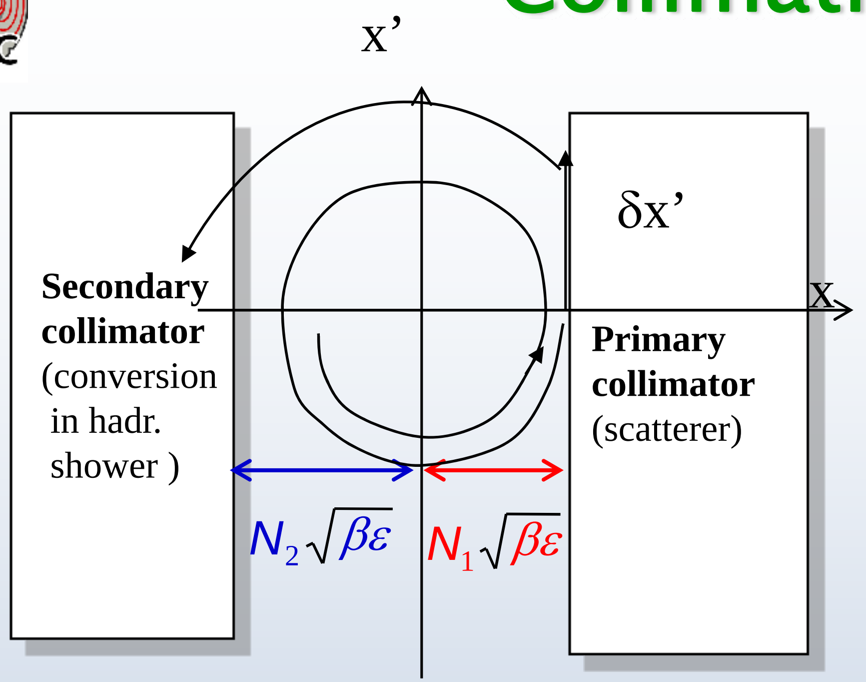
New cross section estimates for ion collimation

R. Bruce, G. Bellodi, H. Braun, S. Gilardoni, J. M. Jowett

Collimation of ions



Necessary condition :

$$\delta x' > \sqrt{\frac{\left(N_2^{\,2} - N_1^{\,2}\right)\varepsilon_N}{\gamma_{REL}\,\beta_{TWISS}}}$$

scattering at primary collimator *δx'* is mainly due to multiple Coulomb scattering with

$<\delta x'^2> \sim L$

But:

if required $L > L_{INT}$ particle undergoes nuclear reaction before secondary collimator is reached !

	2.76 A TeV Pb ions on graphite	7 TeV protons on graphite
Nucl. Interaction length	2.2 cm	38.1 cm
EM dissociation length	19 cm	
RMS multiple scattering angle	4.72 μ rad/$m^{1/2}$	4.72 μ rad/$m^{1/2}$

Ion collimation (continued)

- Large probability for fragmentation in primary collimator

  ⇒ Production of isotopes with different Z/A ratio (different rigidity) that are not intercepted by secondary collimator, assuming same collimation optics as for protons.

  These particles follow the local dispersion and may be lost downstream, causing heat deposition in superconducting magnets

The ICOSIM code

Nuclear interaction cross-sections from RELDIS & ABRATION/ ABLATION routines

(Igor Pshenichnov)

ICOSIM (H. Braun et al)

- Generates initial beam distribution
- Tracks particles through machine (linear + leading order in chromatic effects, thin sextupoles)
- Simulates ion-matter interactions in collimators (nucl. fragm., em. dissociation, ionization, mult. scatt.)
- Tracks heaviest fragment, computes impact sites of ions in LHC lattice

MAD-X optics files and aperture tables

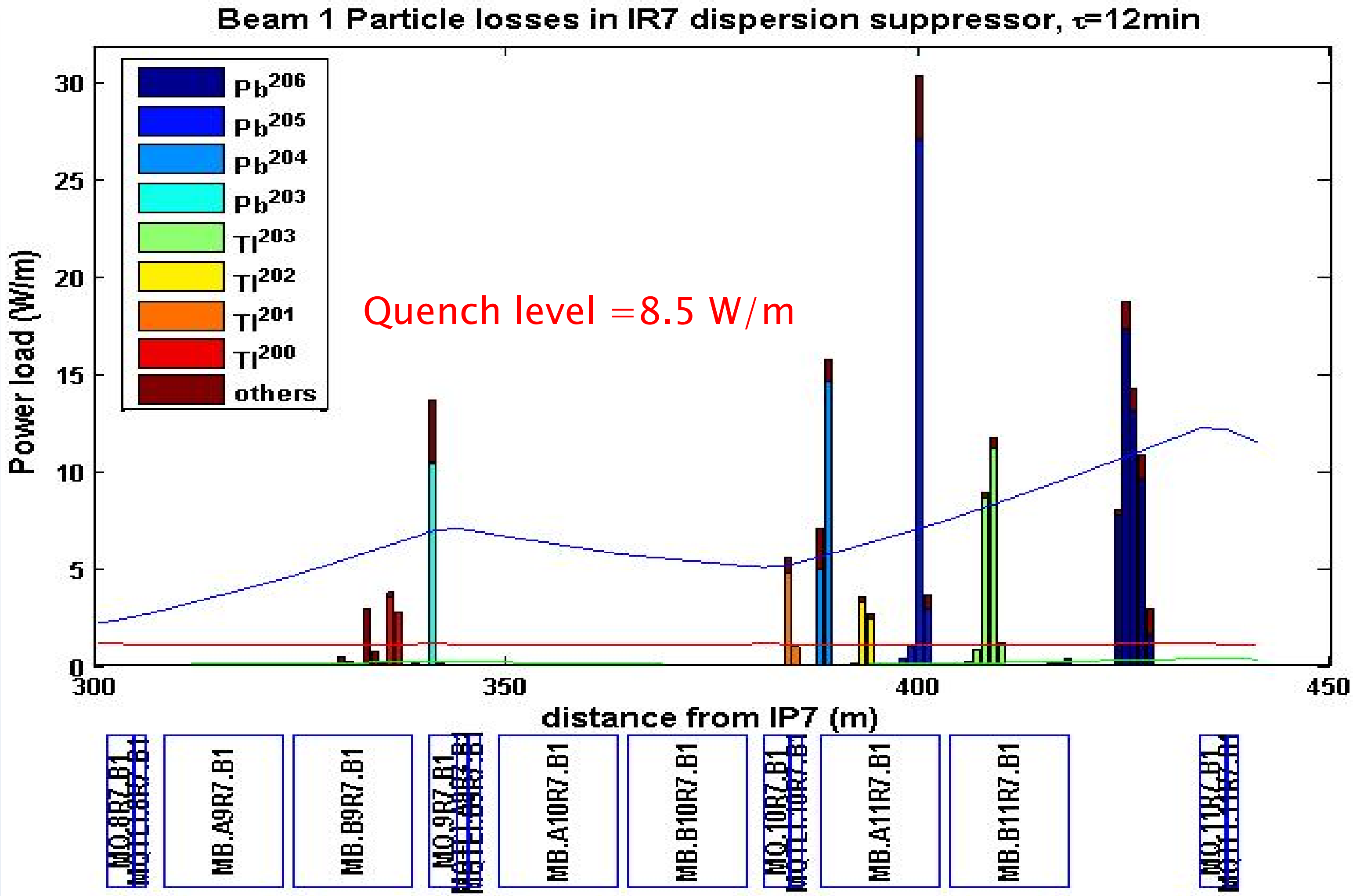
OUTPUT:

Loss patterns

Collimation efficiencies

(For more details, see H. Braun et al in EPAC04)

LHC example



Loss map after IR7 (betatron cleaning).
Collision optics, standard collimator settings, tertiary W collimators

(G. Bellodi)

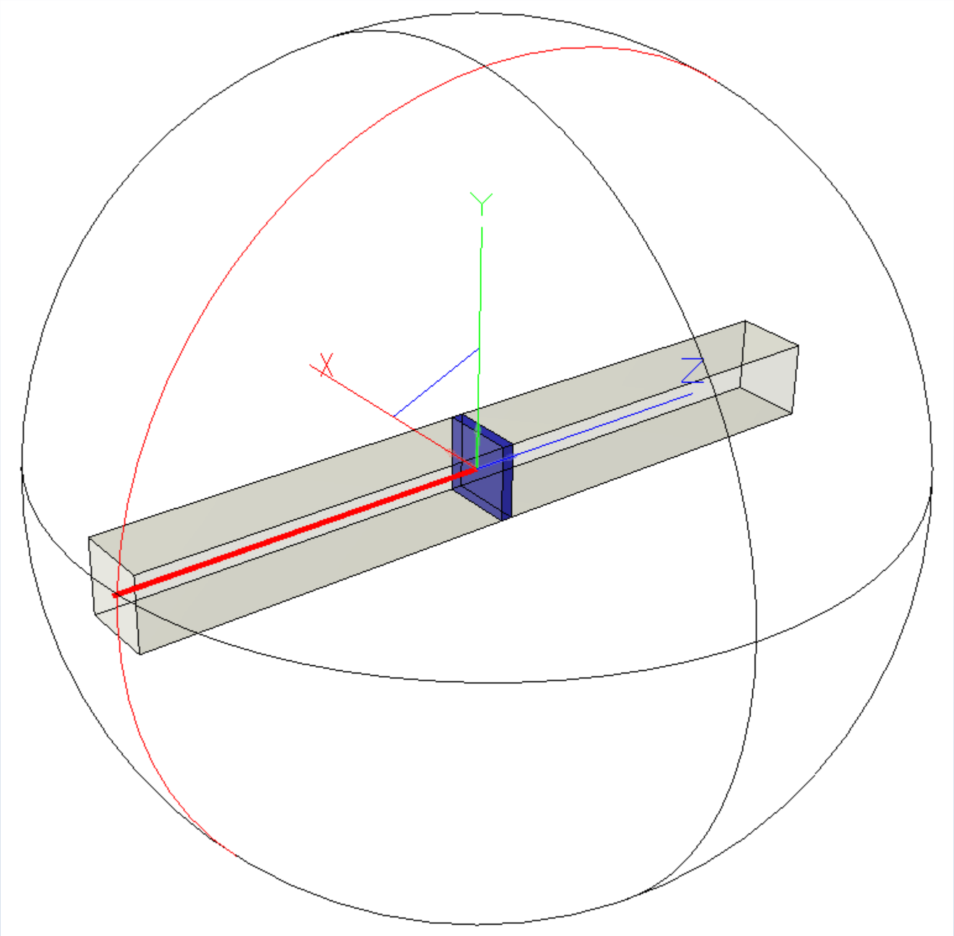
Uncertainties in ICOSIM

- Uncertainties:
  - Quench limit (not well known and depends on magnet type)
    - Studies ongoing in AT department
  - Uncertainty in the impact distribution on the collimator and assumed beam life time
  - Nuclear cross sections for ion interaction have large error bars
    - Obviously we cannot measure cross sections for primary ions at 2.76 A TeV without the LHC

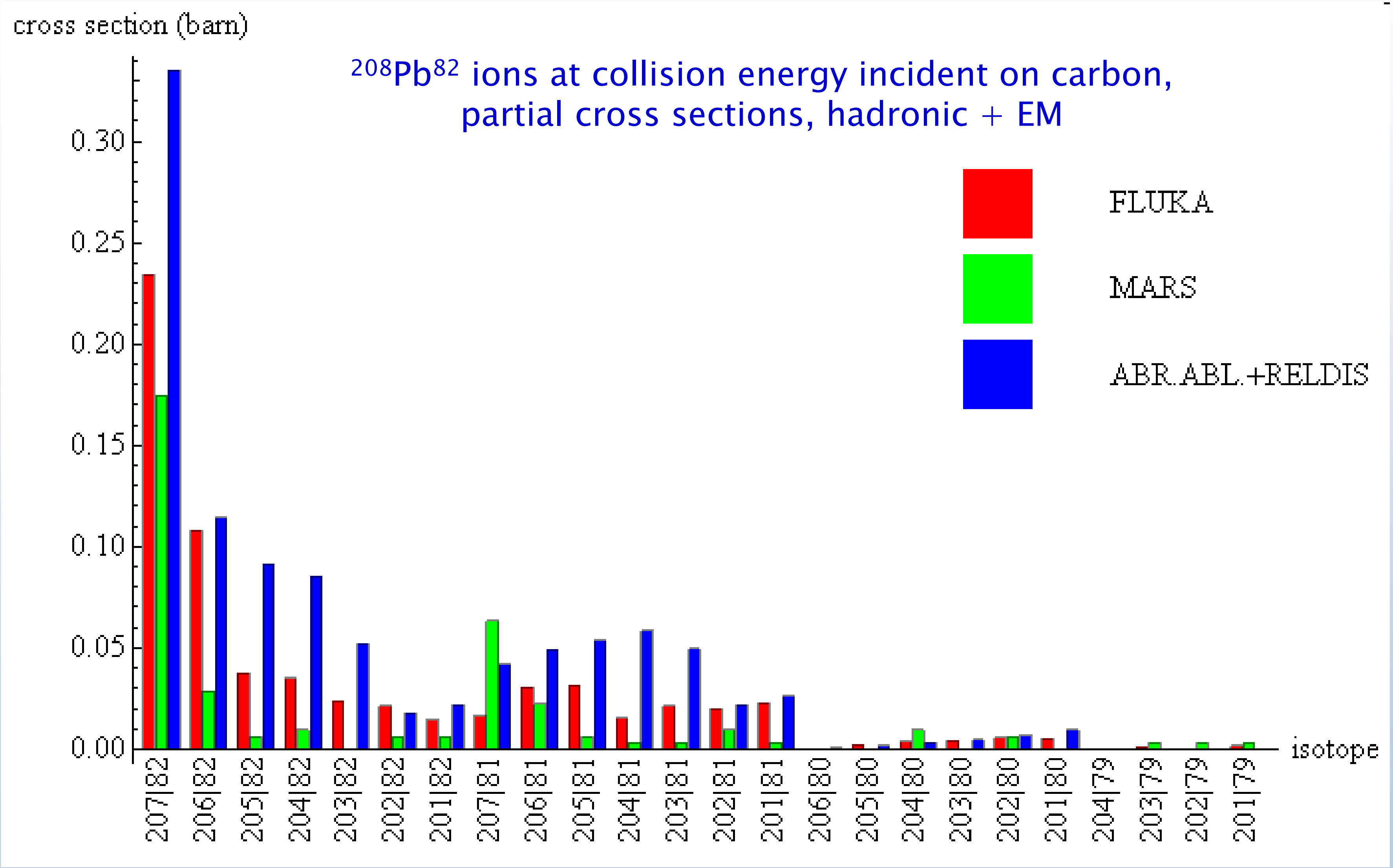
- New cross sections needed for several reasons:
  - Cross check of old results
  - Simulation of points on energy ramp
  - Simulation with new materials
  - Existing code based on RELDIS & ABRATION/ABLATION routines not straight-forward to use

New calculations of cross sections

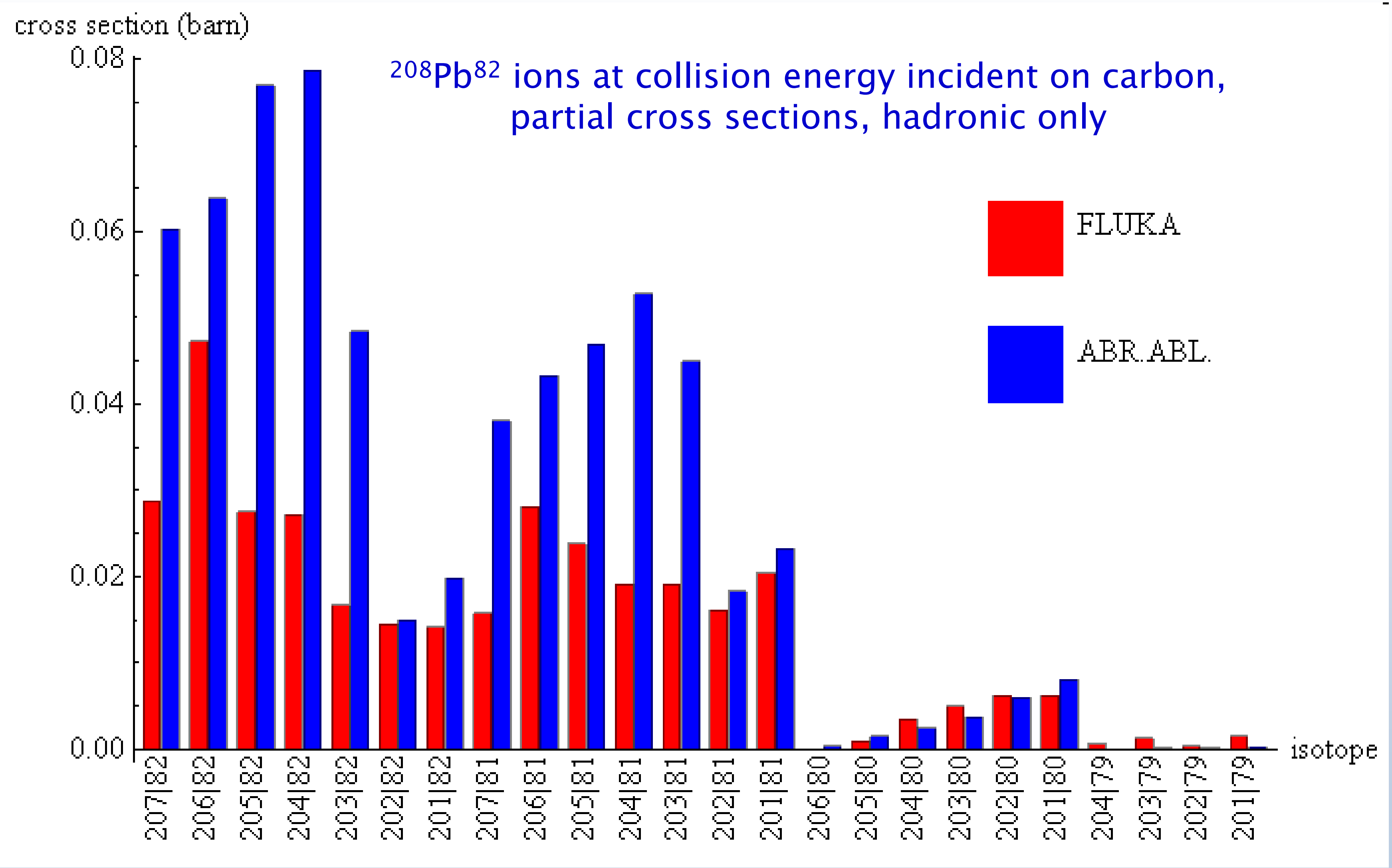
- FLUKA and MARS used to simulate thin target experiment
- Ion beam hitting target
- Counting number of fragments allows us to calculate total and partial cross sections
- Electromagnetic dissociation on or off
- If target is thin enough, reinteraction is not an issue
- Allows us to easily and quickly calculate cross sections for any fragment on any target in an automated framework



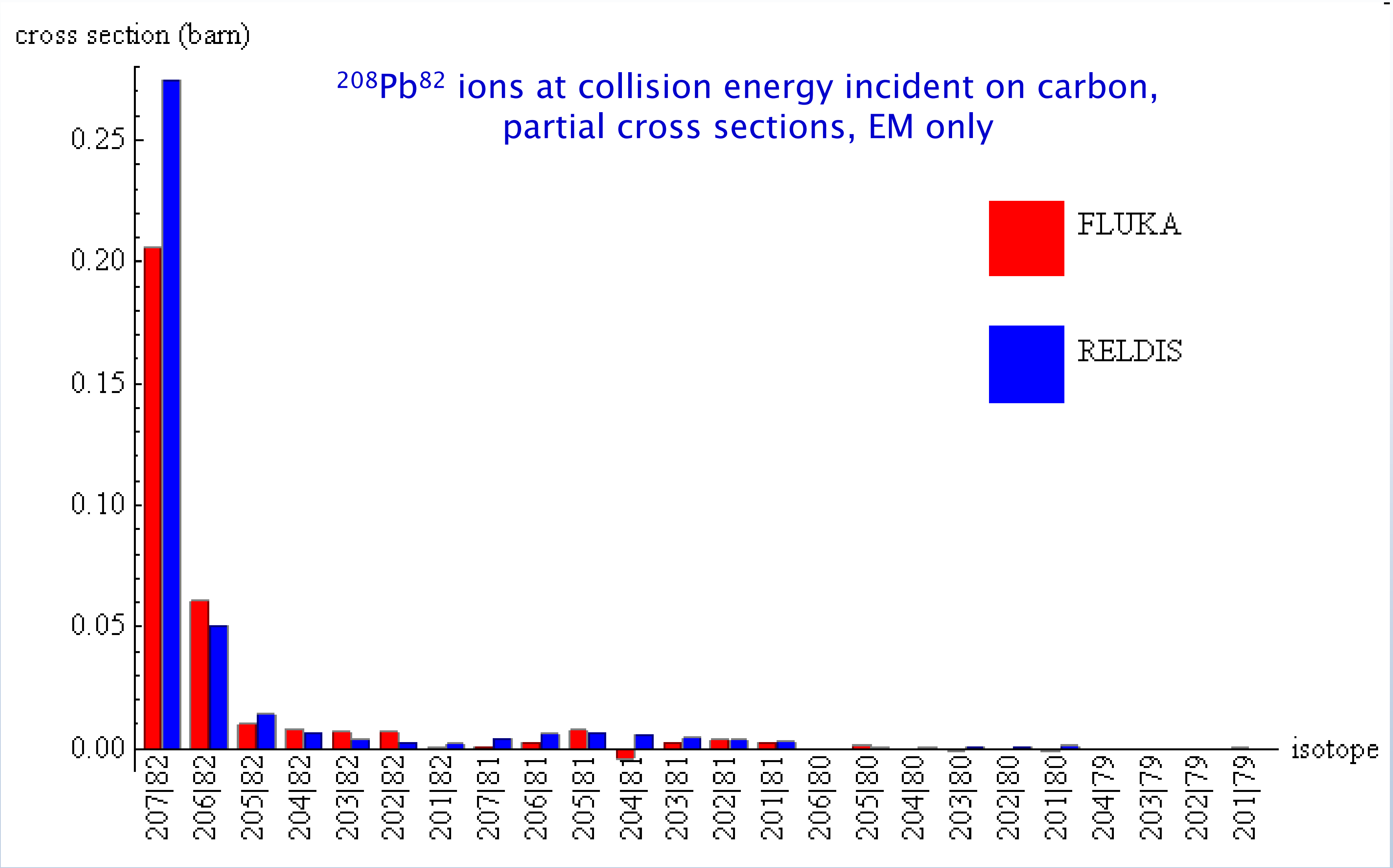
Preliminary results, collision



Preliminary results collision

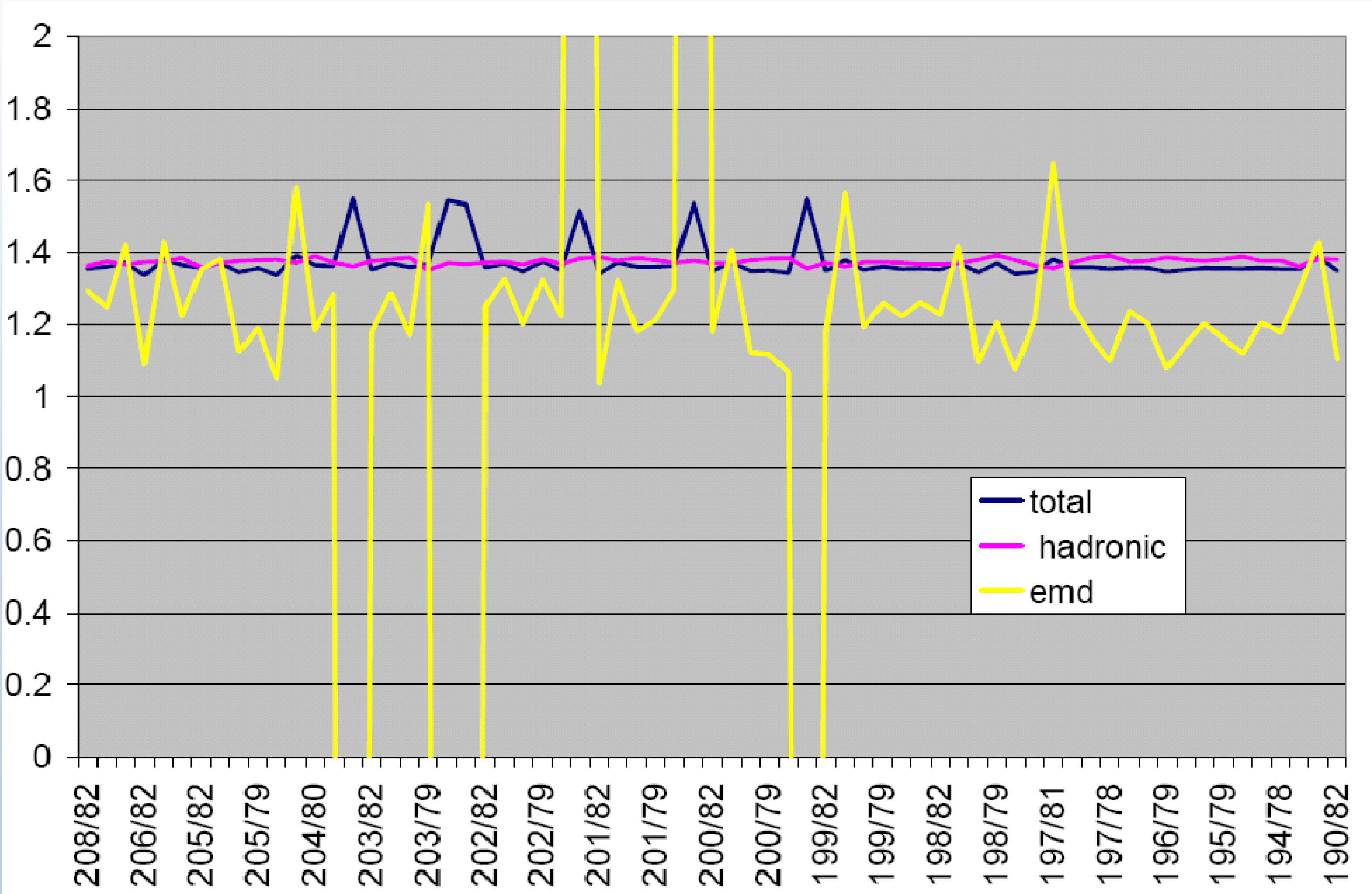


Preliminary results collision



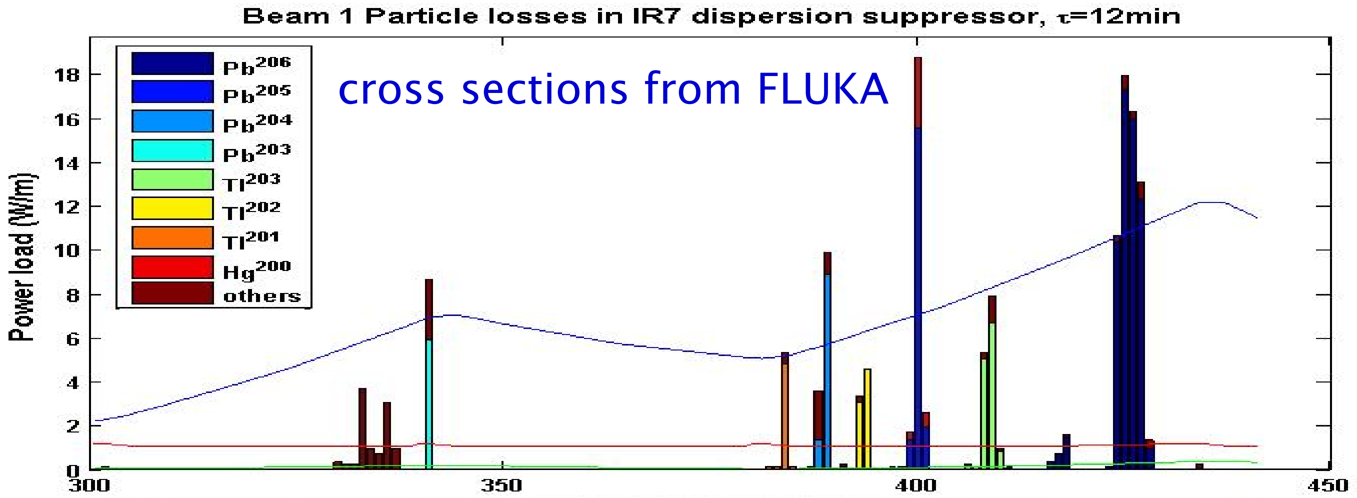
Preliminary results collision

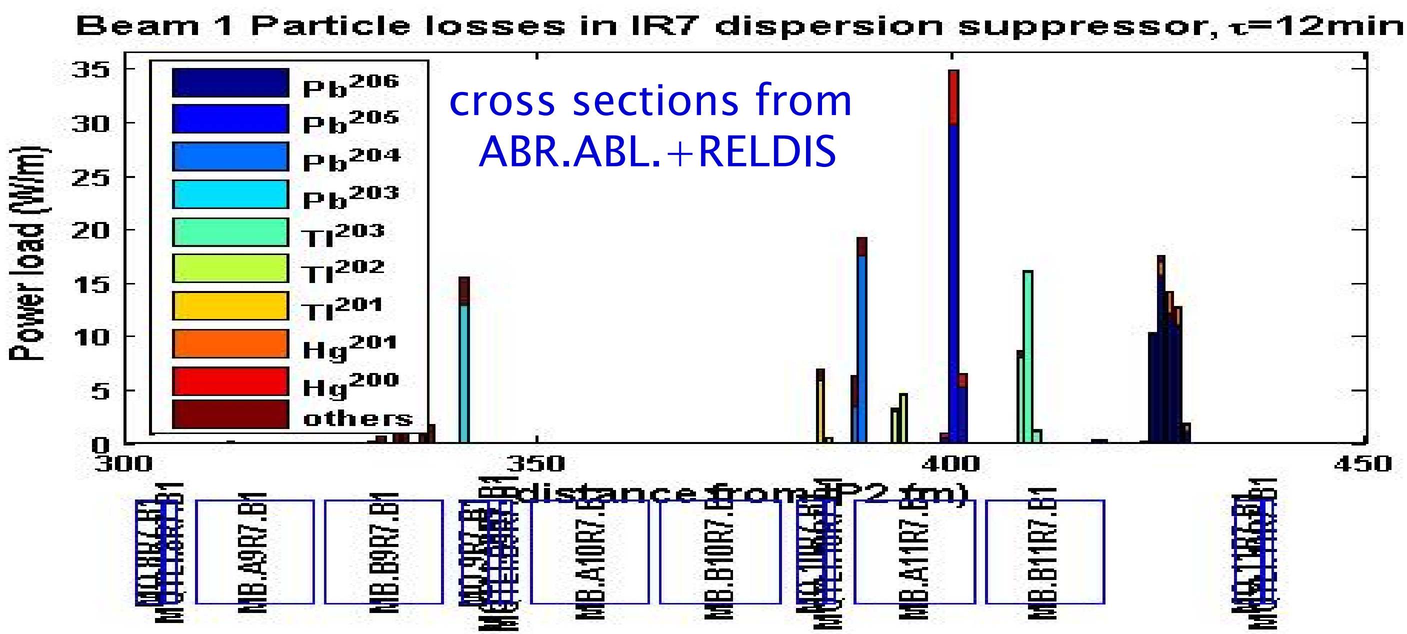
Total cross section for fragments at collision energy incident on C:
Ratio (ABR.ABL+RELDIS)/FLUKA



(G. Bellodi)

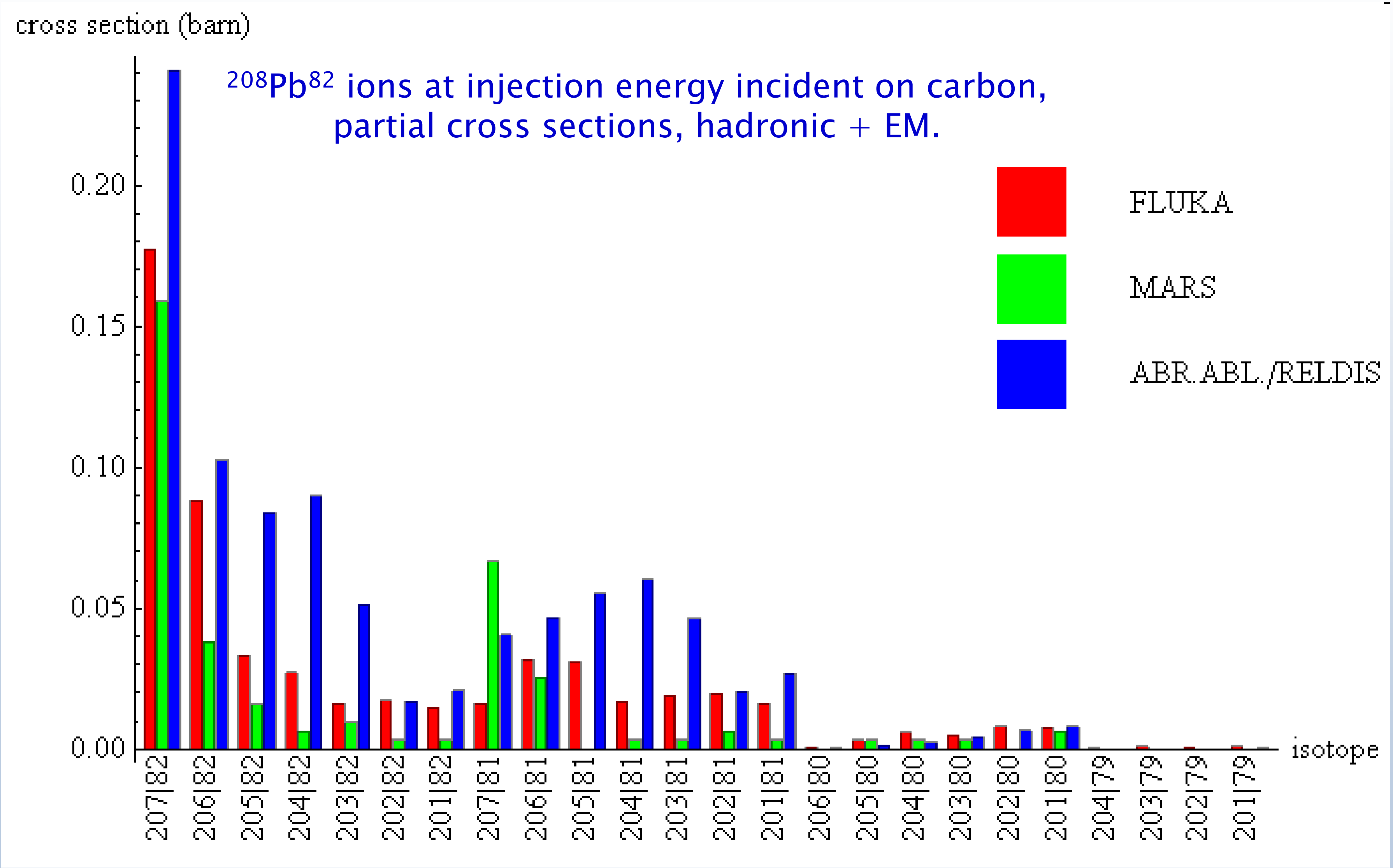
Preliminary results collision



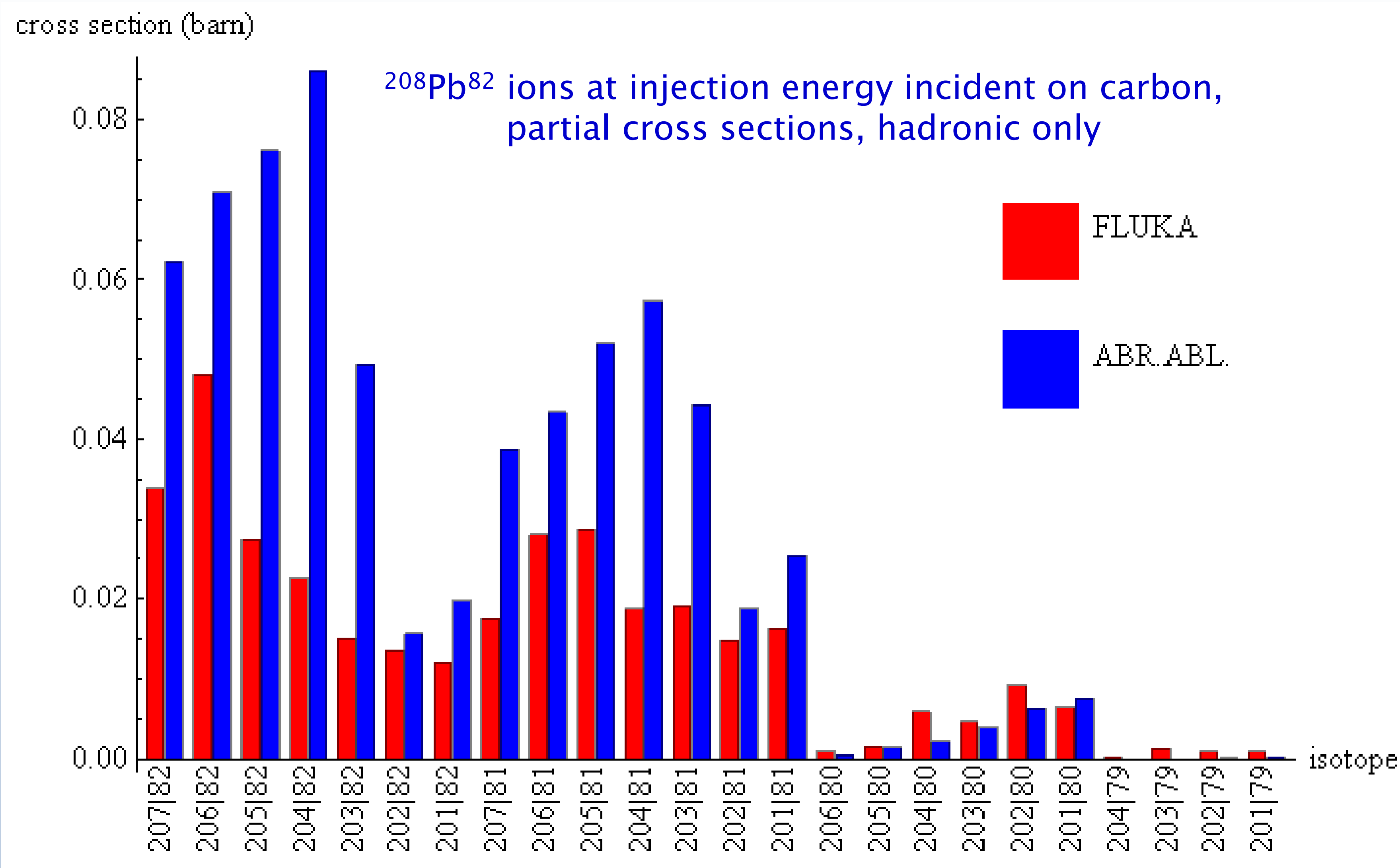


(G. Bellodi)

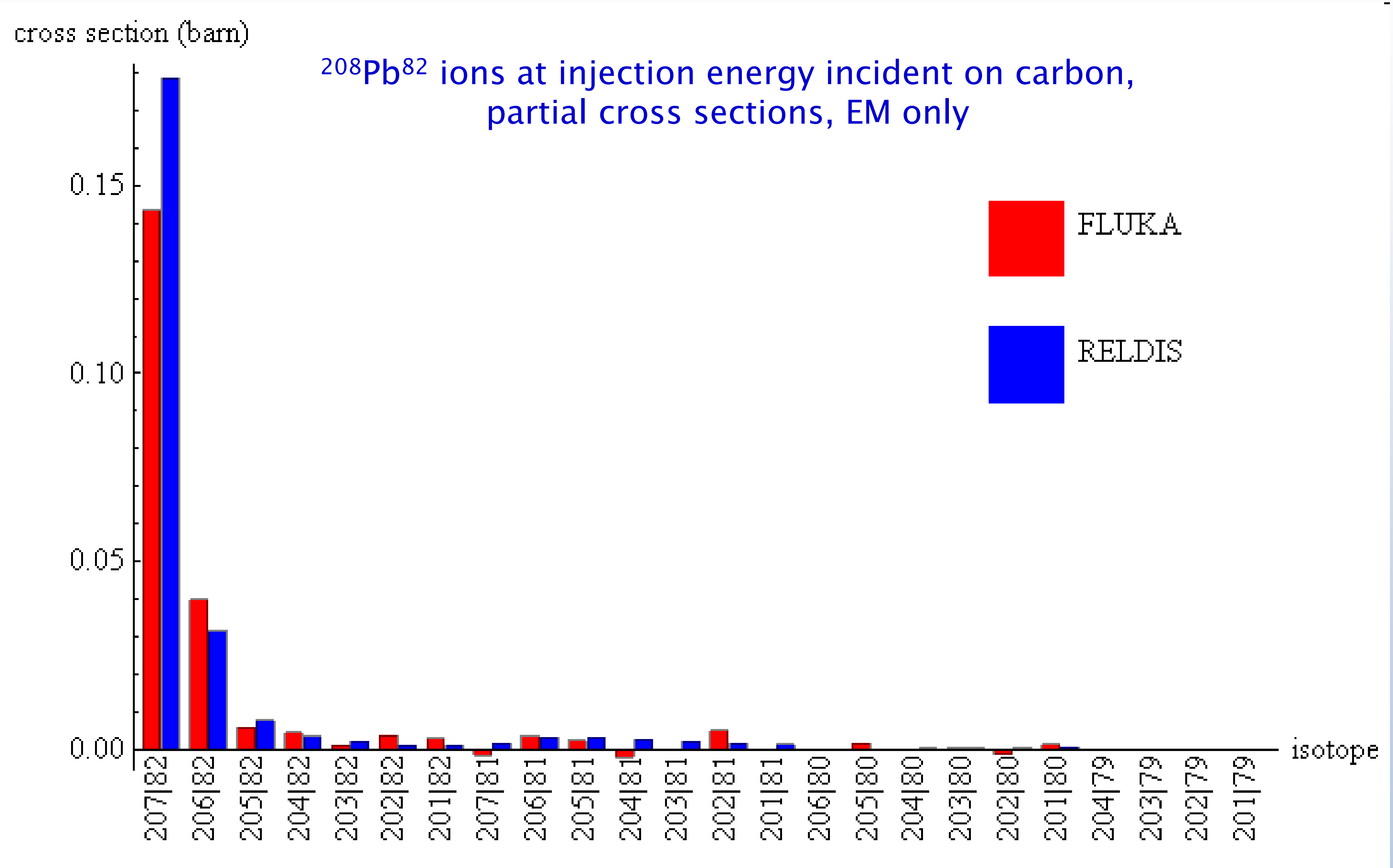
Preliminary results, injection



Preliminary results, injection



Preliminary results, injection



Conclusions

- Old RELDIS & ABRATION/ABLATION routines give consistently higher cross sections than FLUKA, which in turn is higher than MARS
- Often a factor 2 difference
- Comparison of different simulations can be used to estimate a part of the error on the ICOSIM results
- Electromagnetic partial cross sections agree within 30%
- Difference mainly due to the hadronic part, which is highly model dependent and not well known
- Using the new cross sections from FLUKA, the expected heating from lost fragments exiting the collimation region goes down correspondingly
- Further studies needed to better understand model-dependent discrepancies