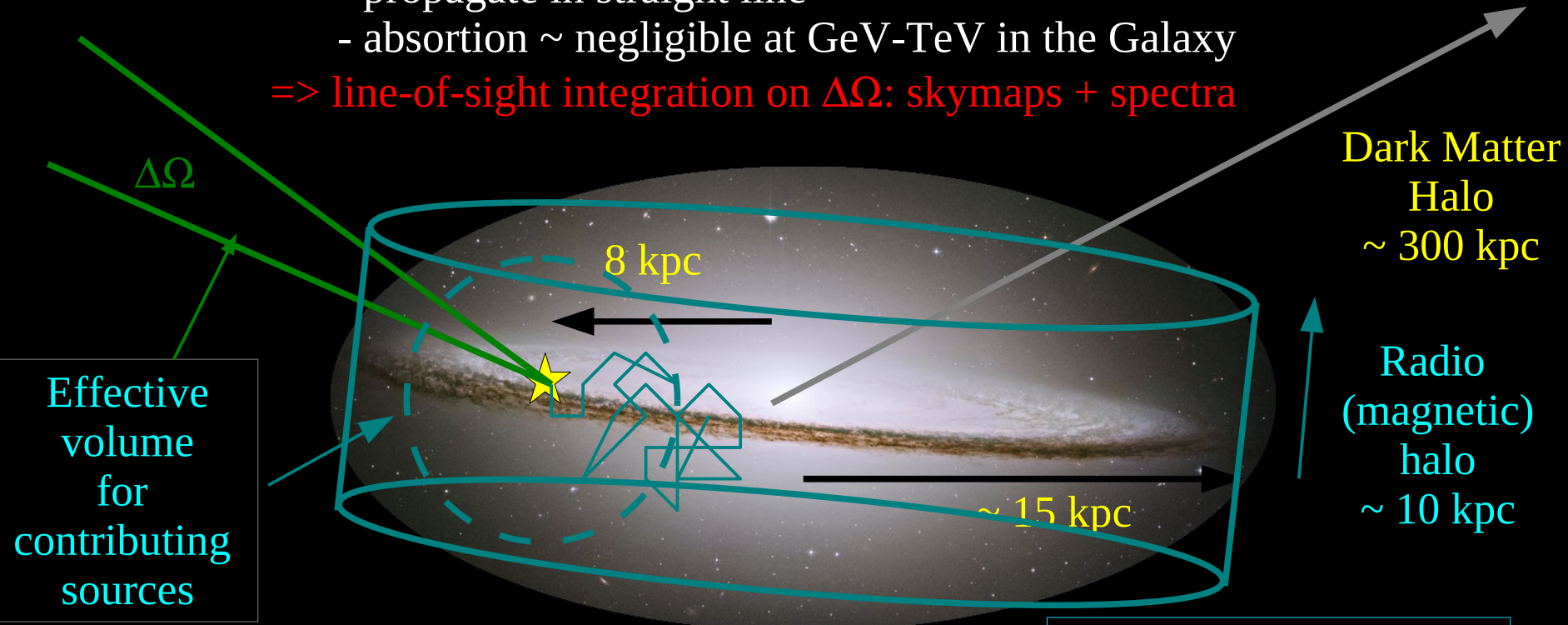
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CLUMPY
<http://lpsc.in2p3.fr/clumpy/>



Charge particles:

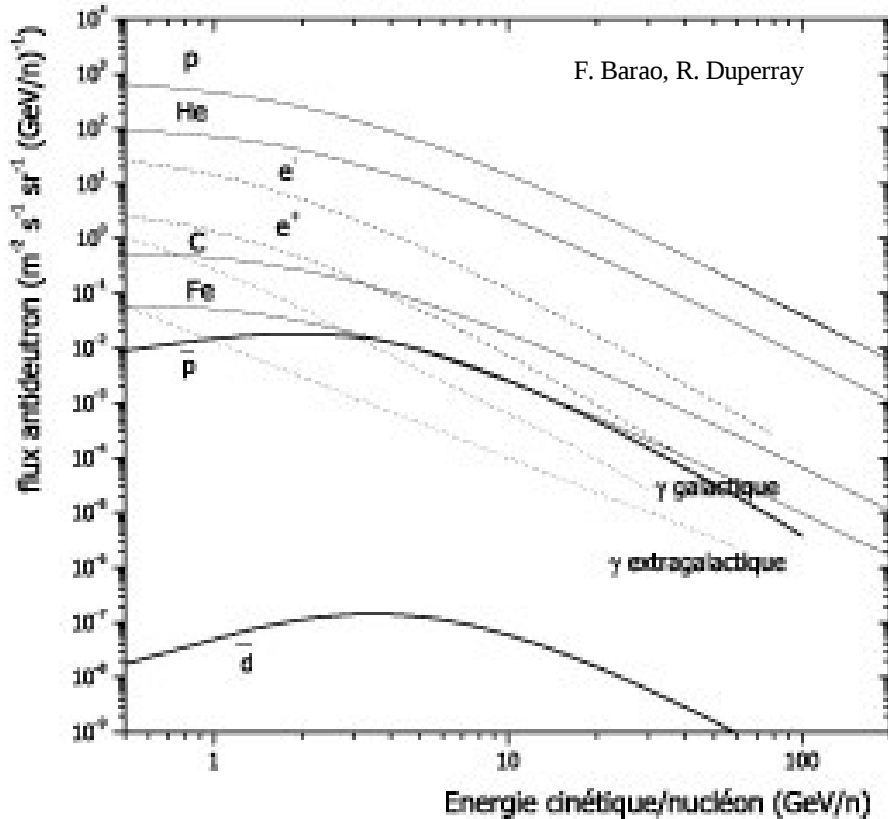
- Diffusion (random walk) in magnetic fields
- Continuous (energy) and catastrophic losses (destruction)

\Rightarrow 'local' (~ 100 pc to a few kpc, depending on E)

effective diffusive volume and isotropisation: single spectrum

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

GeV-TeV GCR spectra.



GCR content

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

Matter

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

Anti-Matter

γ and ν

Neutral

=> Search for DM where “standard” production is rare (secondary)

=> Use 2H, 3He, LiBeB, sub-Fe to calibrate the transport

- DM 'signal' as 'features' (or excess) in GCR spectra
- Do we know well the expected astrophysical spectra?

AMS on ISS: 19th of May 2011

TRD
Electrons



Particles are identified by their mass, charge and energy.

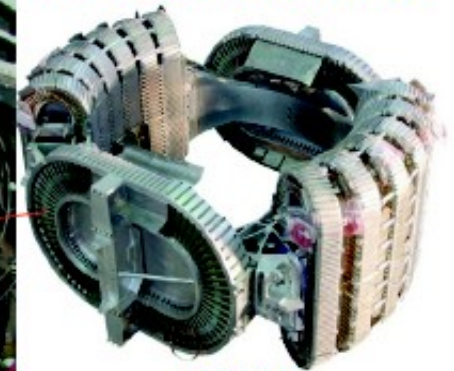
TOF
Mass, Charge, Energy



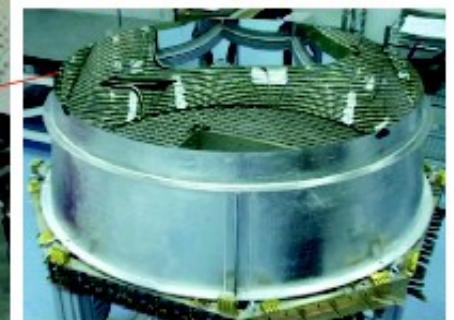
Silicon Tracker
Mass, Charge, Energy



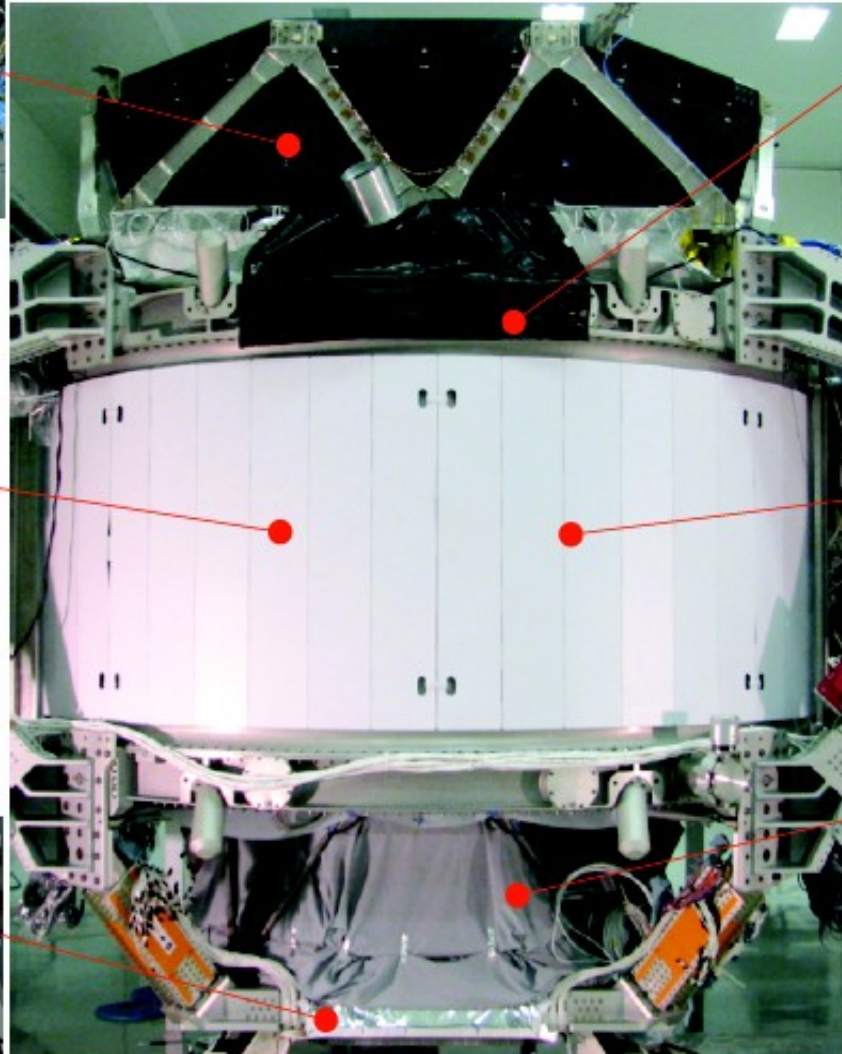
Magnet
Mass, \pm Charge, Energy



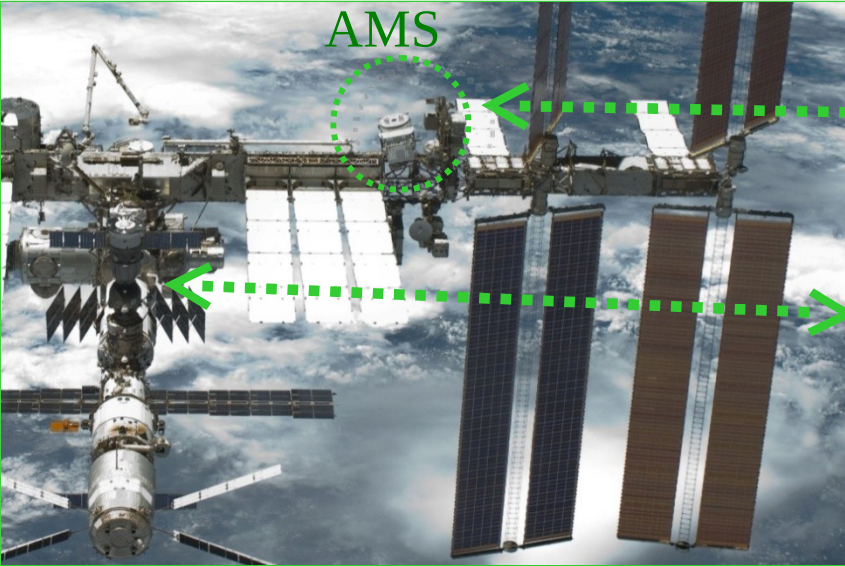
RICH
Mass, Charge, Energy



ECAL
Electrons, Gamma-rays



AMS data flow



AMS



TDRS Satellites



Astronaut at ISS AMS Laptop

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

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



AMS Payload Operations Control and
Science Operations Centers
(POCC, SOC) at CERN



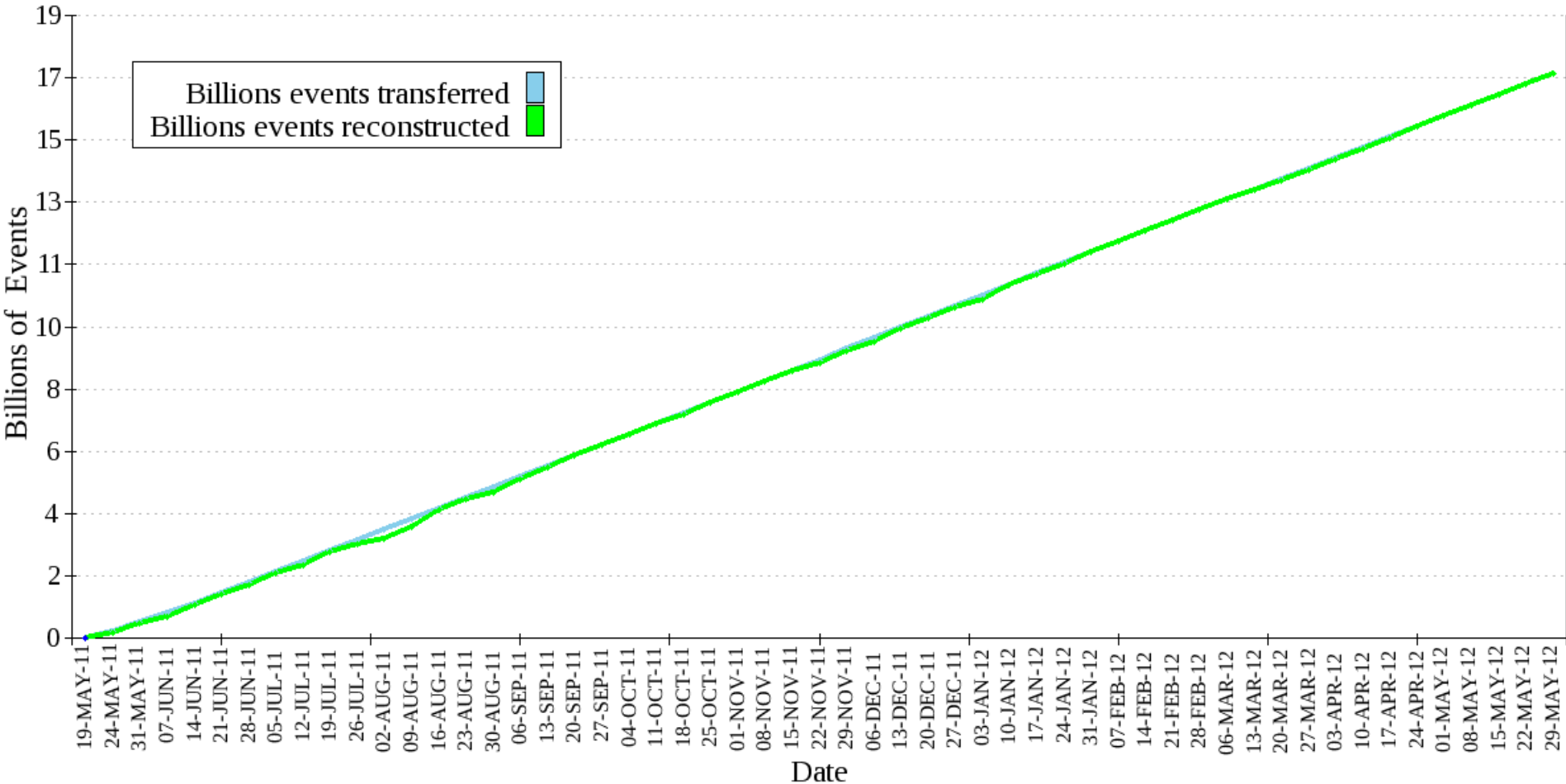
AMS Computers
at MSFC, AL



White Sands Ground Terminal,
NM

AMS collected more than 17 billion events

$$N_{\text{events}} \sim 46 \cdot 10^6 / \text{day}$$



=> Several times the whole statistic previously accumulated since the discovery of cosmic rays one century ago!



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Collaboration LAPP/LAPTh/LPSC

	Laurent DEROME AMS-02 group @ LPSC	Sylvie ROSIER-LEES AMS-France AMS-02 group @ LAPP	Pierre SALATI Astroparticle group @ LAPTh
Team	<ul style="list-style-type: none">- 1 ½ CNRS- 1 émérite- 1 ½ MdC/Prof.- 1 post-doc	<ul style="list-style-type: none">- 5 CNRS- 2 émérites- 1 post-doc- 1 PhD	<ul style="list-style-type: none">- 1 CNRS- 2 Prof.- 1 PhD
“Science”	<ul style="list-style-type: none">- Nuclear fluxes (RICH)- Propagation + GreAT- Dark matter	<ul style="list-style-type: none">- e- and e+ fluxes (ECAL)- Dark matter	<ul style="list-style-type: none">- Propagation- Dark matter

Collaboration *LAPP/LAPTh/LPSC*

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Collaborations	<div style="display: flex; justify-content: space-around; align-items: center; margin-bottom: 10px;"> <div style="border: 2px solid red; padding: 5px; text-align: center;">AMS-01 (1998) +02 (2011-XX) => 5 meetings since launch</div> <div style="border: 2px solid red; padding: 5px; text-align: center;">P. Brun, J. Pochon (PhD) A. Fiasson (Post-doc) => several papers</div> </div> <div style="border: 2px solid red; padding: 5px; text-align: center; margin-bottom: 10px;">A. Barrau, L. Derome, D. Maurin, P. Salati, R. Taillet => ~ 15 papers (since 2001)</div> <div style="border: 2px solid red; padding: 5px; text-align: center;">ANR USINE-CRYPTIC (JCJC 2011) + ANR GCRPAE (blanc 2012) => USINE project (overlap with <i>DMastro</i>, see Geneviève's talk)</div>		

ANR Project – 2010 (JCJC)

Nom et prénom du coordinateur / coordinator's name	MAURIN David		
Acronyme / Acronym	USINE-CRYPTIC (Cosmic RaY PropagaTIon Code)		
Titre de la proposition de projet	Rayonnement cosmique galactique et matière noire		
Proposal title	Galactic Cosmic Rays and Dark Matter		
Comité d'évaluation / Evaluation committee	SIMI 5/6		
Type de recherche / Type of research	<input checked="" type="checkbox"/> Recherche Fondamentale / Basic Research <input type="checkbox"/> Recherche Industrielle / Industrial Research <input type="checkbox"/> Développement Expérimental / Experimental Development		
Aide totale demandée / Grant requested	320 000 Euros	Durée de la proposition de projet / Proposal duration	48 mois

=> Rejected...

ANR Project – 2011 (blanc)

Acronyme / Acronym	GCRPAE		
Titre du projet	Propagation du rayonnement cosmique Galactique avec AMS-02		
Proposal title	Galactic Cosmic-Ray Propagation in the AMS-02 Era		
Comité d'évaluation/Evaluation Committee	SIMI 5		
Type de recherche / Type of research	<input checked="" type="checkbox"/> Recherche Fondamentale / Basic Research <input type="checkbox"/> Recherche Industrielle / Industrial Research <input type="checkbox"/> Développement Expérimental / Experimental Development		
Coopération internationale (si applicable) / International cooperation (if applicable)	<input type="checkbox"/> OUI <input checked="" type="checkbox"/> NON		
Aide totale demandée / Grant requested	402 315 €	Durée du projet / Projet duration	36 mois

=> Rejected...

ANR project: tasks and objectives

LPSC

PI: L. Derome

Task 1

Data Analysis:
Nuclei

Sub-task 1.1: Elemental identification

Sub-task 1.2: Isotopic identification

Sub-task 1.3: Fragmentation

Sub-task 1.4: Monte-Carlo simulations

LAPP

PI: S. Rosier-Lees

Task 2

Data Analysis:
e-, e+, γ -rays

Sub-task 2.1: e+ and e- identification

Sub-task 2.2: e+ and e- flux measurements

Sub-task 2.3: Diffuse γ -rays (AMS/HESS)

Sub-task 2.4: Pulsar Nebula with HESS2

LPSC + LAPTh

PI: D. Maurin

Task 3

Tools development

Sub-task 3.1: Leptons and γ in USINE

Sub-task 3.2: Solar modulation

Sub-task 3.3: Numerical methods

Sub-task 3.4: GreAT 2.0

*LPSC + LAPTh
+ LAPP*

PIs: P. Salati & D. Maurin

Task 4

Propagation models
Data interpretation

Sub-task 4.1: Galactic environment

Sub-task 4.2: Propagation and interpretation

Sub-task 4.3: Anisotropy

USINE (in progress)

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

Home

Cosmic-Ray Physics

Online database

Online calculation

Download

Publications

People

People

USINE collaboration:

- IFT (Madrid): T. Delahaye
- LAPP (Annecy-le-vieux): A. Fiasson
- LAPTh (Annecy-le-vieux): P. Salati, R. Taillet
- LIP (Lisbon): F. Barao
- LPSC (Grenoble): C. Combet, L. Derome, D. Maurin
- LUPM (Montpellier): J. Lavalley
- OKC (Stockholm): A. Putze
- Università di Torino: F. Donato

Code development:

- USINE core: D. Maurin
- Graphical User Interface (GUI): F. Barao, A. Putze
- Electrons/positrons/gamma-rays: based on T. Delahaye, A. Fiasson, J. Lavalley, R. Lineros, P. Salati
- Other contributions: C. Combet, F. Donato, A. Putze, R. Taillet

Web support:

- Website: D. Maurin, A. Putze, R. Taillet
- Online database: R. Taillet
- Online calculation: D. Maurin

Thanks:

- F. Melot for technical support

USINE (in progress)

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+ regular meetings (LAPP/LAPTh/LPSC)

- ✓ USINE 1 (02/12/2010) : <http://indico.in2p3.fr/conferenceDisplay.py?confId=4728>
- ✓ USINE 2 (24/02/2011) : <http://indico.in2p3.fr/conferenceDisplay.py?confId=5152>
- ✓ USINE 3 (22/06/2011) : <http://indico.in2p3.fr/conferenceDisplay.py?confId=5590>
- ✓ USINE 4 (14/12/2011) : <http://indico.in2p3.fr/conferenceDisplay.py?confId=6112>

Access key: dark

- Other contributions: C. Combet, F. Donato, A. Putze, R. Taillet

Web support:

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Thanks:

- F. Melot for technical support

P. Salati

Conclusions

Big time with AMS-02!

Strong existing synergy between 3 ENIGMASS labs!

[we work together, we sometimes fail, but we mostly succeed!]

- AMS regular meetings since launch

- Phenomenology 'USINE' regular meetings

=> Strong collaboration since 1998 (involving several researchers from each team)

ENIGMASS post-docs would be greatly appreciated!

[ANR projects failed, SMINGUE post-doc ranked 1st but not attributed...]

N.B.: we have a highly recommended post-doc candidate
in store who wishes to work with us

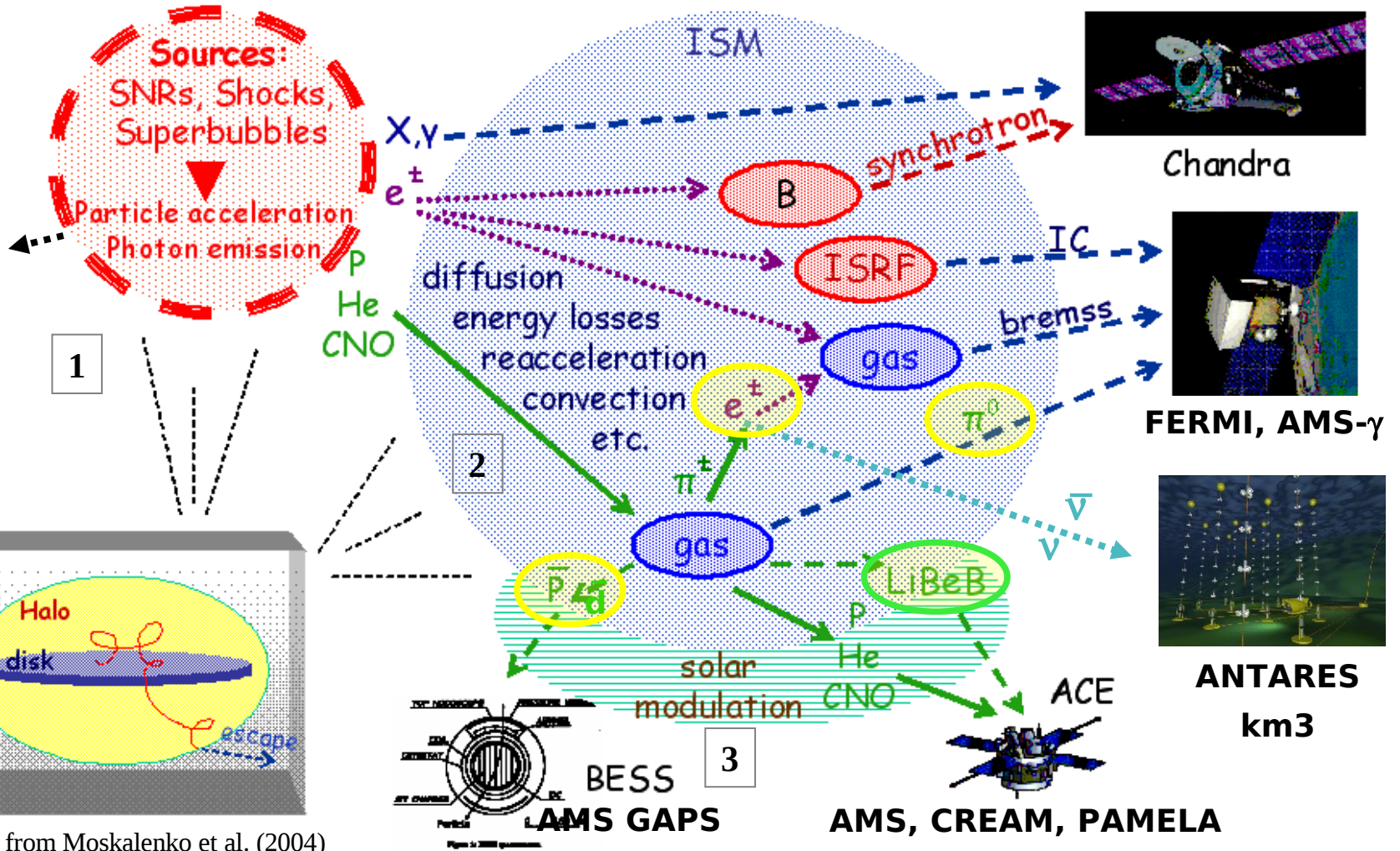
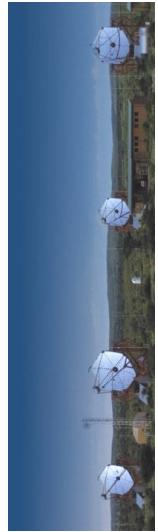
... and we have plenty of nice studies to carry on!

=> Profile for the post-docs: modelling and data analysis

Dos-dessus

From sources to detection: modelling the astrophysical 'backgrounds'

HESS



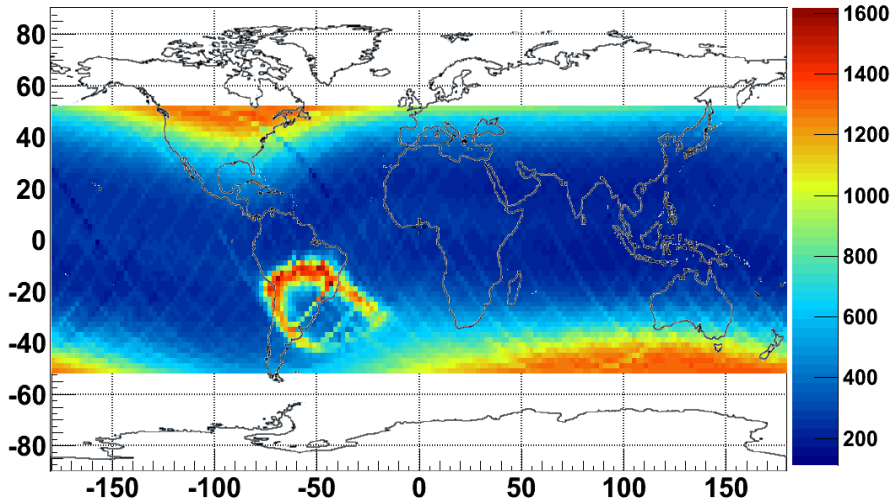
Adapted from Moskalenko et al. (2004)

=> Search for DM where "standard" production is rare (secondary)

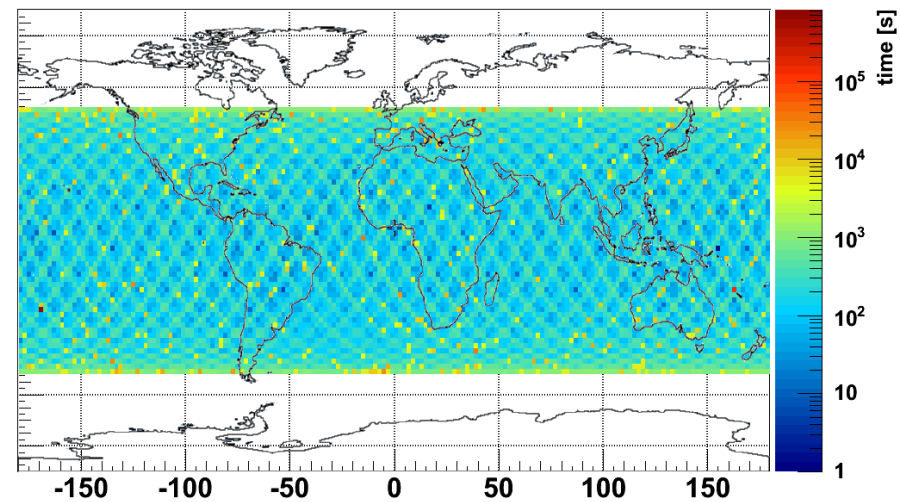
=> Use LiBeB to calibrate the transport coefficients

Orbital DAQ parameters

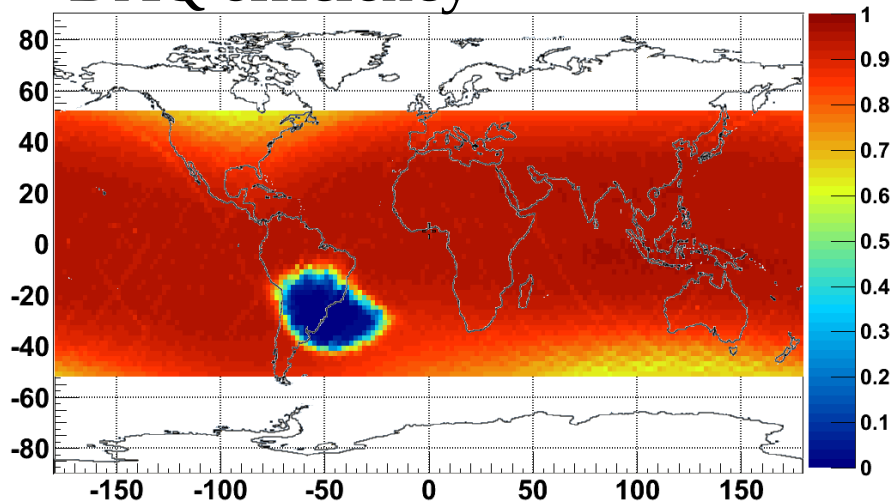
Acquisition rate [Hz]



Time at location [s]



DAQ efficiency



Particle rates vary from
200 to 2000 Hz per orbit

On average:
DAQ efficiency 85%
DAQ rate ~ 700 Hz

Timeline

