A database of charged cosmic rays (CRDB)
+
Interstellar flux (IS) and modulation level using neutron monitors (NM) data

I. CRDB: presentation and tools
II. IS flux, Solar modulation, and NM

David Maurin (LPSC)
dmaurin@lpsc.in2p3.fr

CRISM - Montpellier
24/06/2014

I. CRDB: presentation and tools

II. IS flux, Solar modulation, and NM

Based on

A database of charged cosmic rays
http://arxiv.org/abs/1302.5525
DM, F. Melot, R. Taillet

CRDB (Cosmic Ray Data Base)

What?

- *Compilation of CR data:* e^-, e^+, p-bar, and $Z \leq 30$, for energies below the knee
- *On-line tools:* data selection, data export, plots (experimental set-up, data...), etc.
- *Collaborative tool:* submission interface to archive past and future CR data

Where?

- *Website*: https://lpsc.in2p3.fr/crdb
- *Contact:* crdatabase@lpsc.in2p3.fr
- *Publication:* http://arxiv.org/abs/1302.5525

Why?

- *Galactic CR studies:* acceleration, propagation, interstellar (IS) fluxes
- *Dark matter indirect detection:* positrons, antiprotons
- *Solar studies:* Solar modulation, ground level measurements
- *Experimentalists:* quick access to previous experimental set-ups, data, etc.

Versions

- *V1.0 (Feb. 2013):* first release
- *V1.2 (Oct. 2013):* export to GALPROP, enable combinations of data in query...
- *V1.3 (Feb. 2014):* REST interface, re-plot (more plot options)...
- *V2.1 (this morning):* major change for solar modulation values implementation

CRDB: behind the scene (1)

Application developer
Frédéric Melot (LPSC)

- Hosted by LPSC website

- https protocol (administrators access protected areas)

- Web pages in PHP (Hypertext PreProcessor)

- Structure in AJAX (Asynchronous JavaScript and XML)

- Third-party libraries: jquery, Jquery-ui, jquery.cluetip, table-sorter

LAMP solution: free open source softwares
- **L**inux operating system
- **A**pache HTTP server
- **M**ySQL database software
- **P**HP

CRDB: behind the scene (2)

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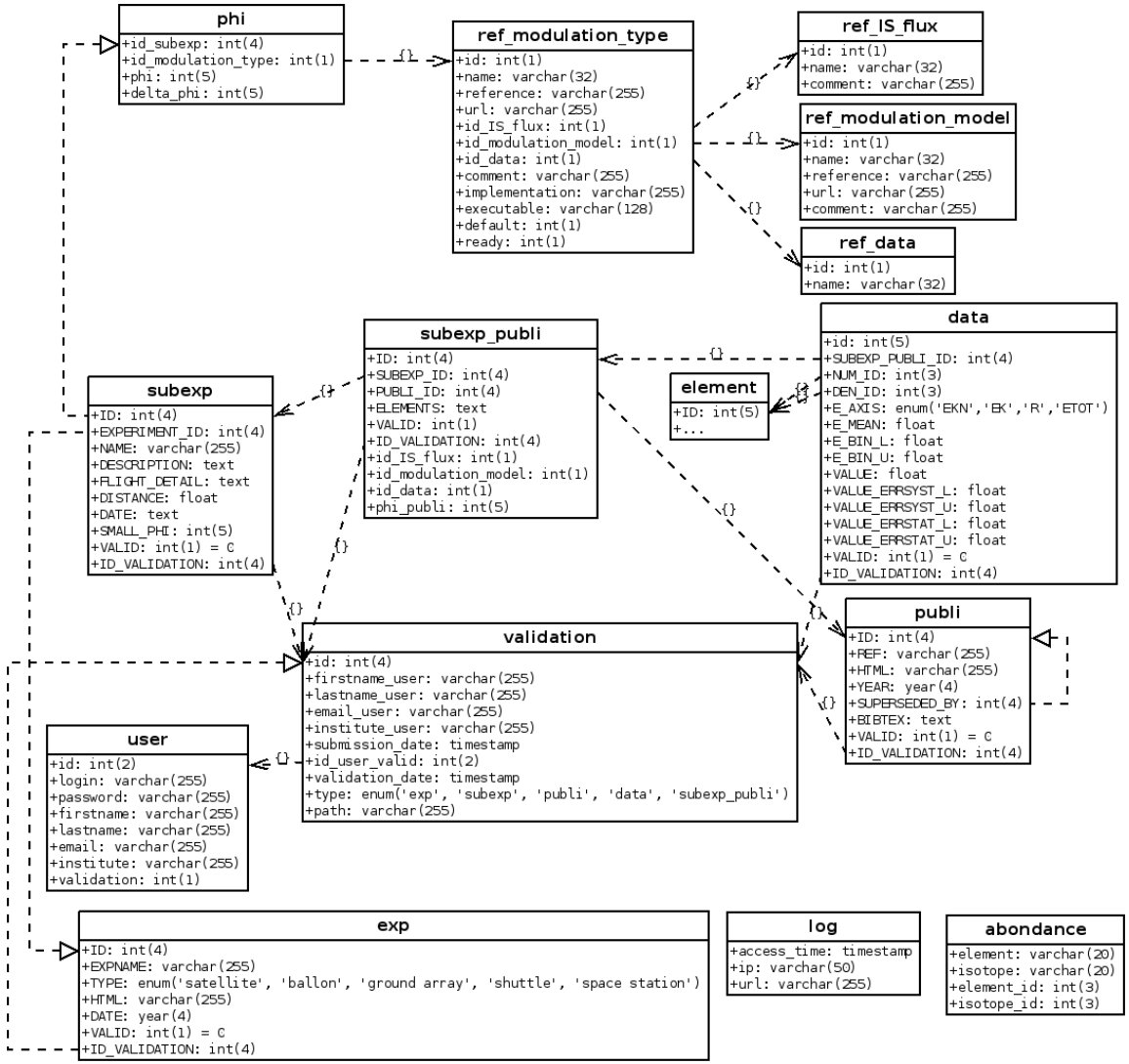
MySQL structure



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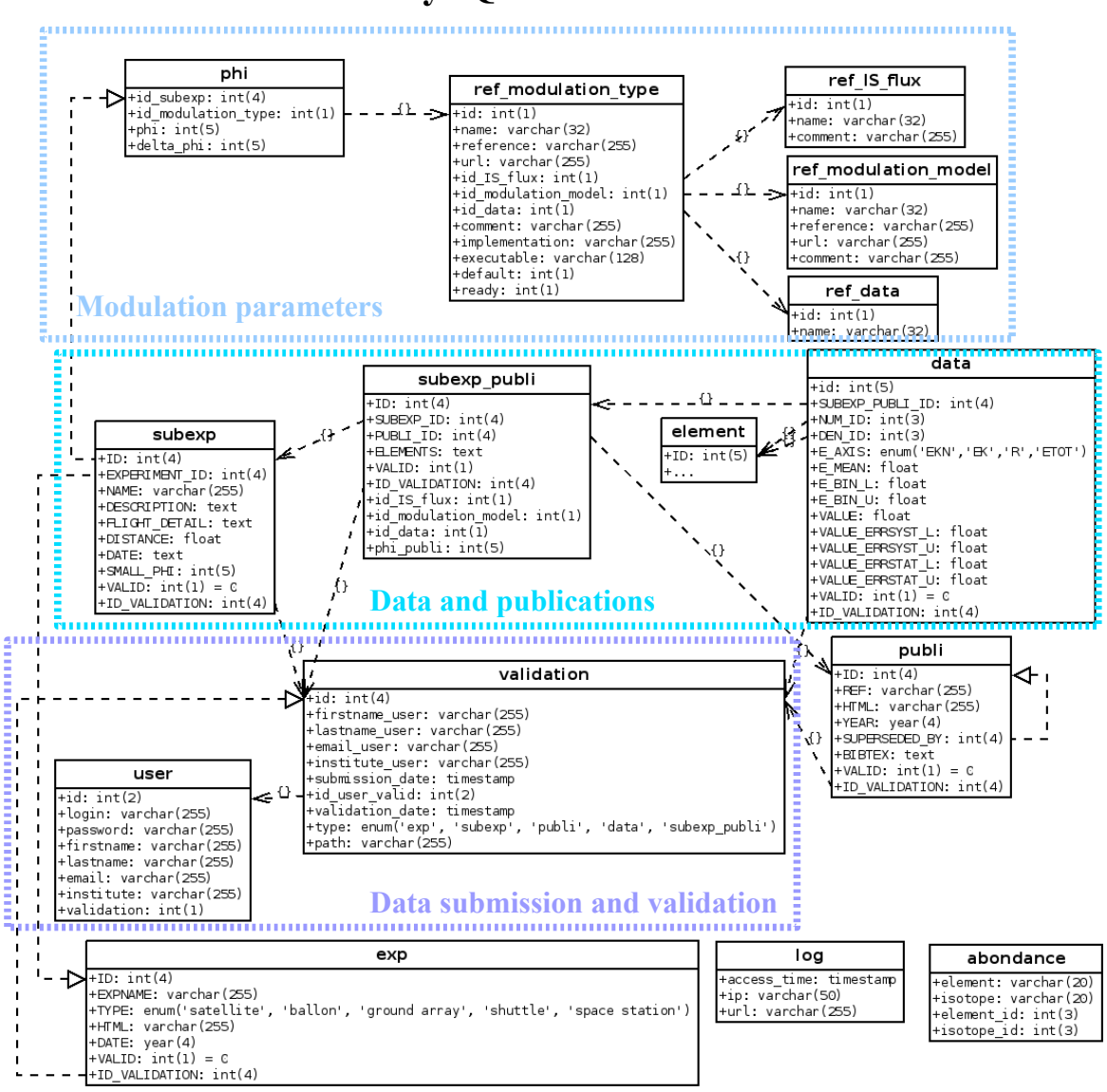


CRDB: useful definitions

Data linked to experiments, analyses, publications
→Issue: multiple flight dates, sub-detectors, data...

Experiment: *CREAM, AMS* (name of the payload) or *Balloon (YYYY)* for unnamed balloons

Sub-experiment: *Balloon (1972/07), CREAM-I (2004/12-2005/01), CREAM-II (2005/12-2006/01), Ulysses-HET (1990/10-1997/12)*

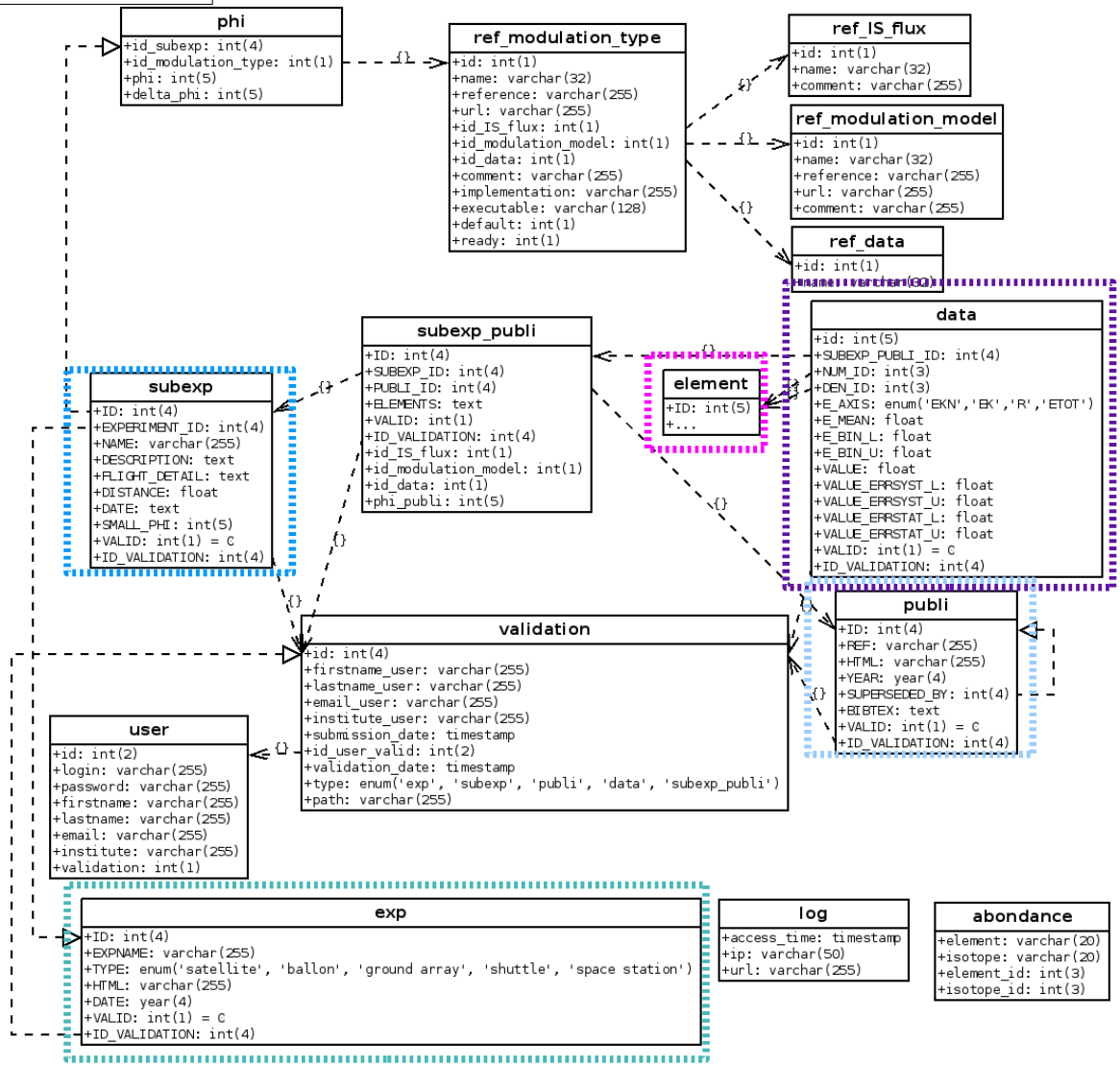
Cosmic-ray quantity: *C* (element), ^{1}H (isotope), e^{-} (lepton), or any ratio *B/C*, $^{10}Be/Be$, $e^{+}/(e^{-}+e^{+})$

Energy axis: *Etot* [GeV], *R* [GV], *Ek* [GeV], *Ekn* [GeV/n]

Data: CR quantity measurements and uncertainties at one or several E bins

Publication: journals or proceedings where the data were published

MySQL structure



CRDB: data description and units

<E>: central bin from publication (if not given, $\langle E \rangle = \sqrt{(E_{min} E_{max})}$)

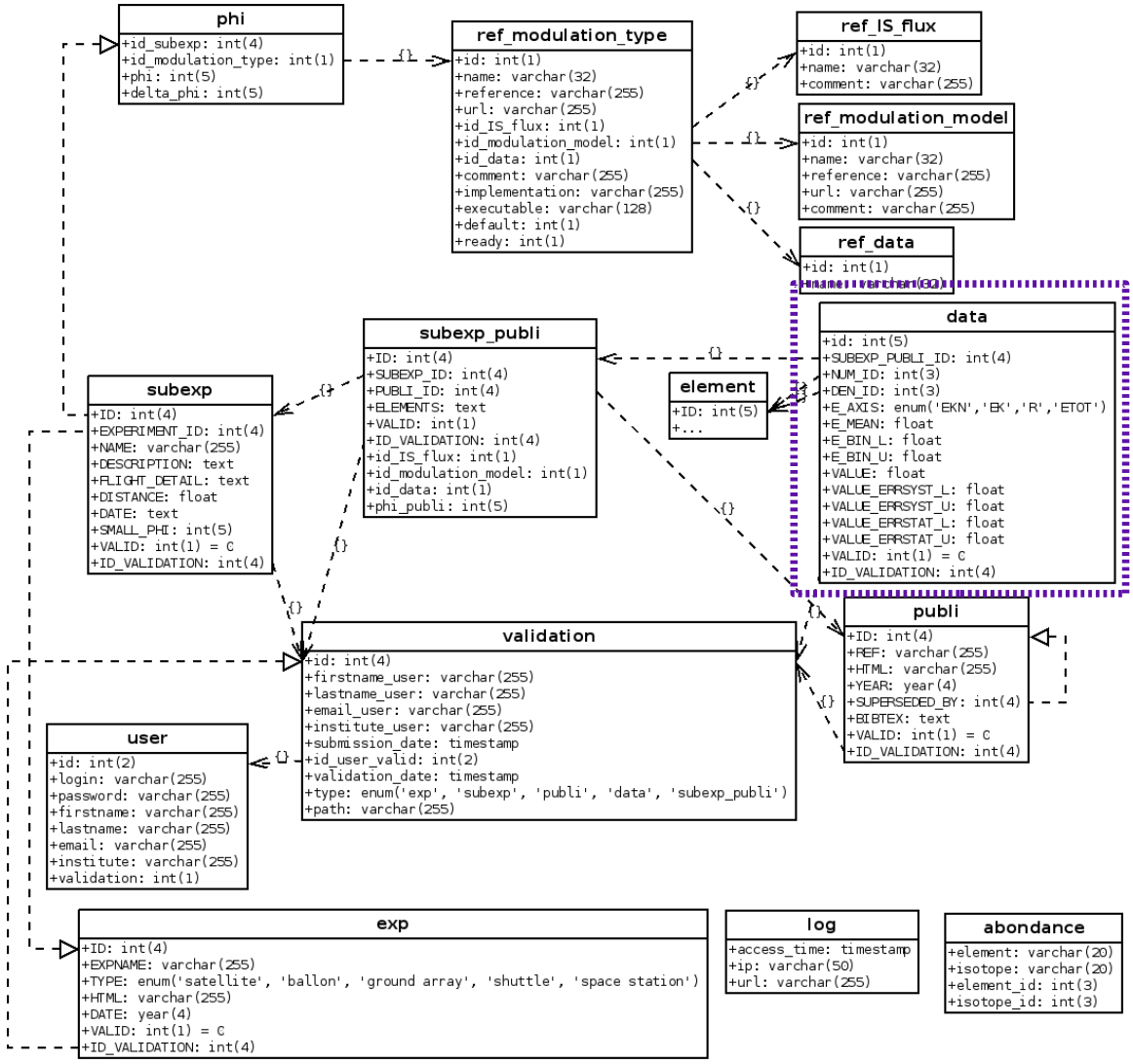
Bin range: same unit as <E> (if not given, $E_{min} = E_{max} = \langle E \rangle$)

Value: measured quantity in unit of
- [(<E> m 2 s sr) −1] for fluxes;
- unitless if ratio.

Stat Err: statistical errors (same unit as *Value*).

Syst Err: systematic errors (same unit as *Value*), set to 0 if not provided

MySQL structure

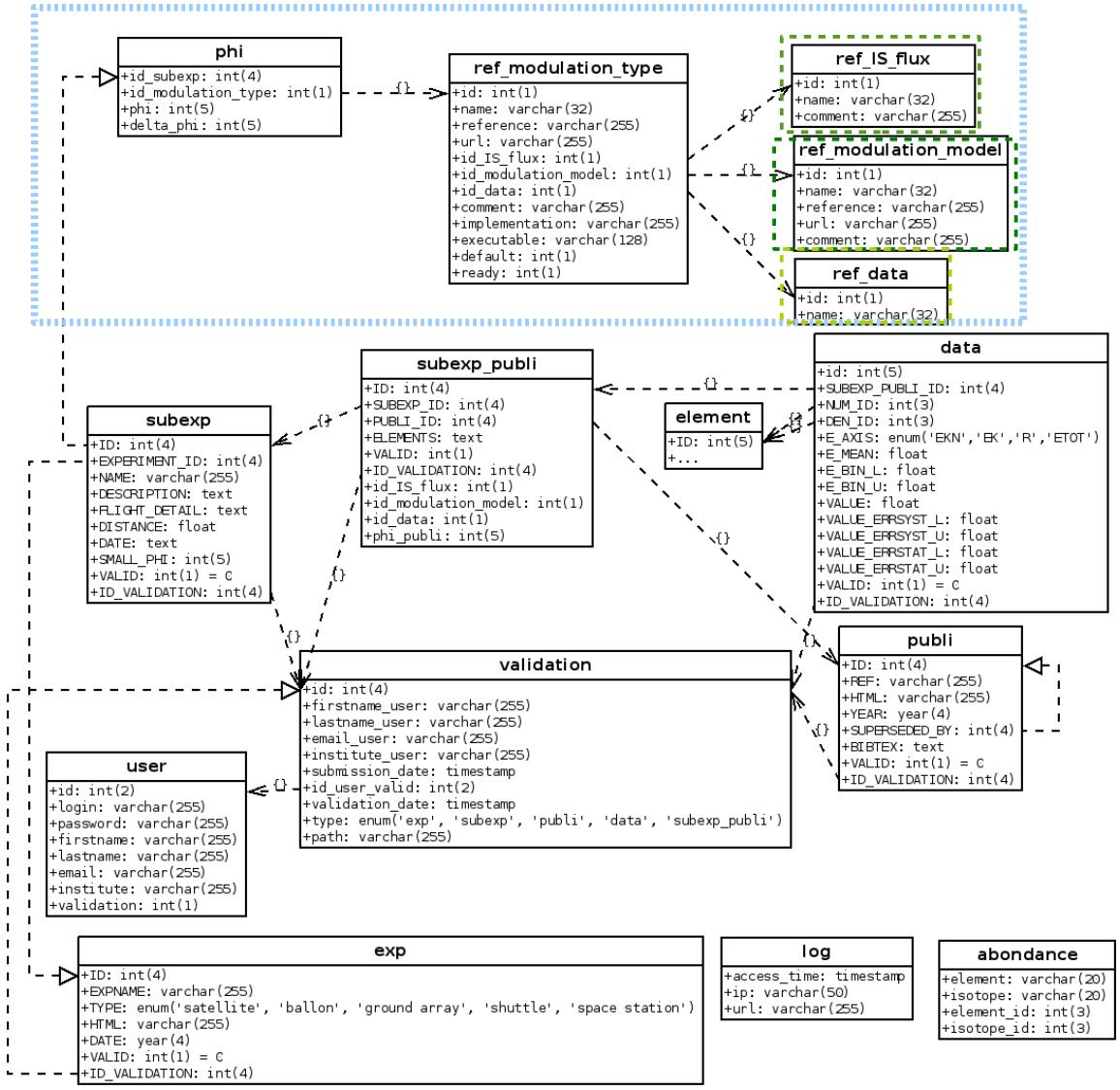


CRDB: Solar modulation parameters

1. **From publication:** solar modulation values taken from publications
   - not homogeneous set (relies on ≠ **IS fluxes**, **models**, **data**;
   - underlying hypotheses not always provided;
   - only small fraction of publications provide it!

2. **NM [Uso11]**: based on NM data analysis of Usoskin *et al.* (2011)
   - homogeneous set (same modelling for all, Force-Field);
   - limited to 07/1936 – 12/2009;
   - monthly averaged.

MySQL structure



CRDB snapshots: main page (1)

http://lpsc.in2p3.fr/crdb

Welcome | Experiments/Data | Data extraction | Links | New data

Database of Charged Cosmic Rays

D. Maurin (LPSC), F. Melot (LPSC), R. Taillet (LAPTh)

If you use this database, please cite Maurin, Melot, Taillet (arxiv.org/abs/1302.5525).

New release V2.1 - June 2014 [changelog]

Last code modification: 20/06/2014

Description

This database is a compilation of experimental cosmic-ray data. The database includes electrons, positrons, antiprotons, and nuclides up to Z=30 for energies below the knee. If you spot any errors or omissions, want to contribute, or simply comment on the content of the database, please contact us. We are eager to extend the database to Z>30 and to higher energy ground measurements and any help is welcome.

Warning: several sets of Solar modulation values are provided per sub-experiment. We refer the user to the discussion in Sect.2.3 of Maurin et al. (2013) for a complete discussion, and only give below a brief description of the different sets of modulation parameters available in the CRDB: [read more]

Current version / Latest data added / Acknowledgements

Structure of the database

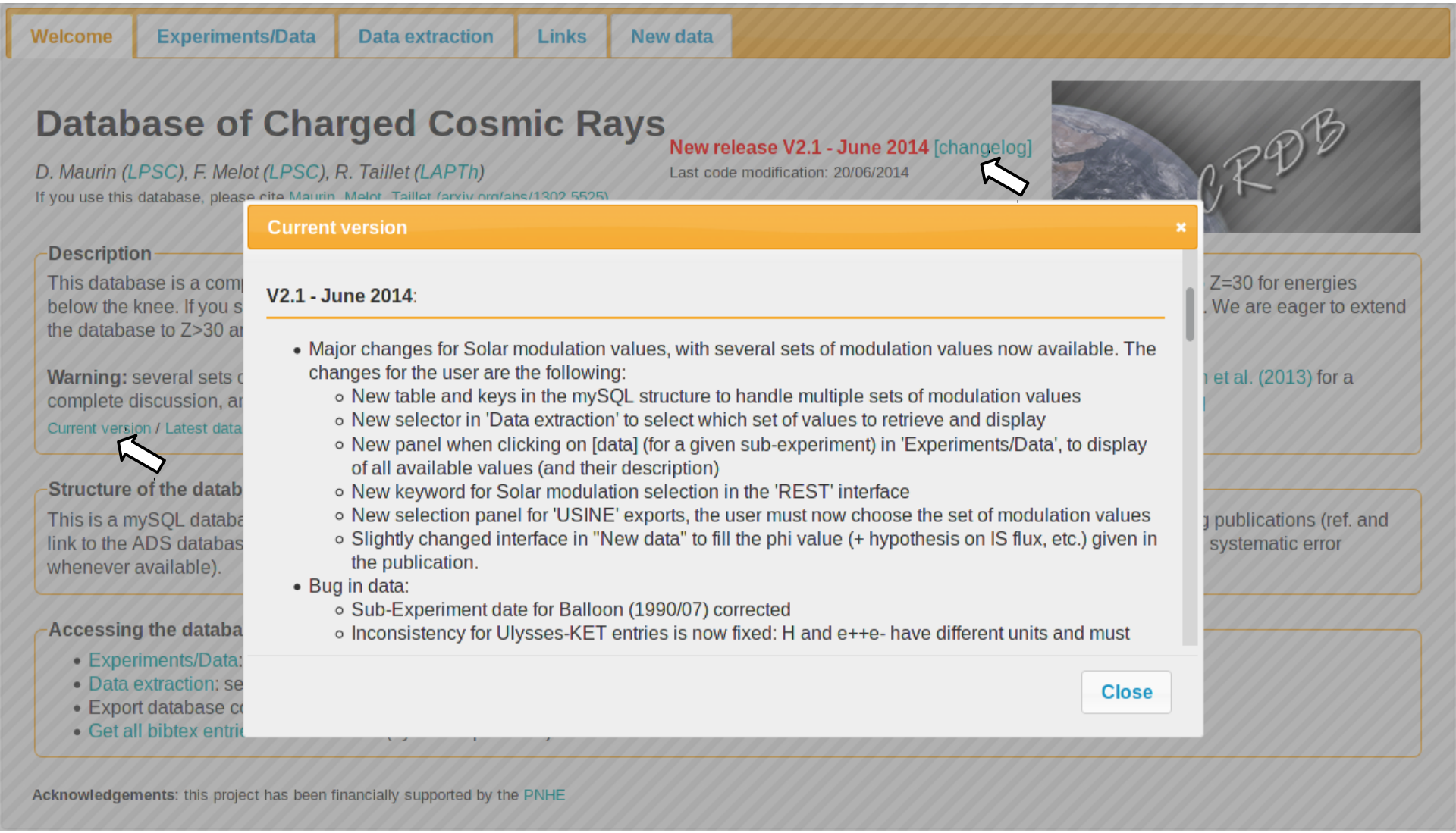
This is a mySQL database containing lists of experiments (name, dates of flight, experimental technique in brief, website), the corresponding publications (ref. and link to the ADS database), and all available data points (fluxes and ratios of leptons, nuclides, and anti-protons including their statistical and systematic error whenever available).

Accessing the database

- Experiments/Data: list of experiments, publications, data
- Data extraction: selection by flux/ratio/energy range... (on this web site or via a REST interface)
- Export database content in USINE or GALPROP compliant format (ASCII files)
- Get all bibtex entries and Latex cite (by sub-experiment)

Acknowledgements: this project has been financially supported by the PNHE

CRDB snapshots: main page (2)



CRDB snapshots: 'Experiment/Data' tab (1)

Welcome | Experiments/Data | Data extraction | Links | New data

[sort by name] [sort by date] List of acronyms 297 entries

- IMP8 (1974/01-1977/11) - 3 years data 74-77
  [data] [Beatty et al., ApJ 294, 445 (1985)] $^{2}H/^{4}He$
- IMP8 (1974/01-1978/10) - 4 years data 74-78
  [data] [Garcia-Munoz et al., ApJS 64, 269 (1987)] *Li/C, Be/C, Be/B, Sc/Fe, V/Fe, B/C, N/O*

Balloon (1964,1965,1966)

- Balloon (1964/07) - 2 flights Fort Churchill (Canada)
  [data] [L'Heureux, ApJ 148, 399 (1967)] e^-+e^+
- Balloon (1965/06+1965/07) - 2 flights Fort Churchill (Canada)
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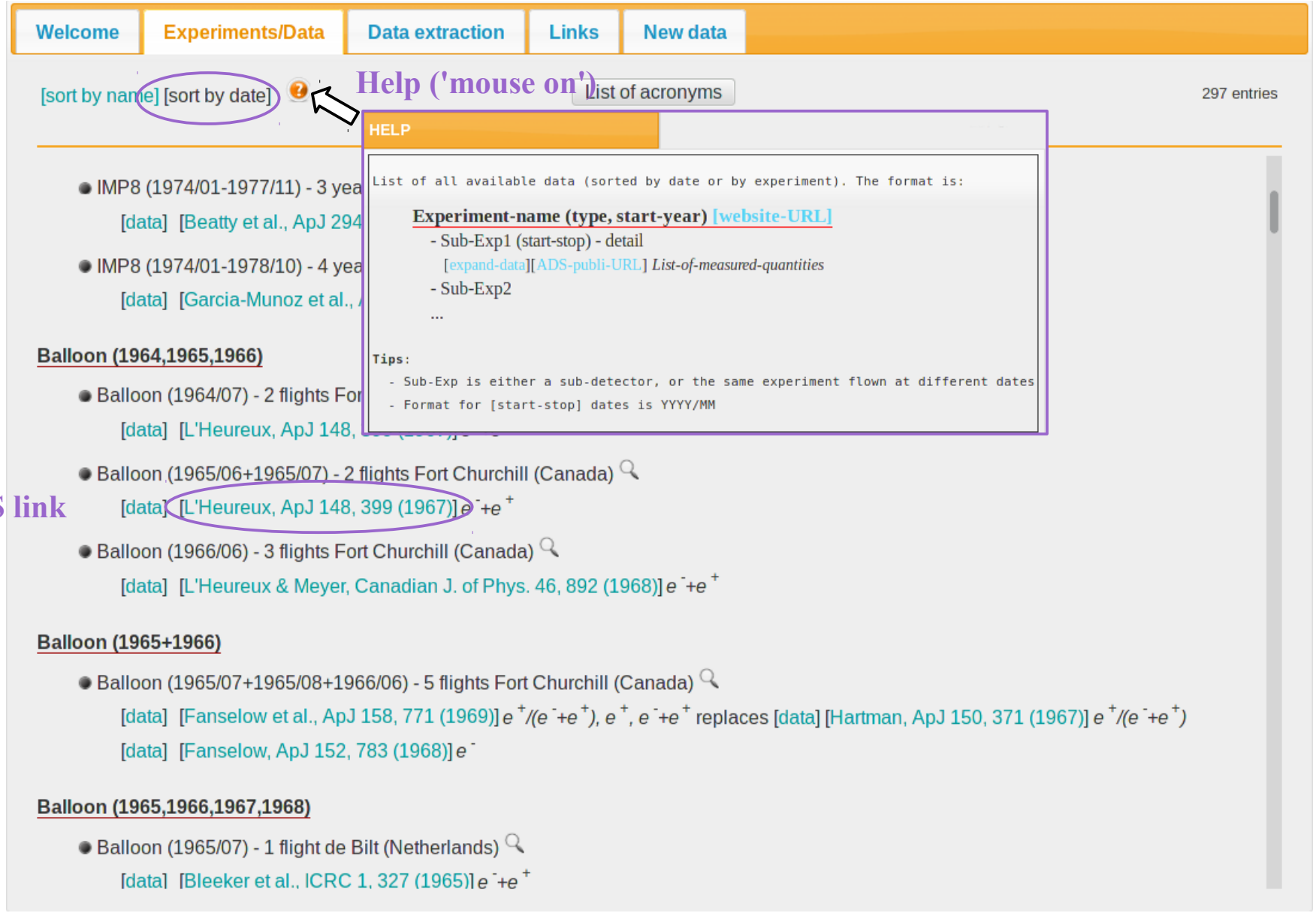
Balloon (1965+1966)

- Balloon (1965/07+1965/08+1966/06) - 5 flights Fort Churchill (Canada)
  [data] [Fanselow et al., ApJ 158, 771 (1969)] $e^+/(e^-+e^+)$, e^+, e^-+e^+ replaces [data] [Hartman, ApJ 150, 371 (1967)] $e^+/(e^-+e^+)$
  [data] [Fanselow, ApJ 152, 783 (1968)] e^-

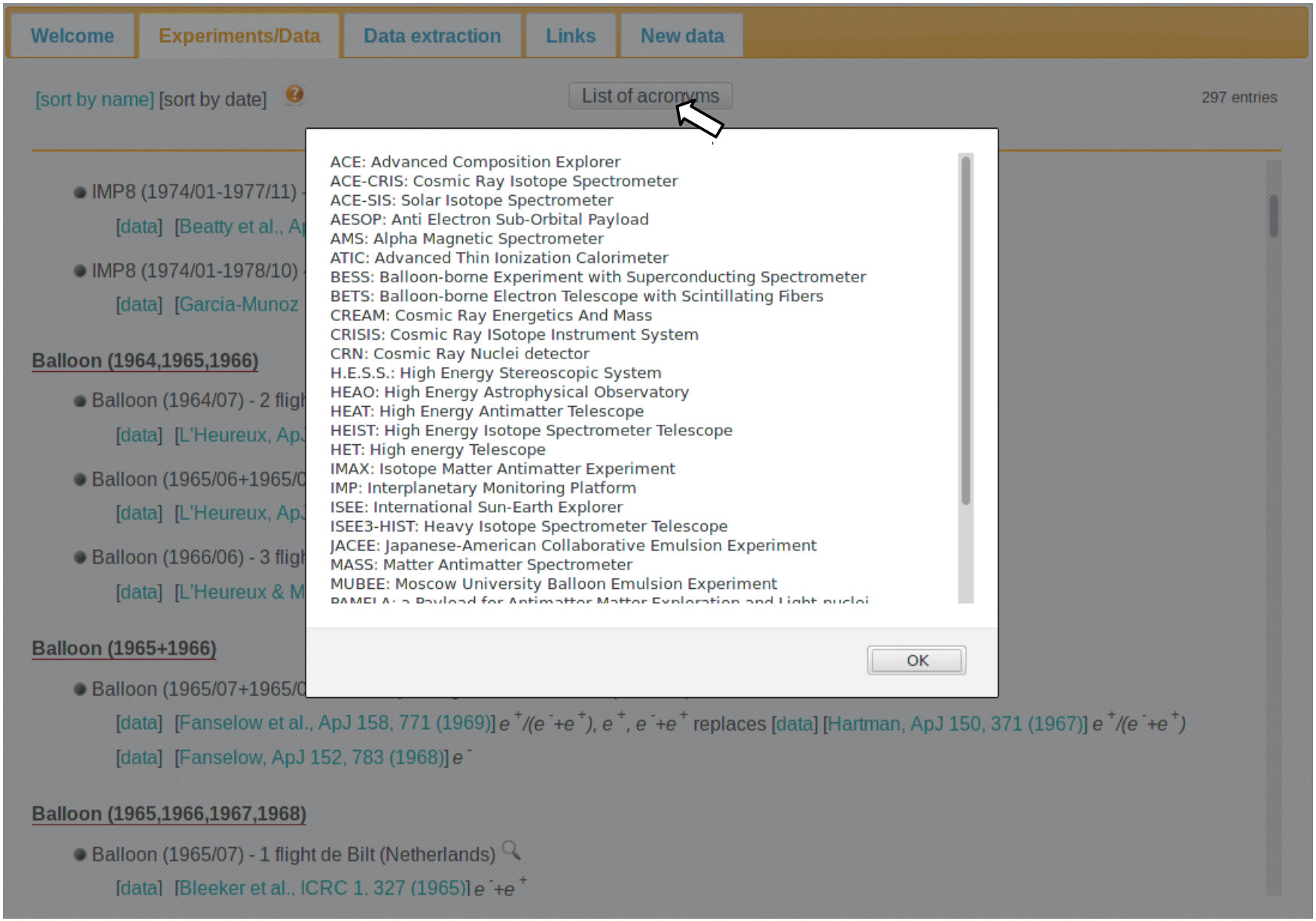
Balloon (1965,1966,1967,1968)

- Balloon (1965/07) - 1 flight de Bilt (Netherlands)
  [data] [Bleeker et al., ICRC 1, 327 (1965)] e^-+e^+

CRDB snapshots: 'Experiment/Data' tab (2)



CRDB snapshots: 'Experiment/Data' tab (3)



CRDB snapshots: 'Experiment/Data' tab (4)

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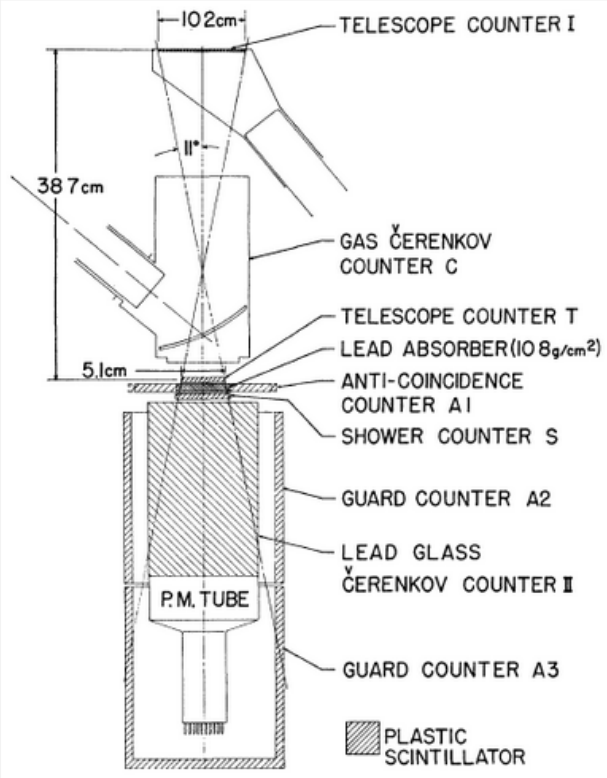
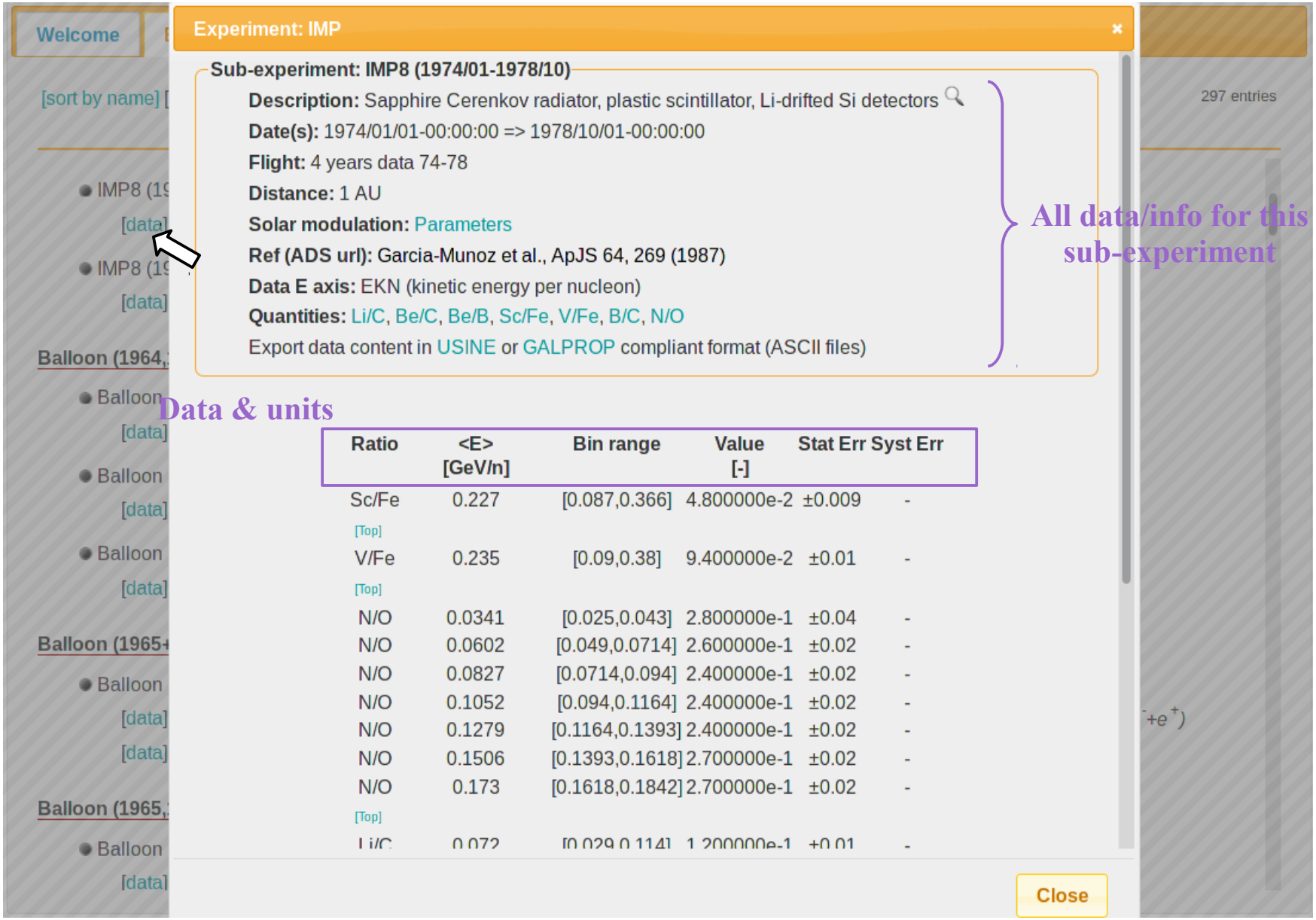
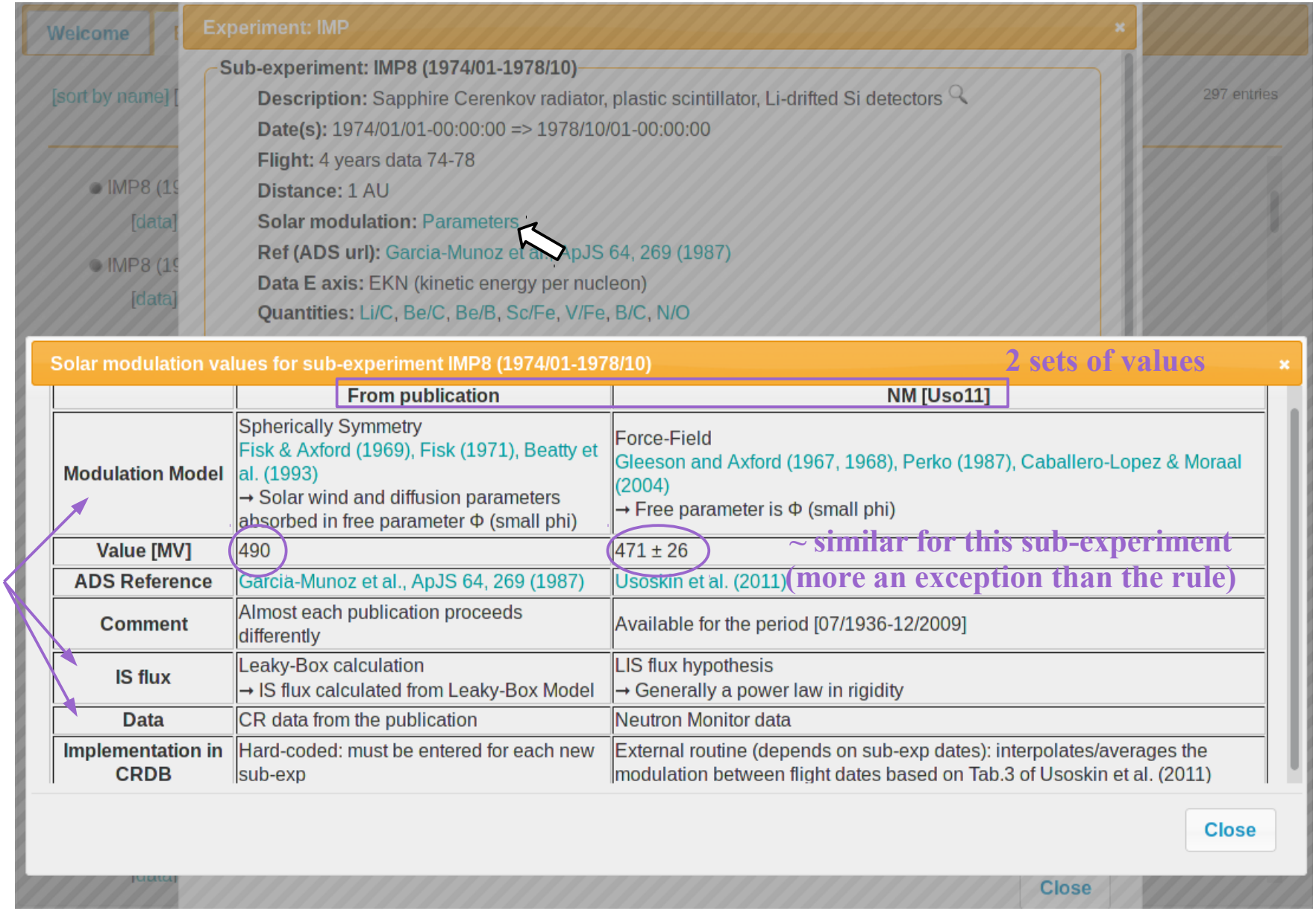


Close

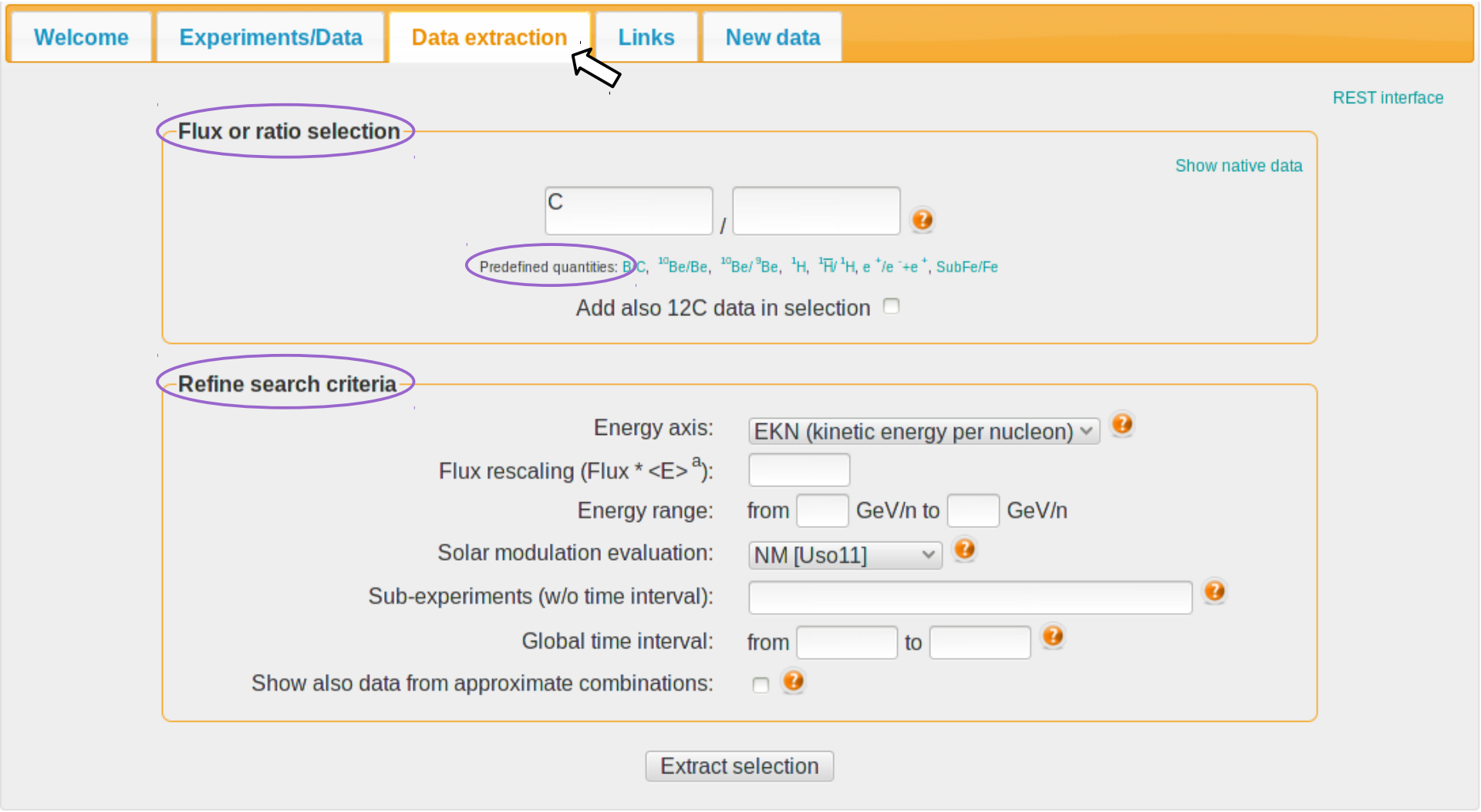
CRDB snapshots: 'Experiment/Data' tab (5)



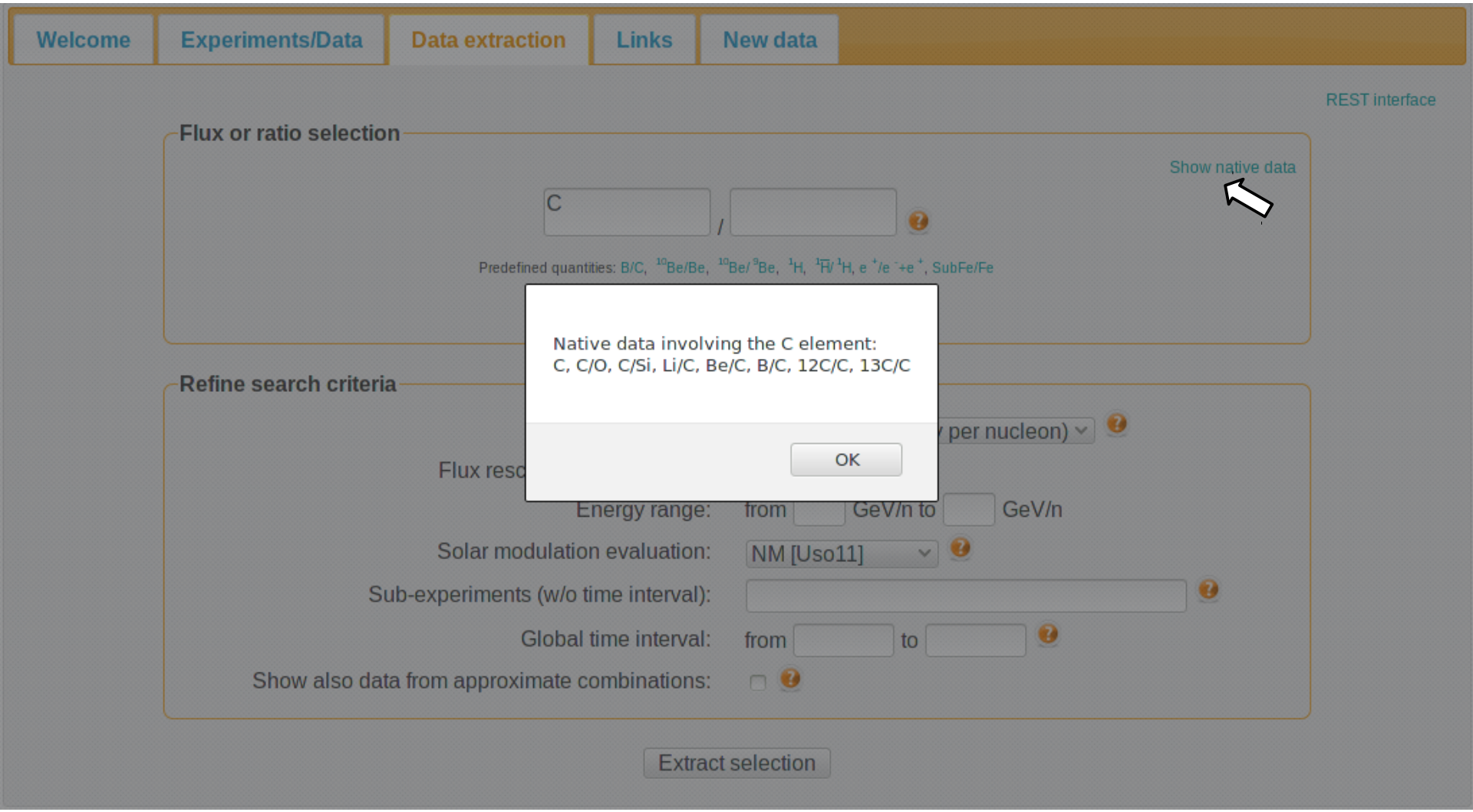
CRDB snapshots: 'Experiment/Data' tab (6)



CRDB snapshots: 'Data extraction' tab (1)



CRDB snapshots: 'Data extraction' tab (2)



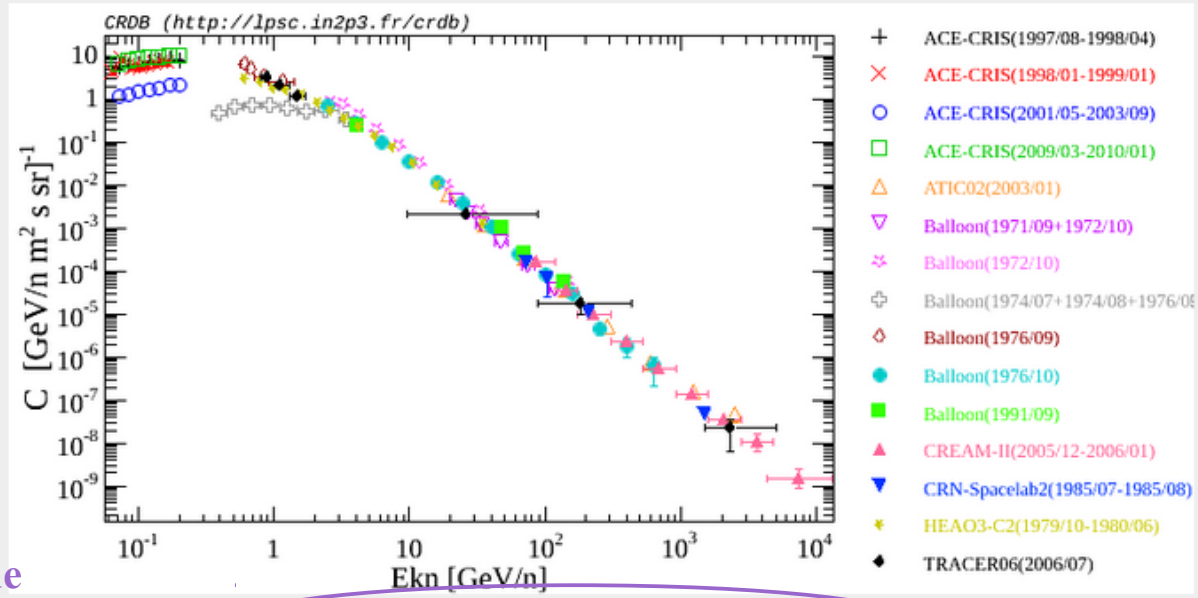
→and click on “Extract selection” to get...

CRDB snapshots: 'Data extraction' tab (3a)

Welcome

C element flux (Energy type: EKN, Solar modulation: NM [Uso11])

Plot & Export - Hide



Get ROOT Macro - Get Data Files - Get Usine File - Get GALPROP File - Get Plot - Replot

Export C++ code

Export data (ASCII, etc.)

Export image

→and click on "Replot" to get...

List of sub-experiments found for C element flux selection - Hide

Get Latex cite | Get Bibtex

Sub-experiment name (dates)	# data	Modulation	Reference
ACE-CRIS (1997/08-1998/04) [WEB]	7	ϕ=425 ± 26 MV	Lave et al., ApJ 770, 117 (2013)
ACE-CRIS (1998/01-1999/01) [WEB]	9 ♠	ϕ=508 ± 26 MV	De Nolfo et al., AdSR 38, 1558 (2006)
ACE-CRIS (2001/05-2003/09) [WEB]	7	ϕ=917 ± 26 MV	Lave et al., ApJ 770, 117 (2013)

CRDB snapshots: 'Data extraction' tab (3b)

Welcome

C element flux (Energy type: EKN, Solar modulation: NM [Usoskin11])

REST interface

Replot interface

Sub-experiment selection

- ☑ ACE-CRIS (1997/08-1998/04)
- ☑ ACE-CRIS (1998/01-1999/01)
- ☑ ACE-CRIS (2001/05-2003/09)
- ☑ ACE-CRIS (2009/03-2010/01)
- ☑ ATIC02 (2003/01)
- ☐ Balloon (1971/09+1972/10)
- ☐ Balloon (1972/10)
- ☑ Balloon (1974/07+1974/08+1976/09)
- ☑ Balloon (1976/09)
- ☐ Balloon (1976/10)
- ☐ Balloon (1991/09)
- ☑ CREAM-II (2005/12-2006/01)
- ☑ CRN-Spacelab2 (1985/07-1985/08)
- ☑ HEAO3-C2 (1979/10-1980/06)
- ☑ TRACER06 (2006/07)

Uncheck All

Graphical settings

Energy bin range: ◉ show ○ hide

Y-axis min value:

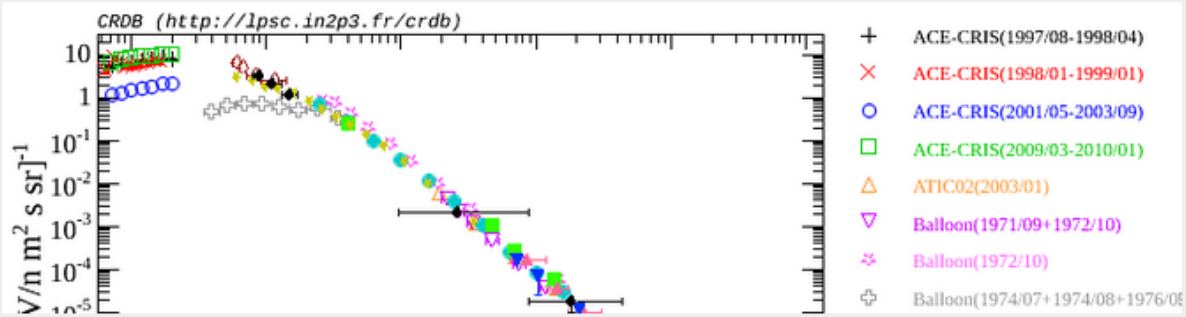
Y-axis max value:

Y-axis scale: ○ linear ◉ log

Image size X: 750

Image size Y: 400

replot



CRDB: 'Data extraction' tab (4)

C element flux (Energy type: EKN, Solar modulation: NM [Uso11])

Balloon (1991/09)	4	MV	Buckley et al., ApJ 429, 736 (1994)
CREAM-II (2005/12-2006/01) [WEB]	9	ϕ=530 ± 26 MV	Ahn et al., ApJ 707, 593 (2009)
CRN-Spacelab2 (1985/07-1985/08)	4	ϕ=544 ± 26 MV	Muller et al., ApJ 374, 356 (1991)
HEAO3-C2 (1979/10-1980/06) [WEB]	14	ϕ=742 ± 26 MV	Engelmann et al., A&A 233, 96 (1990)
TRACER06 (2006/07) [WEB]	6	ϕ=443 ± 26 MV	Obermeier et al., ApJ 724, 14 (2011)

Result Summary

115 results found

♠ 9 additional values from combinations of two native data (same sub-experiment and energy within 5% of each other)

Results Data

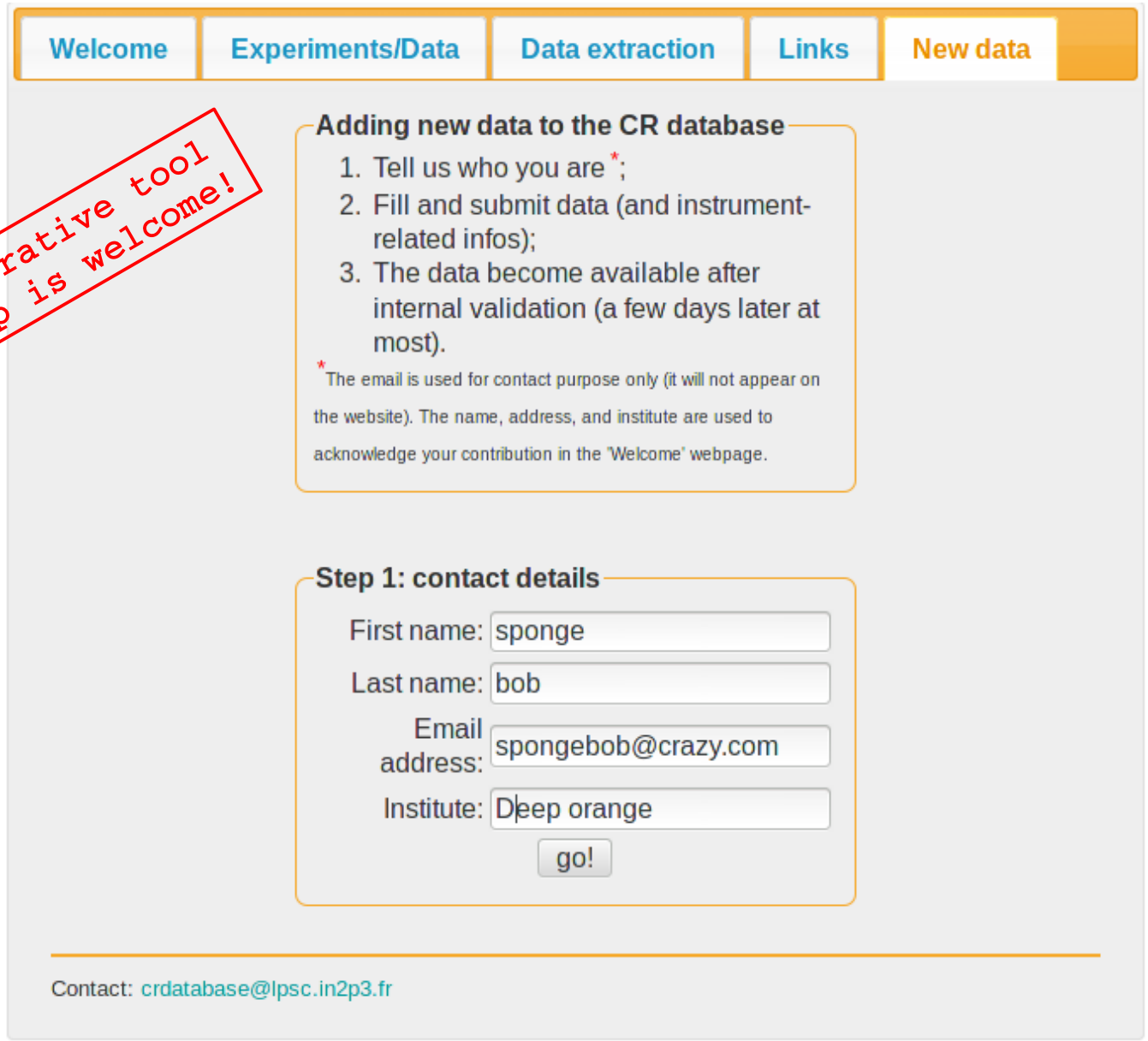
Reduced view

Sub-experiment	<E> [GeV/n]	Bin range [GeV/n]	Value [# (GeV/n m ^{2} s sr) $^{-1}$]	Stat Err [# (GeV/n m ^{2} s sr) $^{-1}$]	Syst err [# (GeV/n m ^{2} s sr) $^{-1}$]	ϕ [MV]
ACE-CRIS (1997/08 1998/04)	7.200e-2	-	5.310000e+0	±1.580e-1	-	425
ACE-CRIS (1997/08 1998/04)	8.500e-2	-	5.849000e+0	±1.750e-1	-	425
ACE-CRIS (1997/08 1998/04)	1.000e-1	-	6.447000e+0	±1.930e-1	-	425
ACE-CRIS (1997/08 1998/04)	1.200e-1	-	7.167000e+0	±2.250e-1	-	425
ACE-CRIS (1997/08 1998/04)	1.420e-1	-	7.604000e+0	±2.530e-1	-	425
ACE-CRIS (1997/08 1998/04)	1.700e-1	-	7.968000e+0	±2.960e-1	-	425
ACE-CRIS (1997/08 1998/04)	2.000e-1	-	7.934000e+0	±3.290e-1	-	425
ACE-CRIS (1998/01 1999/01)	6.596e-2	[6.399e-2,6.799e-2]	4.060086e+0	±6.710e-1	-	508

All data found

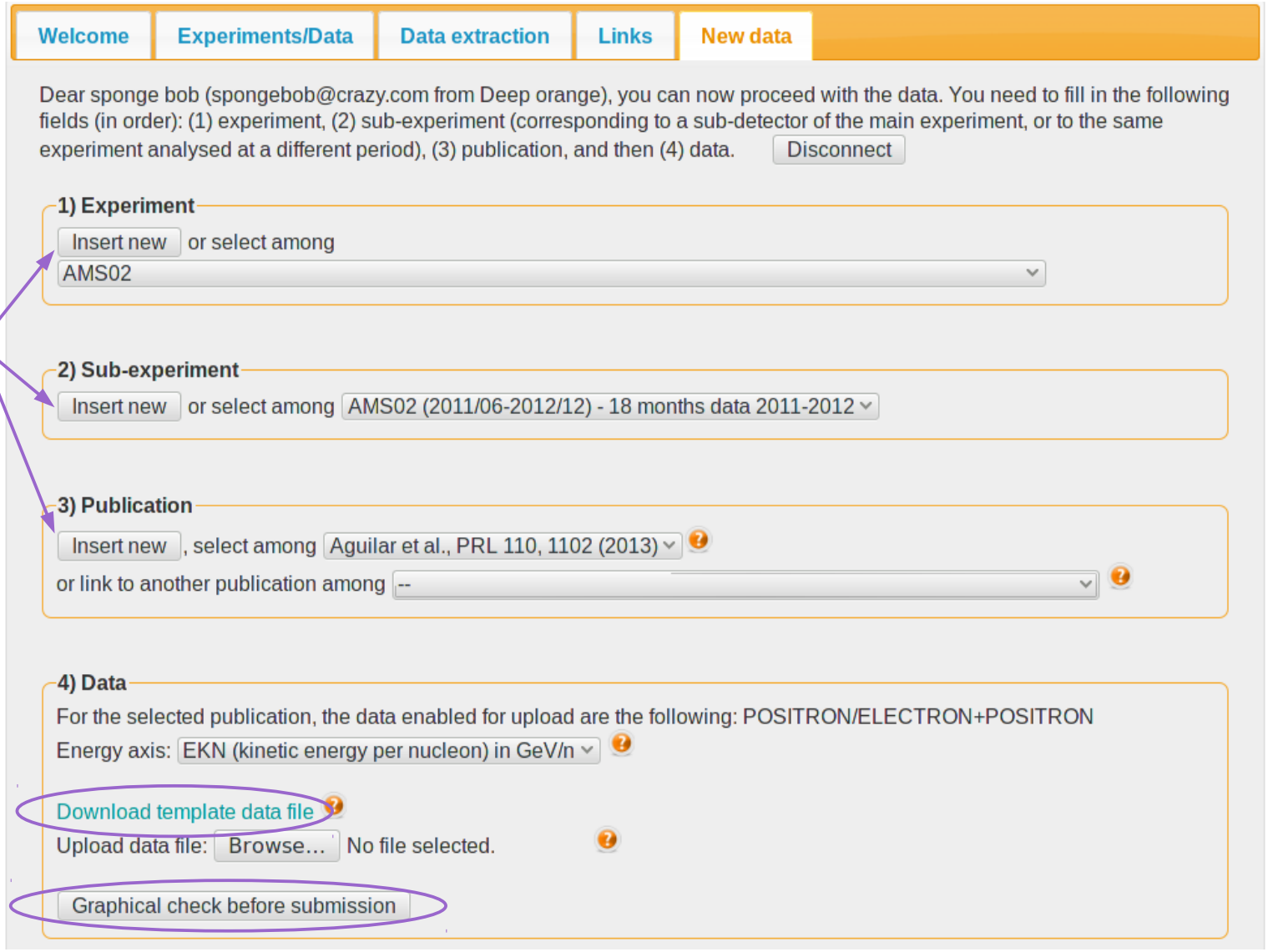
REST interface

CRDB: 'New data' tab (1)



CRDB: 'New data' tab (2)

Lot of stuff to fill (new screens), if new!



→appear online once validated (so far, by me!)

I. CRDB: presentation and tools

II. IS flux, Solar modulation, and NM

Based on

Neutron Monitors and muon detectors for solar modulation studies: interstellar flux, yield function, and assessment of critical parameters in count rate calculations

http://arxiv.org/abs/1403.1612 (to appear in AdSpR)

DM[a], A. Cheminet[b,c], L. Derome[a], A. Ghelfi[a], G. Hubert[b,c]

[a] *LPSC, Grenoble*
[b] *ONERA, Toulouse*
[c] *IRSN, Saint-Paul-Lez-Durance*

Key questions

IS fluxes

- footprint of CR synthesis/acceleration/transport
- Low energy pbar and dbar fluxes for DM detection

- ionisation level of the ISM
- molecules formation in molecular clouds
- X- and γ-ray emisions in molecular clouds

Key questions

IS fluxes **Solar modulation**

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- CR transport in the solar cavity (diffusion, convection, drift...?)
- Space weather, correlation with Sun activity proxies (sunspots, etc.)

- What is the modulation level for my experiment?
- How much variation on a given data taking period?

} Experimentalists (e.g., AMS-02)

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} Experimentalists (e.g., AMS-02)

1. IS fluxes: what are they?
2. Modulation model: charge-dependence, anisotropic diffusion?

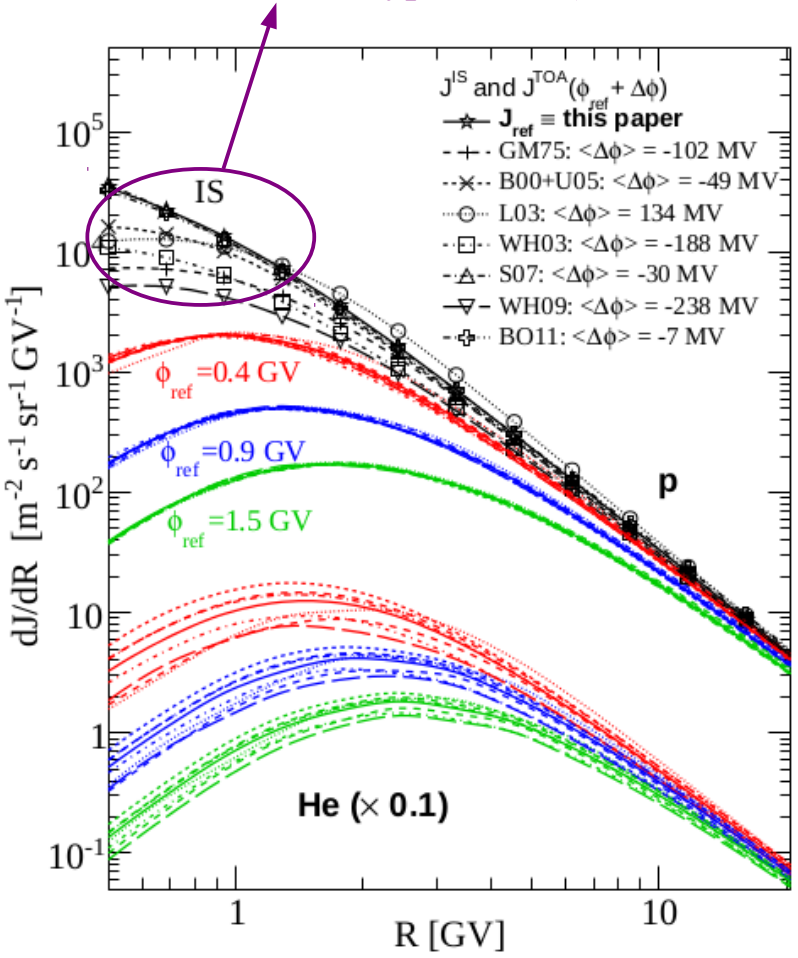
→Obtain homogeneous sets of modulation levels (+ time series), in the context of the force-field approximation: single free parameter ϕ(t)

Force-Field approximation

$$\frac{E^{\rm TOA}}{A} = \frac{E^{\rm IS}}{A} - \frac{|Z|}{A}\phi$$
$$\frac{J^{\rm TOA}(E^{\rm TOA})}{J^{\rm IS}(E^{\rm IS})} = \left(\frac{p^{\rm TOA}}{p^{\rm IS}}\right)^2,$$

Degeneracy between modulation level and IS flux

Different IS flux hypotheses (from literature)



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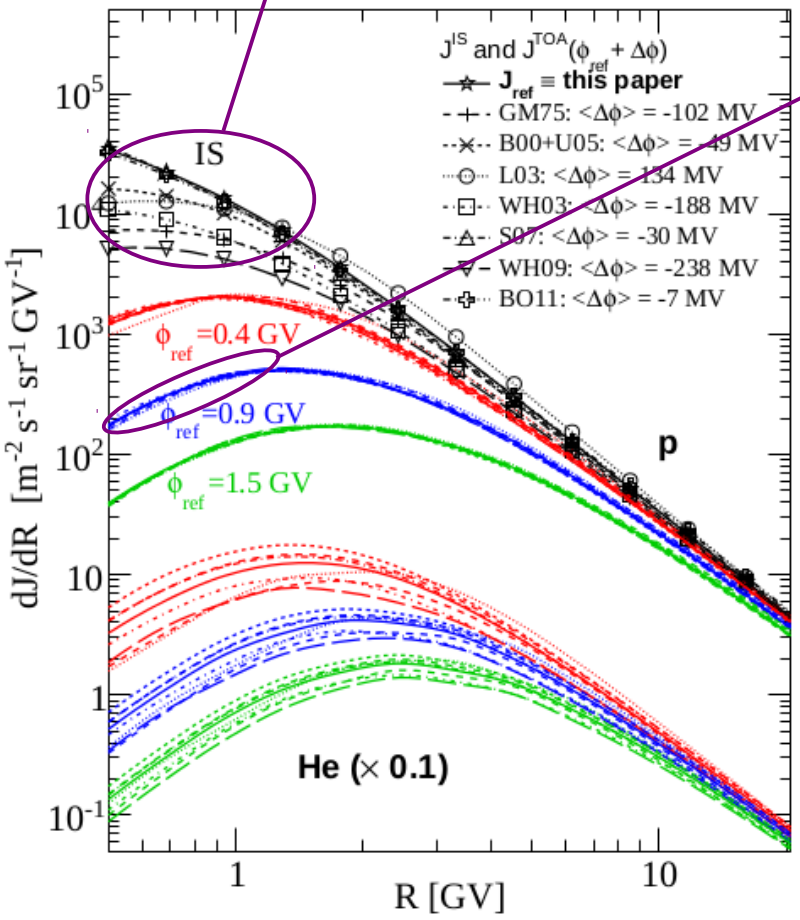

Same top-of-atmosphere (TOA) fluxes, up to a shift of the effective modulation level ϕ

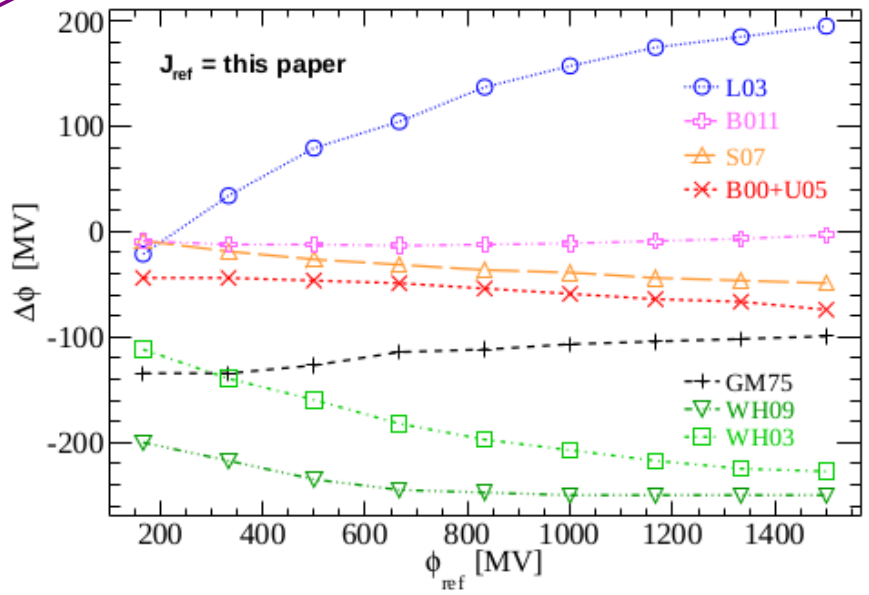

Figure 3: Value of the modulation shift $\Delta\phi_i$ to add to the reference modulation level $\phi_{\rm ref}$, for $J_i^{\rm TOA}(\phi_{\rm ref} + \Delta\phi_i)$ to be as close as possible to $J_{\rm ref}^{\rm TOA}(\phi_{\rm ref})$. The index i runs on the IS flux parametrisations shown in Fig. 2 (see also App. A).

Degeneracy between modulation level and IS flux

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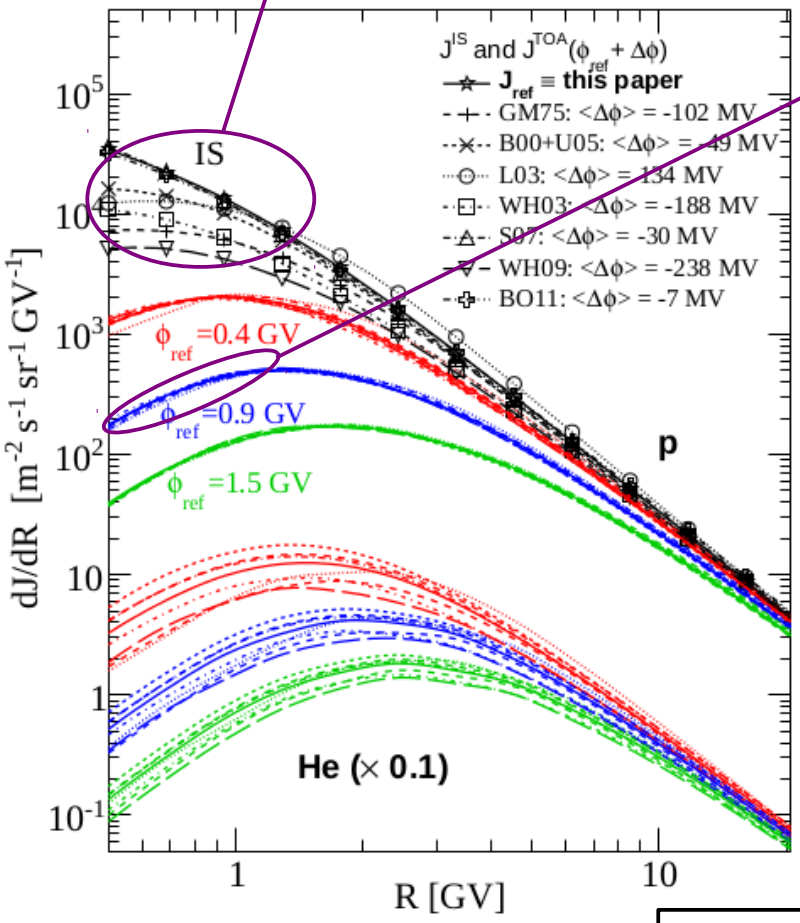


Same top-of-atmosphere (TOA) fluxes, up to a shift of the effective modulation level ϕ

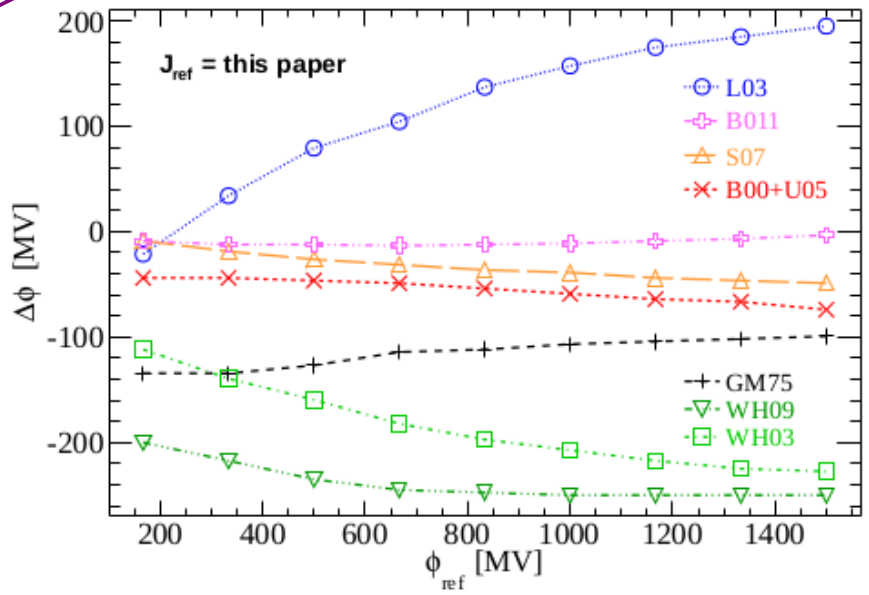


Figure 3: Value of the modulation shift $\Delta\phi_i$ to add to the reference modulation level $\phi_{\rm ref}$, for $J_i^{\rm TOA}(\phi_{\rm ref} + \Delta\phi_i)$ to be as close as possible to $J_{\rm ref}^{\rm TOA}(\phi_{\rm ref})$. The index i runs on the IS flux parametrisations shown in Fig. 2 (see also App. A).

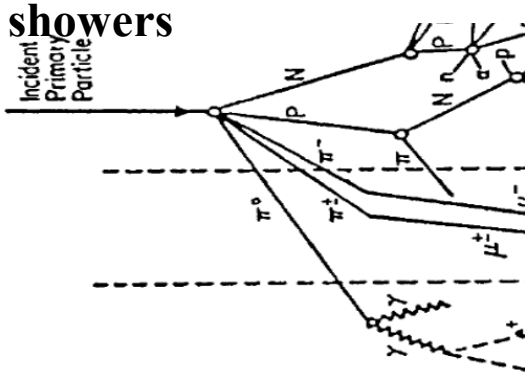
How to lift degeneracies?

→Direct fit to CR TOA: different times + different species
→Use worldwide network of NMs to cross-check values

→ see poster Alexandre Ghelfi

CR showers, ground-based detectors, and count rates

CR showers

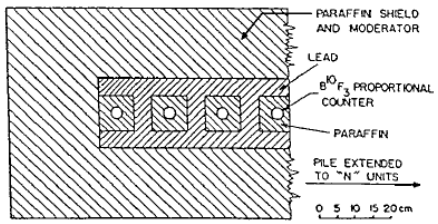


Neutron monitors

Simpson, Space Sci. Rev. **93**, 11 (2000)

$$^{10}\mathrm{B} + \mathrm{n} \rightarrow {}^{11}\mathrm{B}^{*} \rightarrow {}^{7}\mathrm{Li} + {}^{4}\mathrm{He}^{++} + \mathrm{Q}\,.$$

$$^{3}\mathrm{He}_2 \quad + \quad \mathrm{n} \quad \rightarrow \quad ^{3}\mathrm{H}_1 \quad + \quad \text{proton}$$



+ μ detectors (AUGER scaler data)
+ Bonner sphere spectrometers(BSS

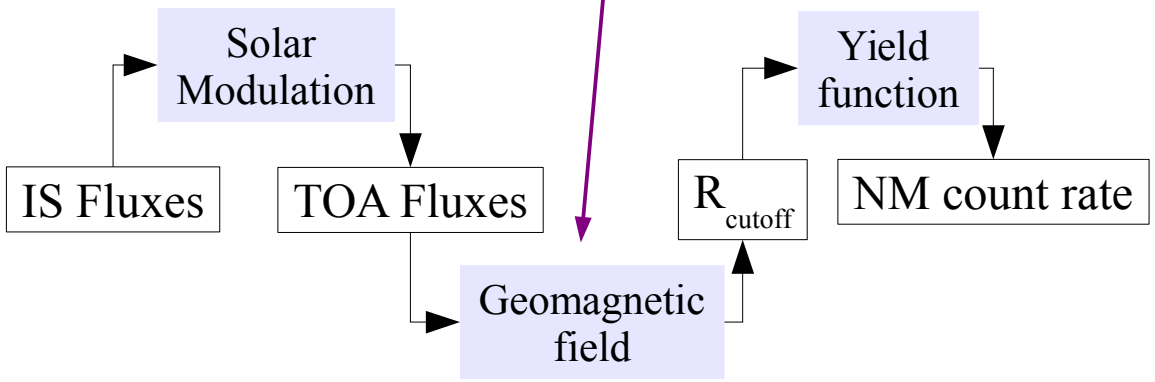
Ground-level count rates:

Dorman's textbooks (1974, 2004, 2009)

$$N^{\mathcal{D}}(\vec{r},t) = \int_0^{\infty} \mathcal{T}(R,\vec{r},t) \times \sum_{i=\mathrm{CRs}} \mathcal{Y}_i^{\mathcal{D}}(R,h) \frac{dJ_i^{\mathrm{TOA}}}{dR}(R,t)\, dR,$$

Transmission

Atmosphere response



Error budget on count rates and modulation level

Ingredient	Effect	Paper	$\frac{\Delta N}{N}$ NM	$\frac{\Delta N}{N}$ μ	$\Delta\phi^*$ [MV] NM	$\Delta\phi^*$ [MV] μ	Comment
Solar modulation	$\phi \in$ *[0.2,1.5] GV*	*Fig.16*	*[+15,-25]%*	*[+5,-10]%*	-	-	*w.r.t.* $\phi = 0.5$ *GV*
Cut-off rigidity	$R_c \in$ *[0,10] GV*	*Fig.11*	*[+10,-20]%*	*[0,-5]%*	-	-	*w.r.t.* $R_c = 5$ *GV*
TOA flux	p and He CR data	Fig.12	±2%	±2%	±66	±140	(t, R_c, ϕ)-independent
	IS flux dispersion¶	Fig.12	±6%	±8%	±200	±570	⇓
	Heavy species	Fig.1	±0.6%	±0.6%	±20	±40	Global norm. factor◇
Yield function	Dispersion	Fig.12	$\lesssim \pm 4\%$	$< 0.2\%$	$\lesssim 120$	$\lesssim 14$	(R_c, ϕ) dependent
Transfer function	Sigmoid$(R_c, x = +\frac{\sigma}{0.1})$	Fig.13	$-2x\%$	$-0.5x\%$	$+66x$	$+35x$	For $R_c \gtrsim 5$ GV
	$H(R_c+\Delta R_c)$: $x=\frac{(\Delta R_c/R_c)}{0.05}$	Fig.13	$-2x\%$	$-x\%$	$+66x$	$+71x$	For $R_c \gtrsim 5$ GV
	- $R_c(t)$: $\frac{\Delta R}{R} \lesssim +0.2\%$/y	§5.2.2	-0.4%/yr	-0.1%/yr	+13/yr	+7/yr	Depends on location
	- $R_c^{\rm eff} \rightarrow R_c^{\rm app}$: +3%	§5.2.2	-1.2%	-0.3%	+40	+21	Depends on R_c
Time-dep. effects	Pressure	§5.3.1	±0.2%	±0.2%	±6	±14	DC‡
	Temperature	§5.3.2	±0.5%	±4%	±15	±290†	DC‡
	Vapour water	§5.3.3	±0.3%	±0.1%	±10	±8	NC‡
	Snow coverage	§5.3.4	-7%	-	+230	-	NC‡ (1 yr period)
	Diurnal variation	§5.4	0.24%	0.24%	8	17	NC‡ (24h period)
NM detector effects	Temperature	§5.4	+0.05%/C	-	-1.5/C	-	(t, R_c, ϕ)-independent
	xNM6 vs yNM64	§5.4	few %	-	~ 100	-	⇓
	Surroundings (hut)	§5.4	few %	-	~ 100	-	Global norm. factor◇

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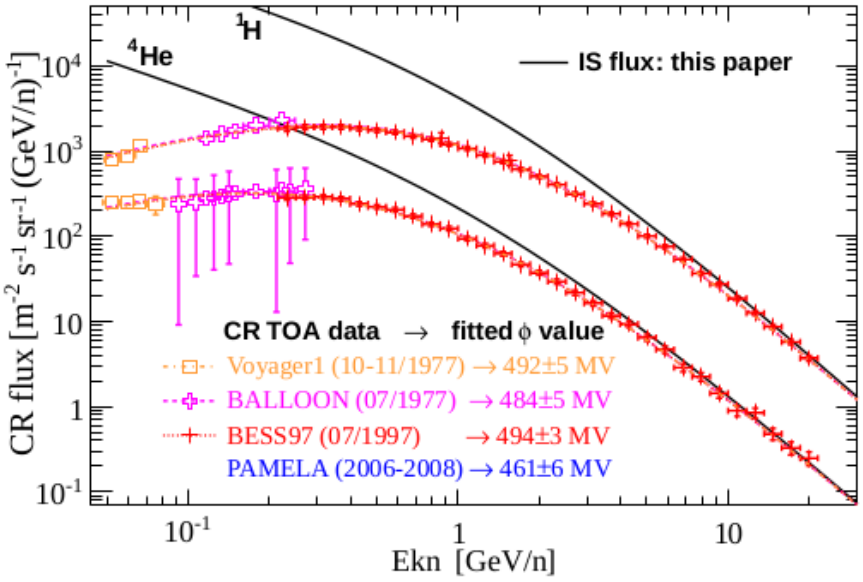
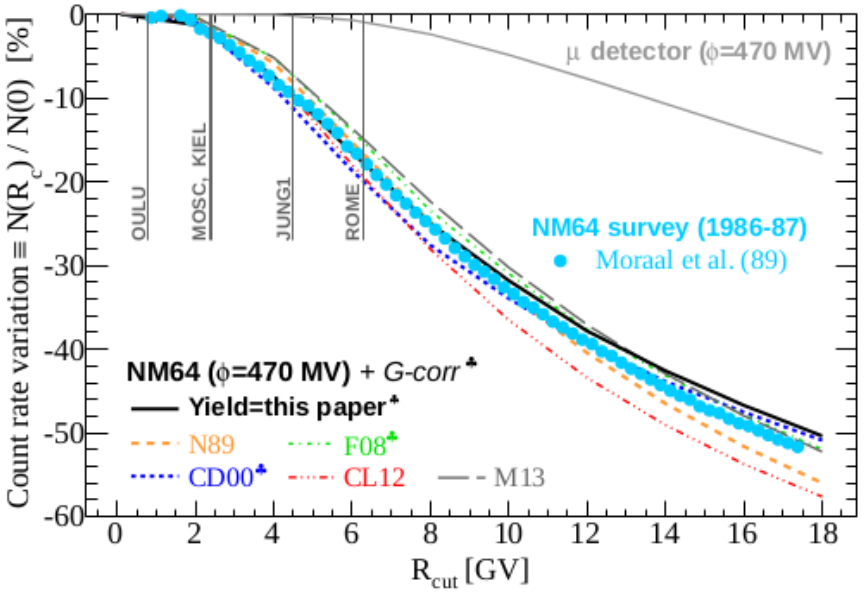
→Modulation level time series for well chosen ground-based detectors
→Add new (more precise) 'homogeneous' sets of modulation level in CRDB
→Use CR data + NM data to find IS flux and test ≠ modulation models

Ghelfi *et al.* (in prep.)

Validation on NM latitude surveys

1. Latitude surveys (vs Rc) every 11 yr at solar minimum
2. Use CR data at same epoch to find ϕ
3. Check surveys with calculated count rates





→Up to 10 GV, our yield gives best fit

→Other yield functions more or less OK as well (dispersion)