Status report from MuScat

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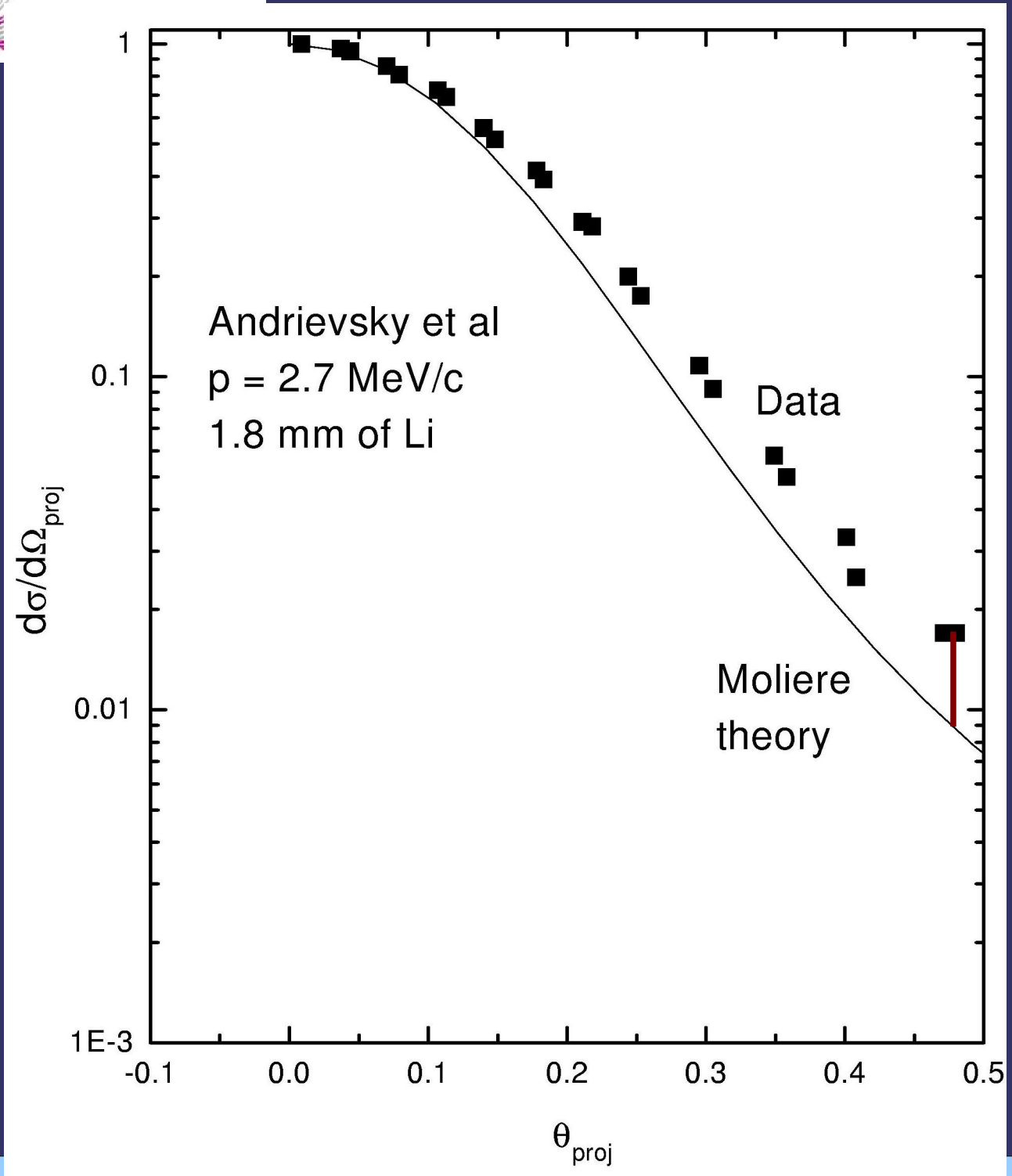
- **Motivation**
- **Description**
- **Data taking**
- **Results**

The History

- MuScat to check multiple scattering of Muons at ~100MeV/c
  - Low Z materials for Ionisation cooling
  - Key is liquid Hydrogen
- Engineering run, Triumf 2000
- Physics run, Spring 2003
  - Fibre tracker
- Final results still not available.



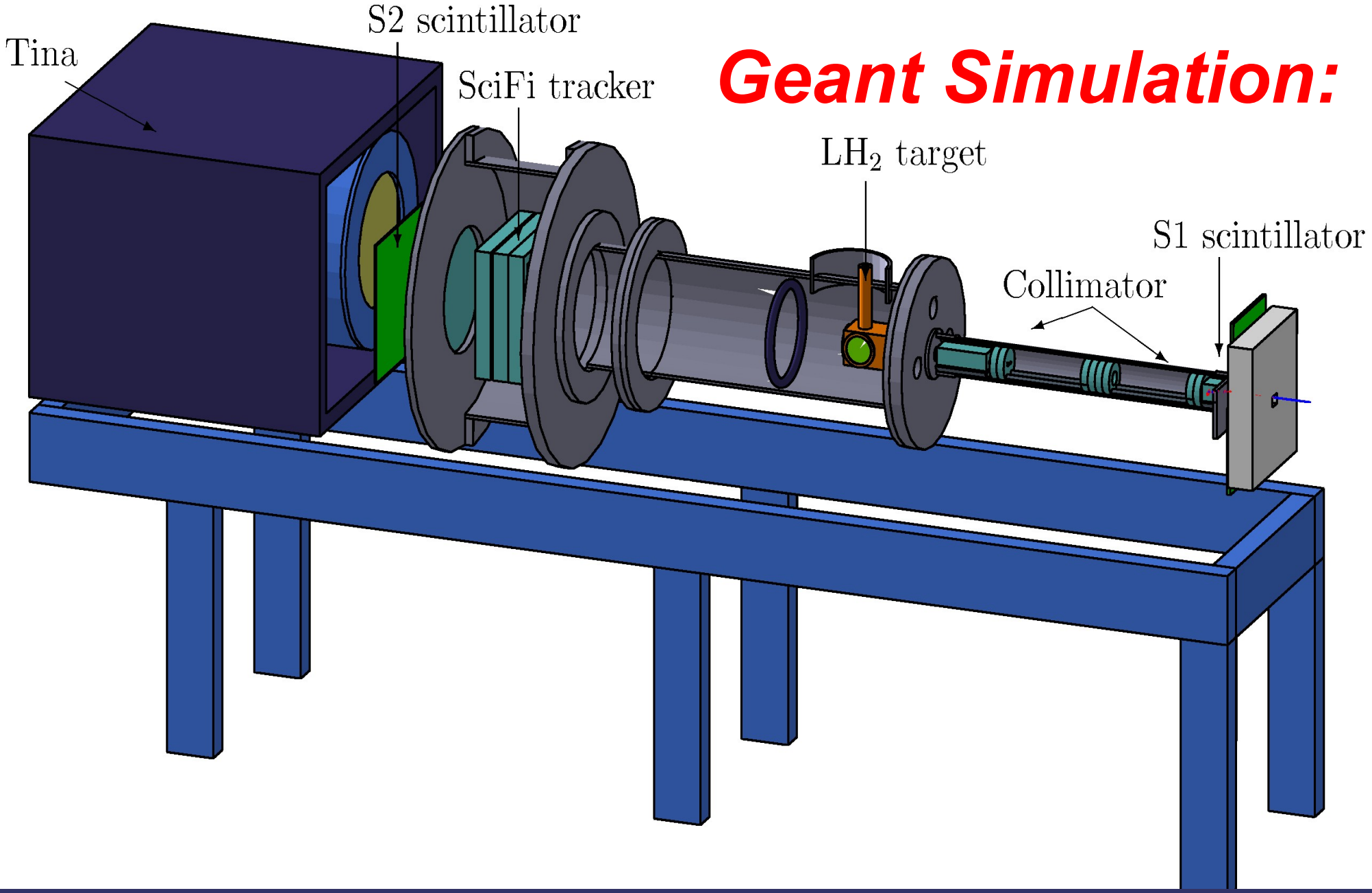
Why check Multiple Scattering?

Ionization cooling is an interaction between cooling and heating

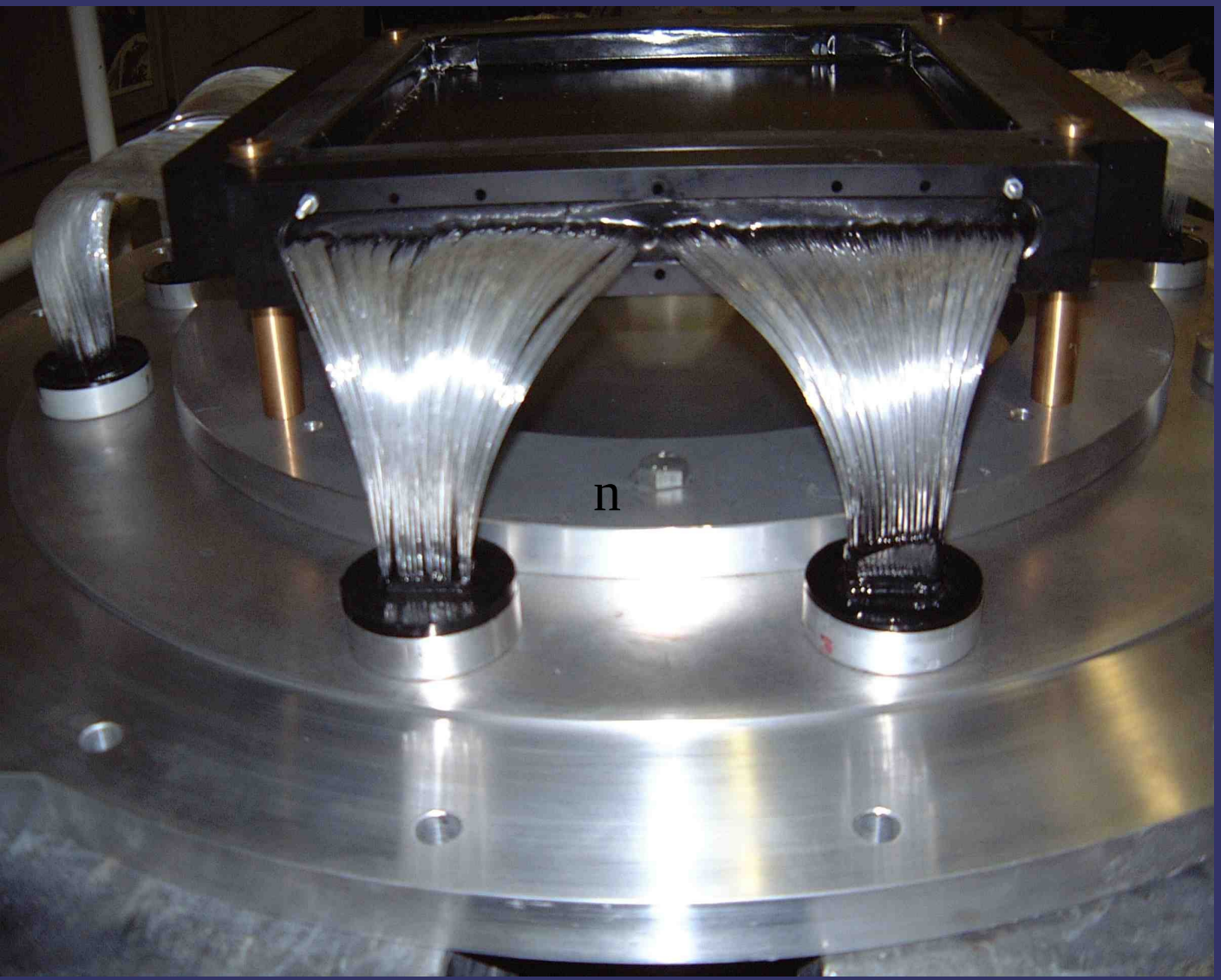
No published data on muon scattering at relevant energies

Electron data from 1942 are the most relevant..

Geant Simulation:



The SciFi tracker

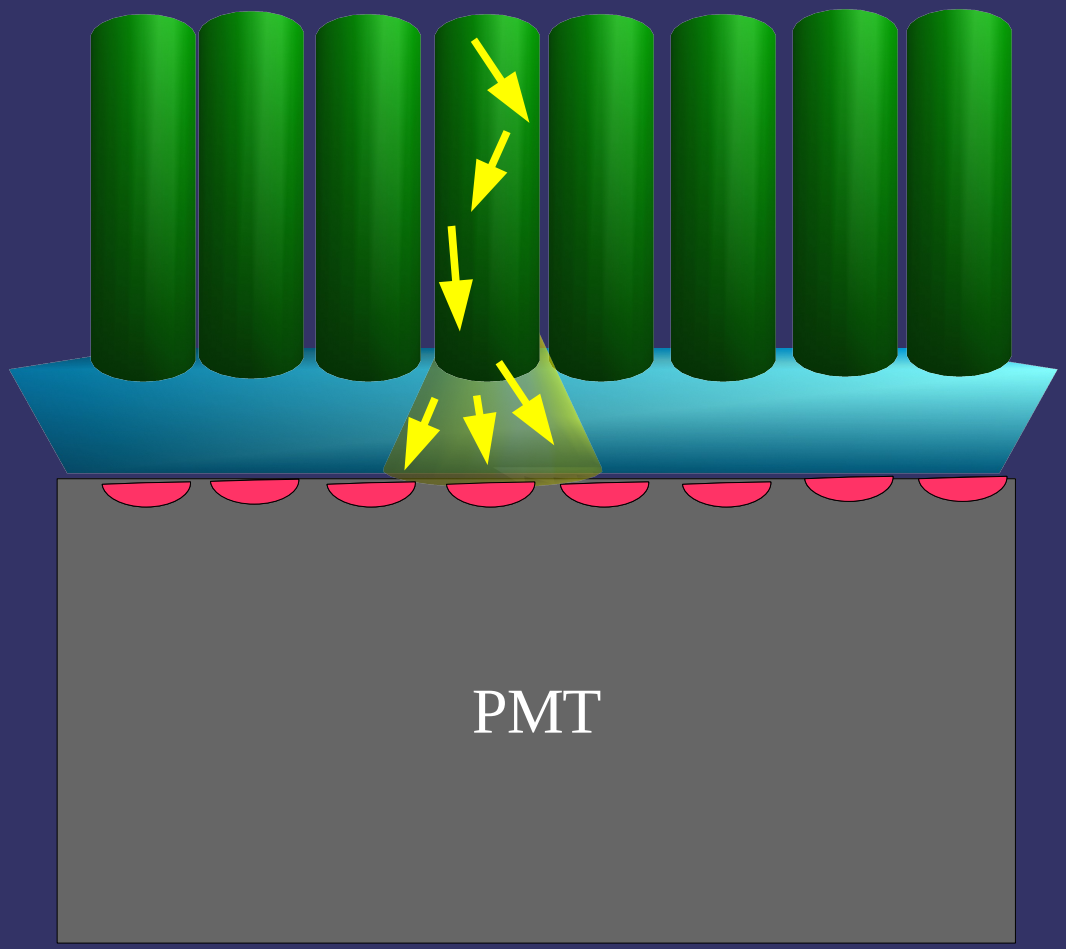


- 3 double planes
- Each 512 fibres, x and y
- 3096 fibres
- 30cm by 30cm
- Black resin to reduce light leakage
- 512 scintillating fibres grouped as 256x2
- 24 bundles

The Fibre to PMT mating

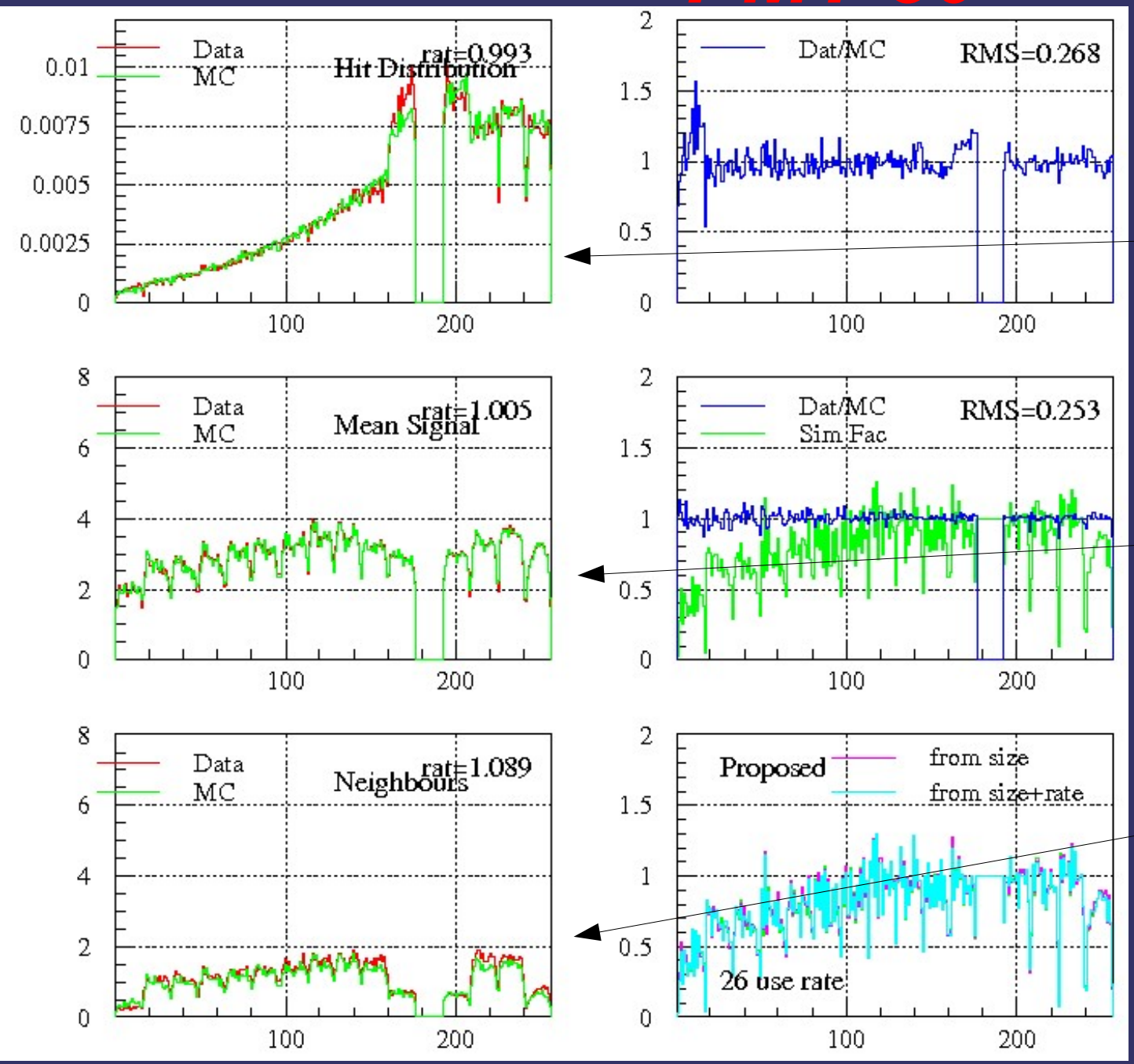
- Each in 16mm^2 grid
- Feeding 256 fibres to 16 anode HPK PMT
- Anodes 16mm by 1mm
- Hard to keep round fibres in square grid
  - ~50% success
- Readout at both SciFi ends gives fibre mapping.

Bundle – PMT mating



- Fibre 1mm diameter
- Anode spaced 1mm
- But..1.5mm of glass separating
- Cone angle 29° in glass
  - Up to 0.8mm trans-verse movement
  - 35% of light on neigh-bours

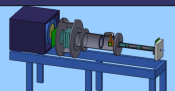
PMT 30



- Hit distribution
  - This PMT has 1 dead anode. No other does
- Mean signal size
  - Forced in simulation
- Mean signal on neighbours
  - not fixed

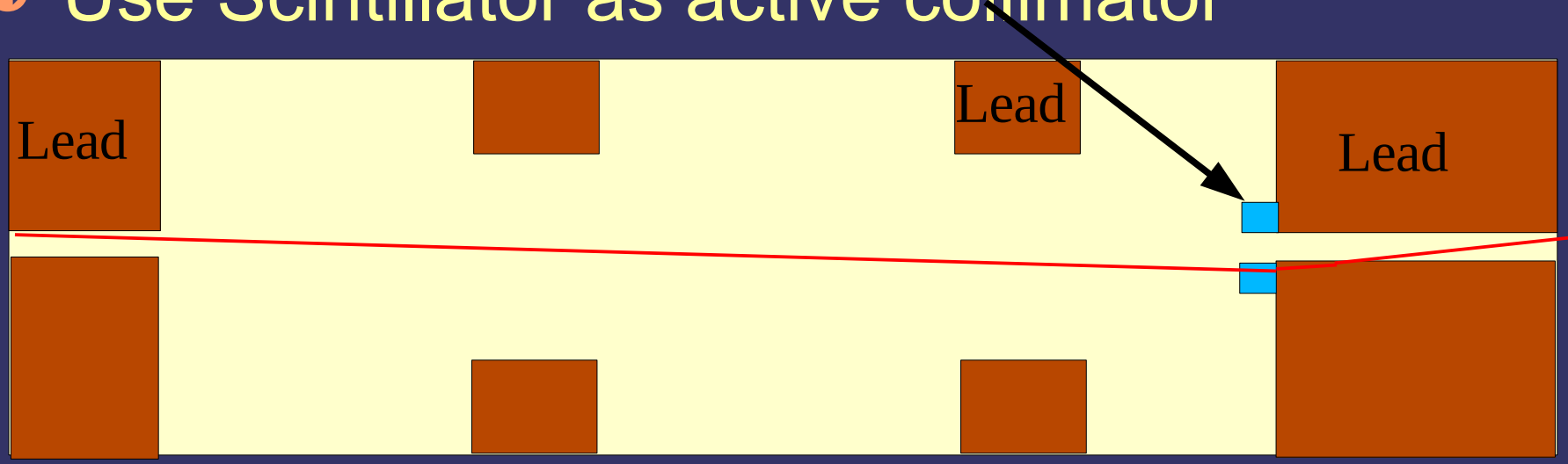
Sci Fi Summary

- Detector was a lot of work to build
  - **Stable** for the run
- Number of P.E. marginal, but OK
- Some cross-talk between channels
  - Quite well understood
- It works

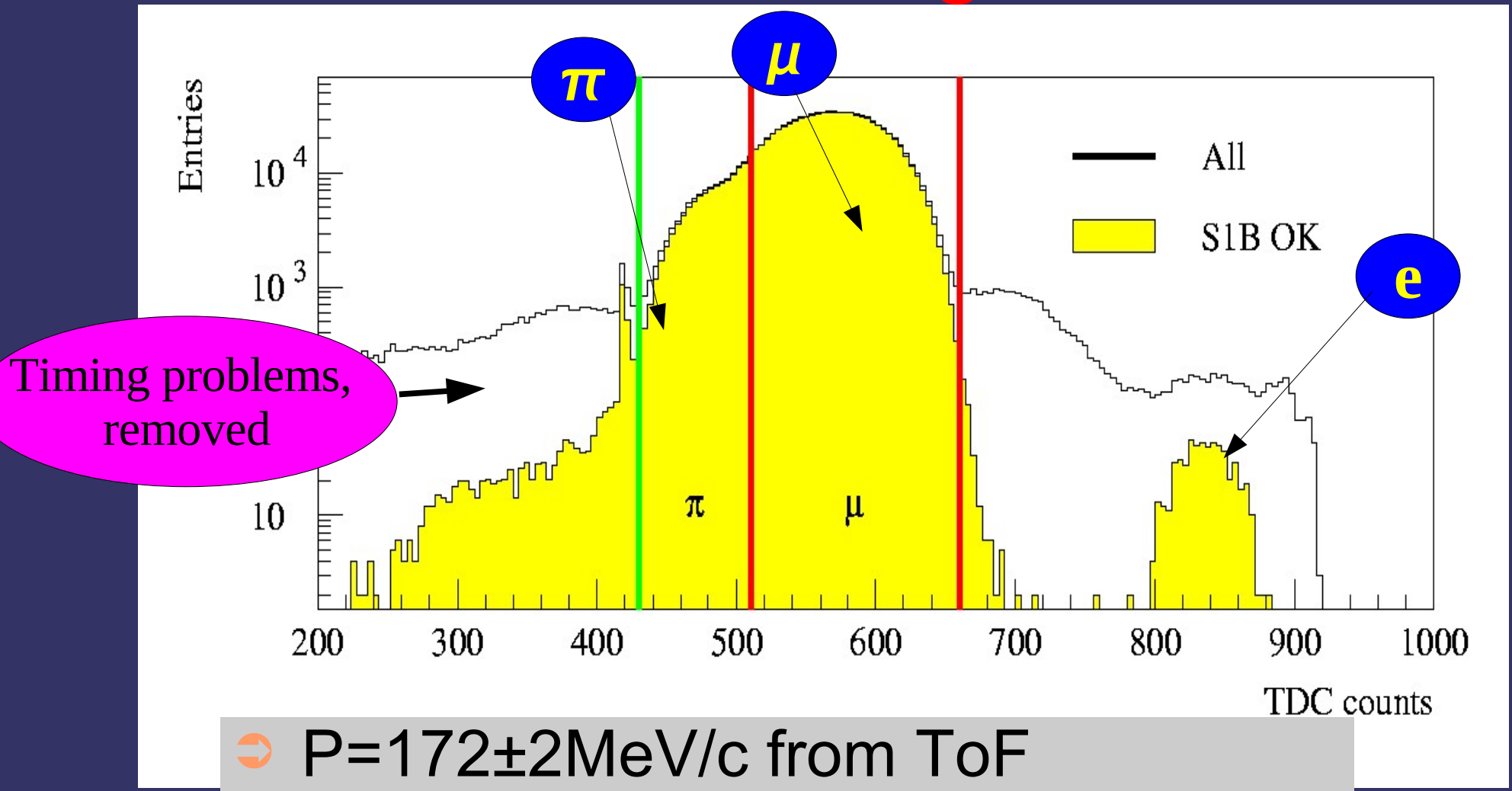


Collimator system

- Obtain clean beam by collimation
  - 80mm lead upstream, 160 mm downstream
  - Slits 2mm by 20mm approx.
  - 1m long
- Use Scintillator as active collimator



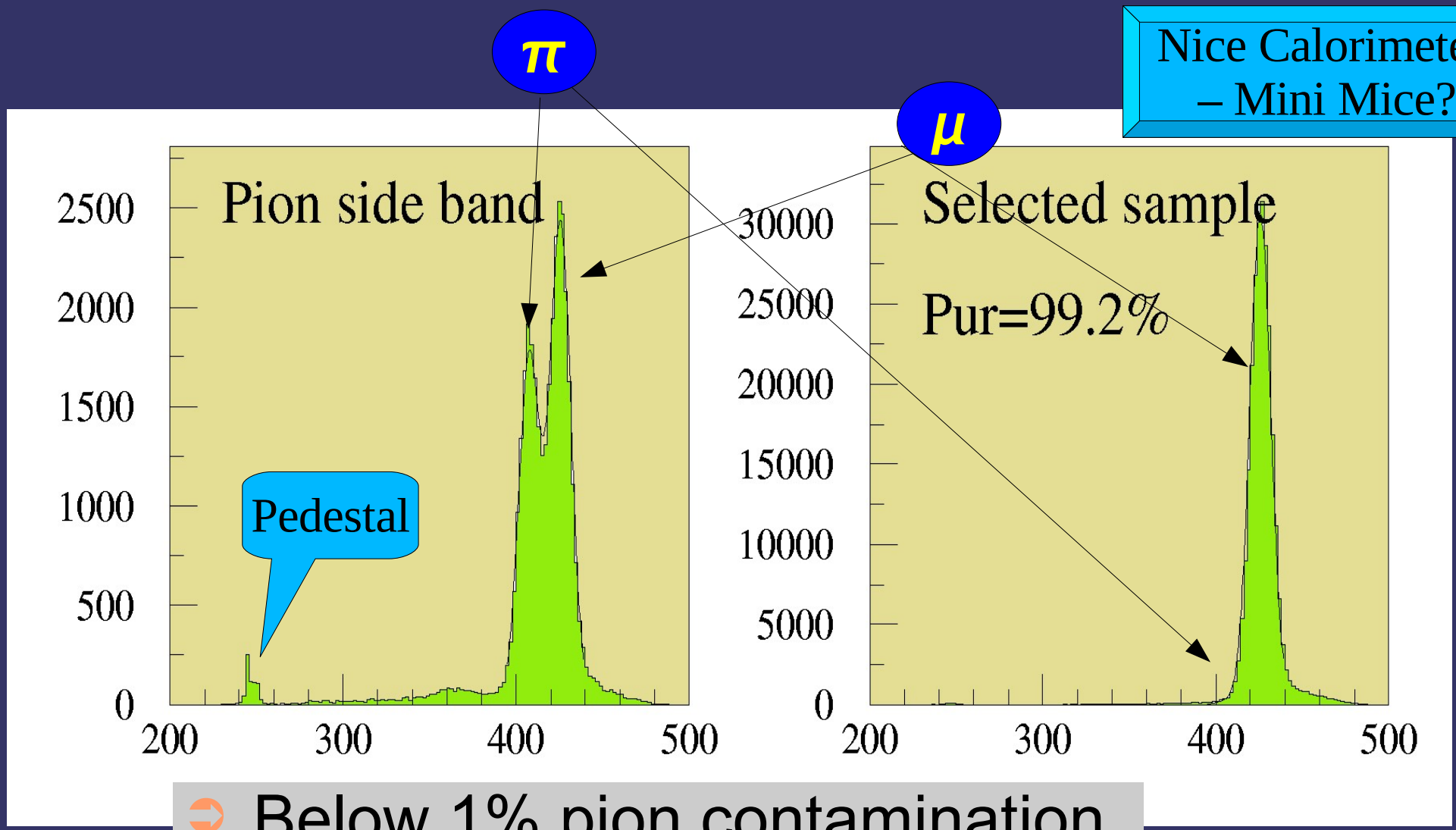
Time of flight



- P=172±2MeV/c from ToF
- Pions only shoulder on muon beam

Contamination from Tina

Nice Calorimeter – Mini Mice?



- Below 1% pion contamination
- Allowed for in analysis

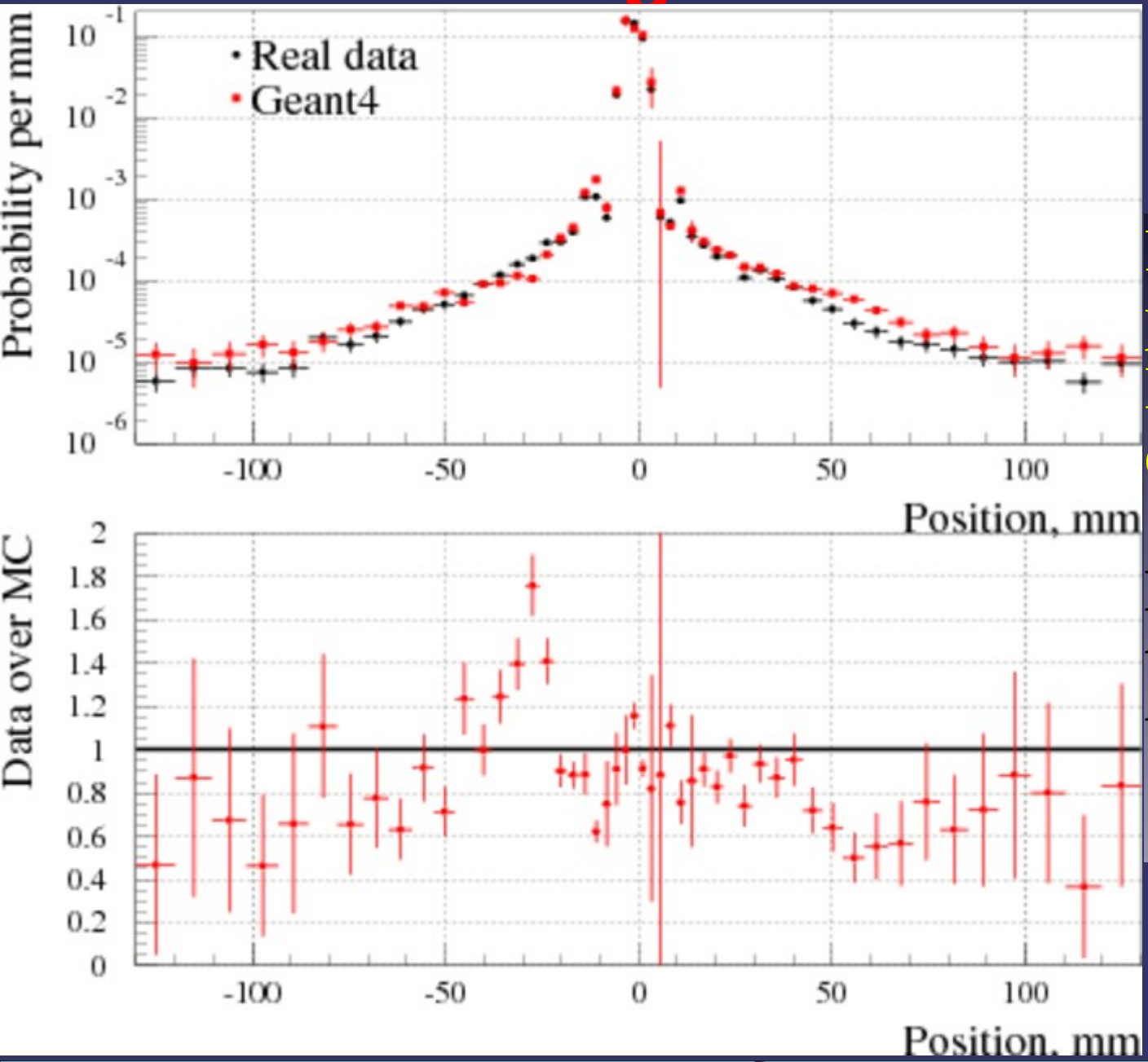
Targets

Millions of events were collected with each of the following targets.

Pink targets are shown now

Target	Thickness, mm	X0, %	Events, Millions
Lithium 2	12.78	0.82	2.0
Lithium 1	6.43	0.41	3.0
Lithium 1	6.4	0.41	2.1
Lithium 2	12.72	0.81	3.0
Beryllium	0.98	0.28	3.4
Beryllium	3.73	1.06	3.8
Polyethylene	4.74	0.99	2.0
Carbon	2.5	1.53	2.0
Aluminium	1.5	1.69	3.0
None			6.0
Iron	0.24	1.36	2.2
Iron	5.05	28.68	3.4
Long, empty	150		4.8
Long, full	150	1.53	5.2
short, empty	100		9.5
short, full	100	1.02	6.0

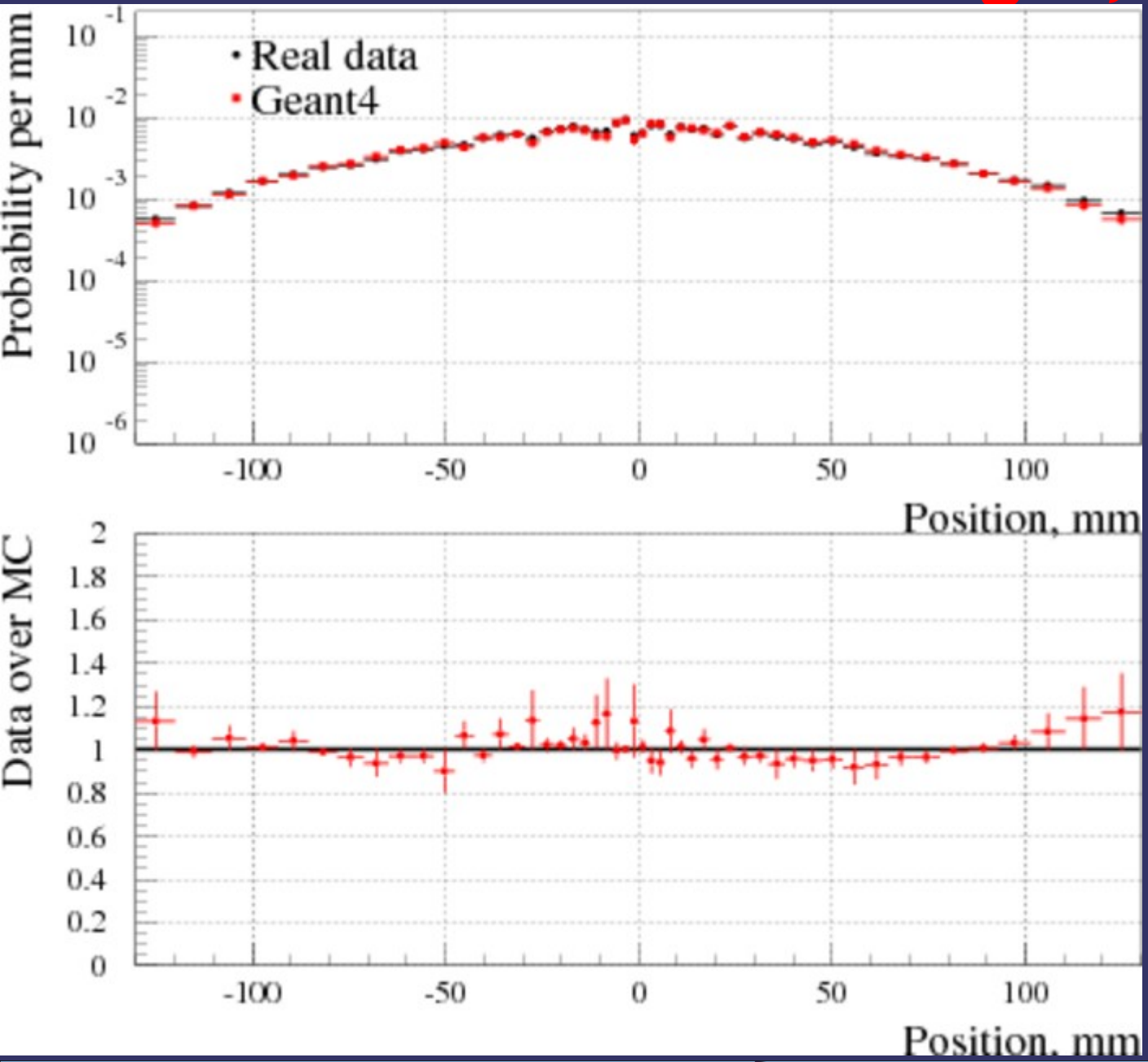
No target: check collimator



Position of hit on 1st plane
Matching hit (±6mm) on plane 2

Deviations visible – these are taken into the systematics.

Thick steel target, 28% X0

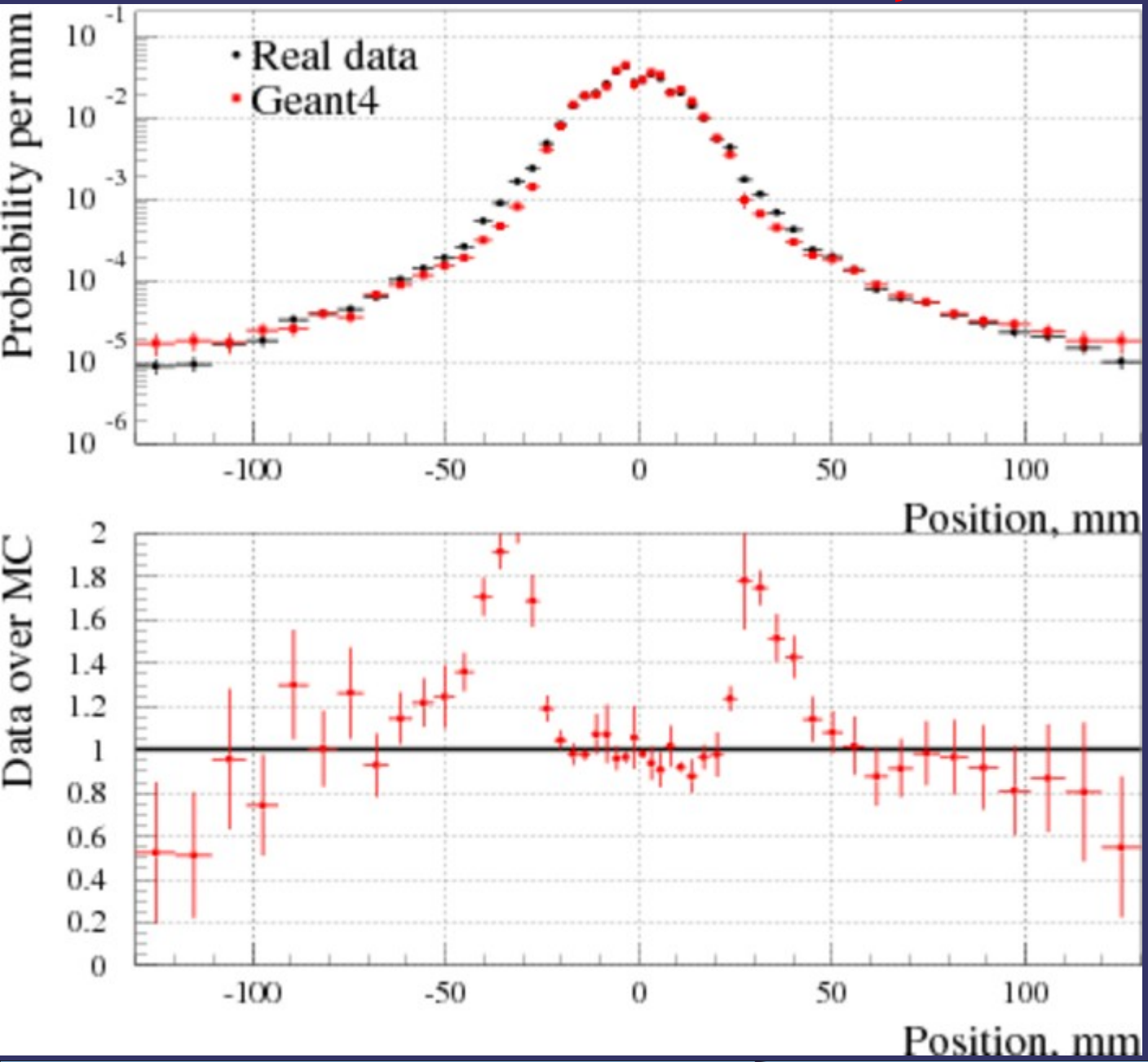


Geant 4.6.1 description good

Used to study detector response:

Differences assigned to efficiency systematic

Thin Steel, 1.36%X0

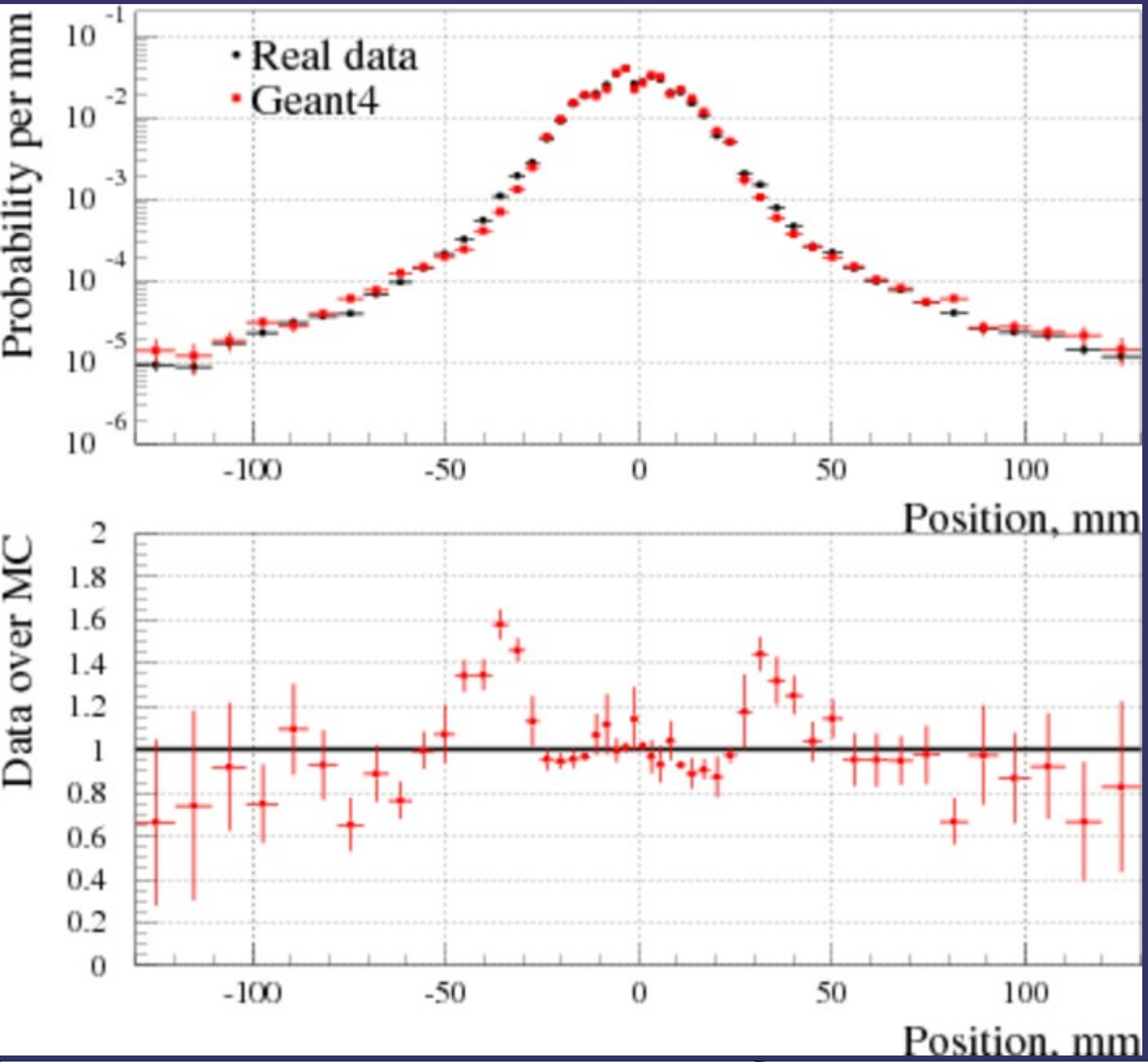


Good in core

Geant deficit from 25 to 50mm

Problem dwarfs collimator mis-modelling

Aluminium, 1.69% X0

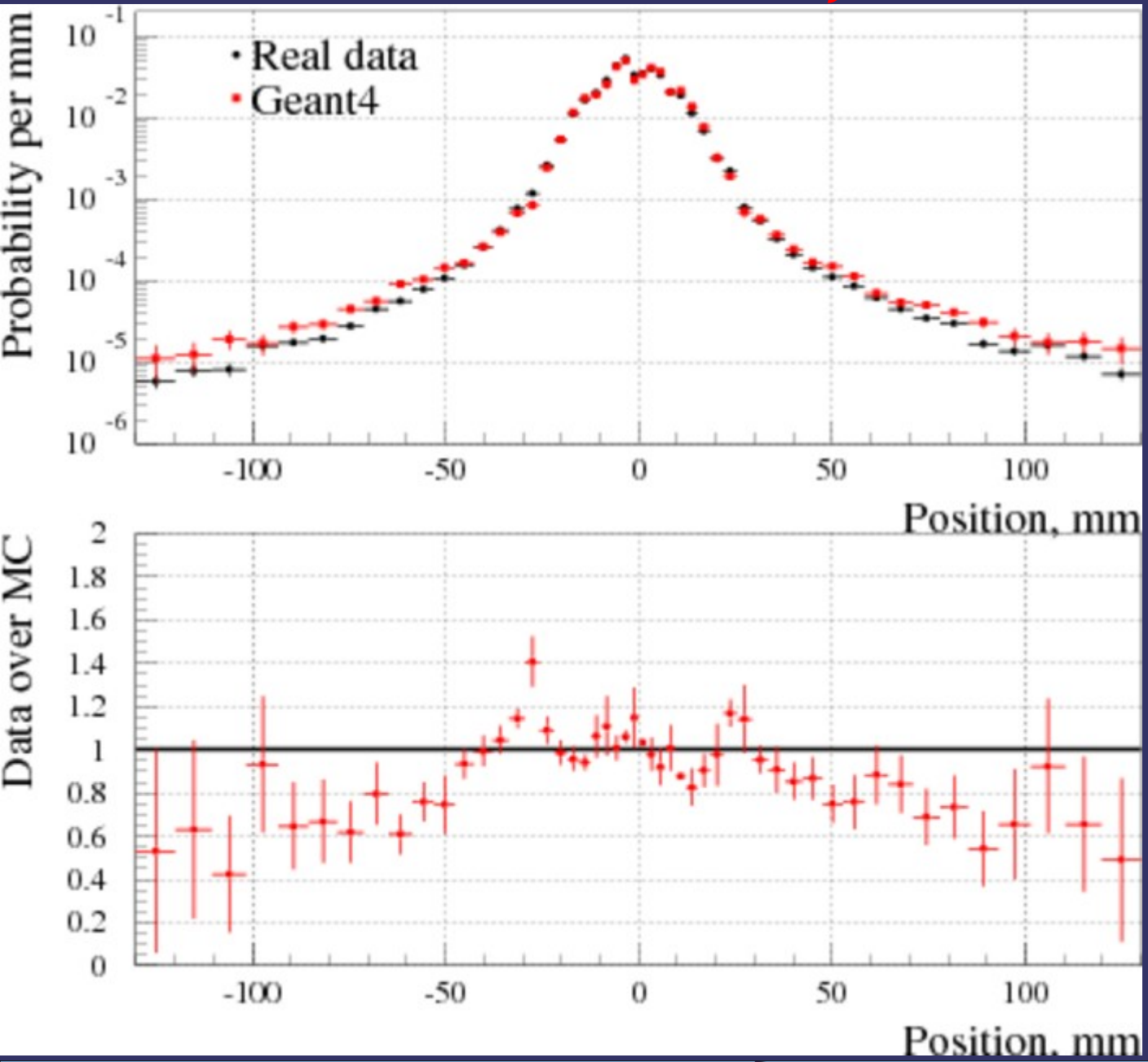


Generally Good

Difference around 30mm

Less pronounced than steel

Carbon, 1.53% X0

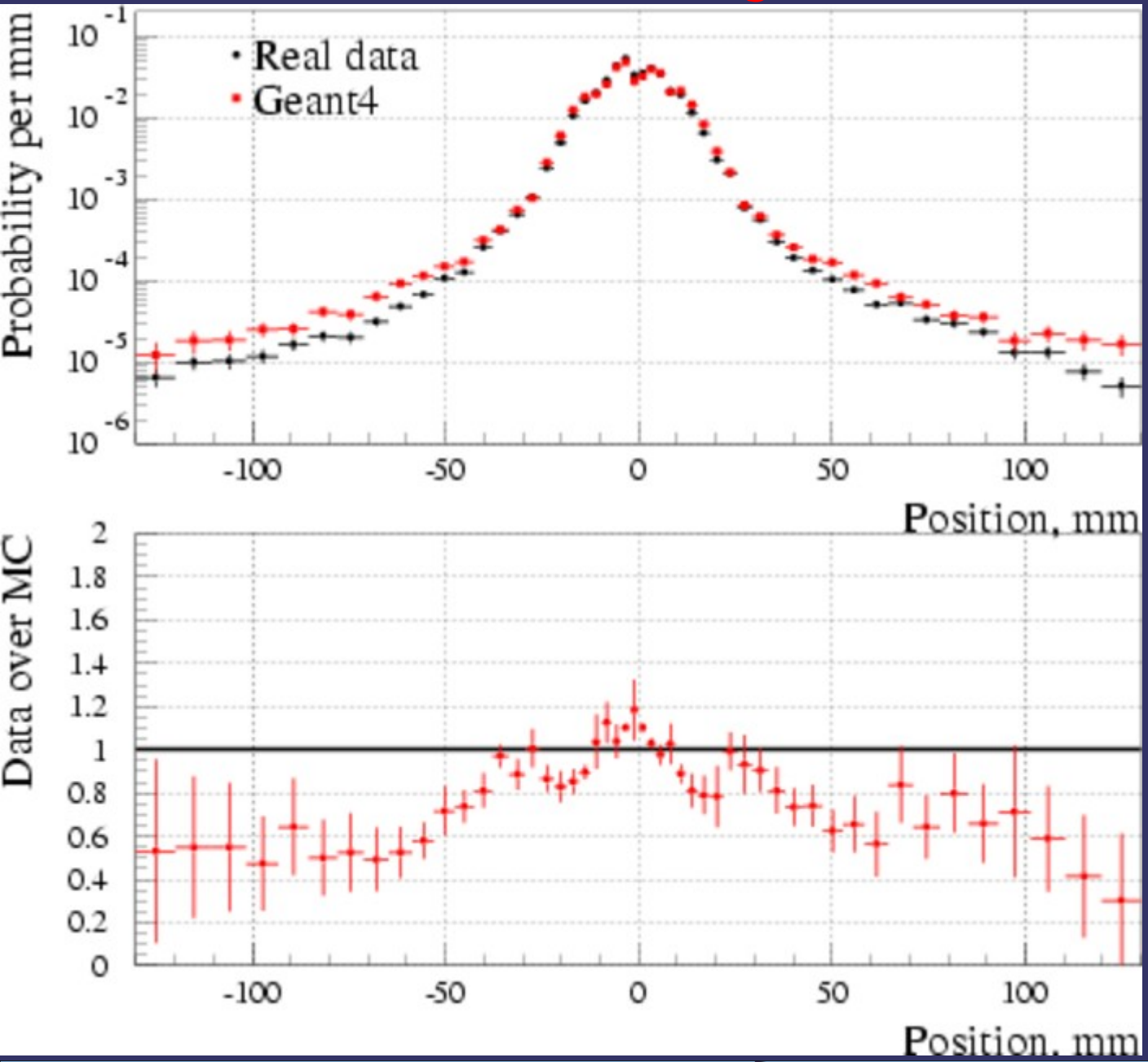


Good in core

Hint of ears at ±30mm

Tail lower in data?

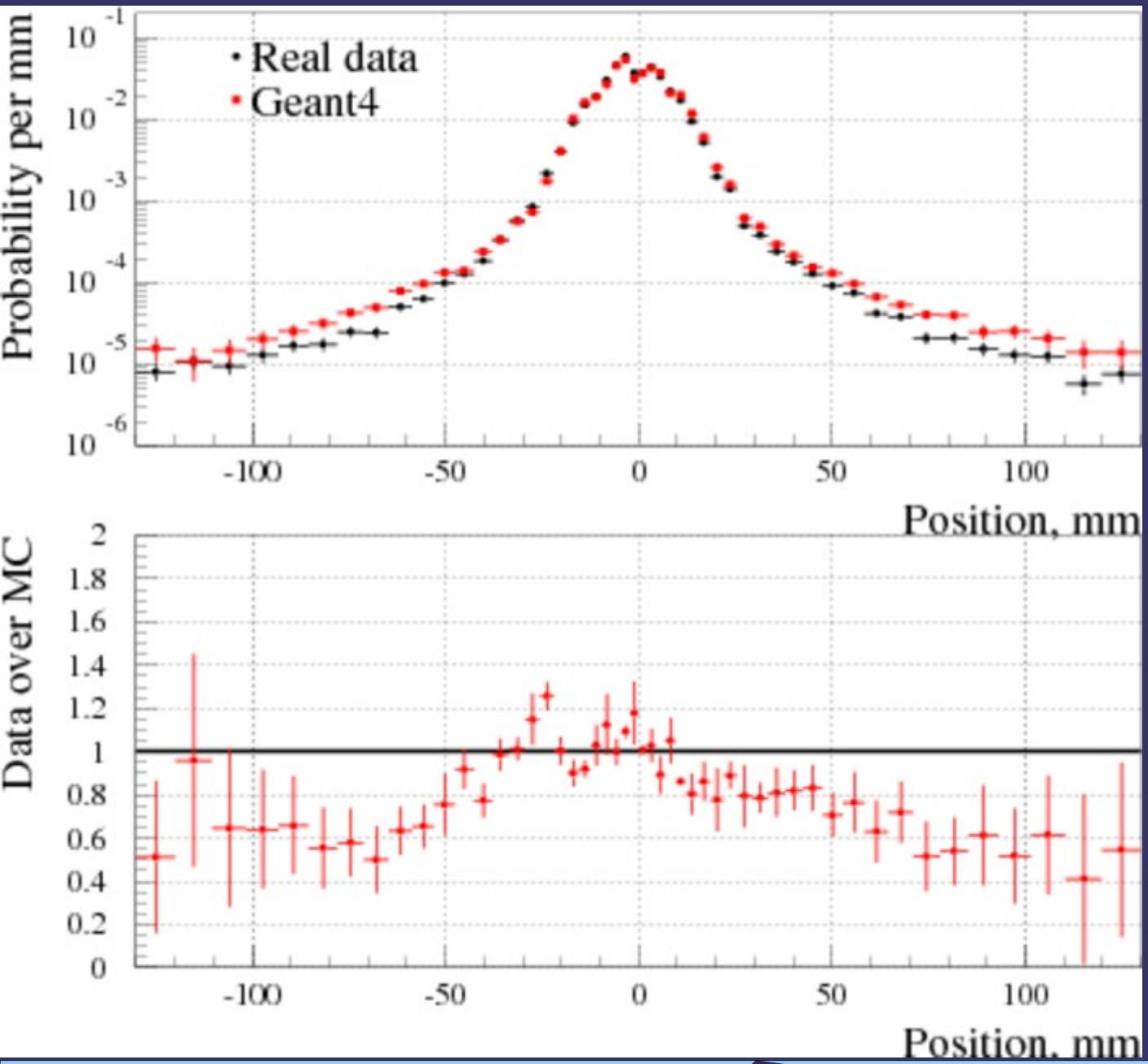
Thick Beryllium, 1.06% X0



Satisfactory agreement, signs of the ears remain

Tails are 40% below G4.6.1

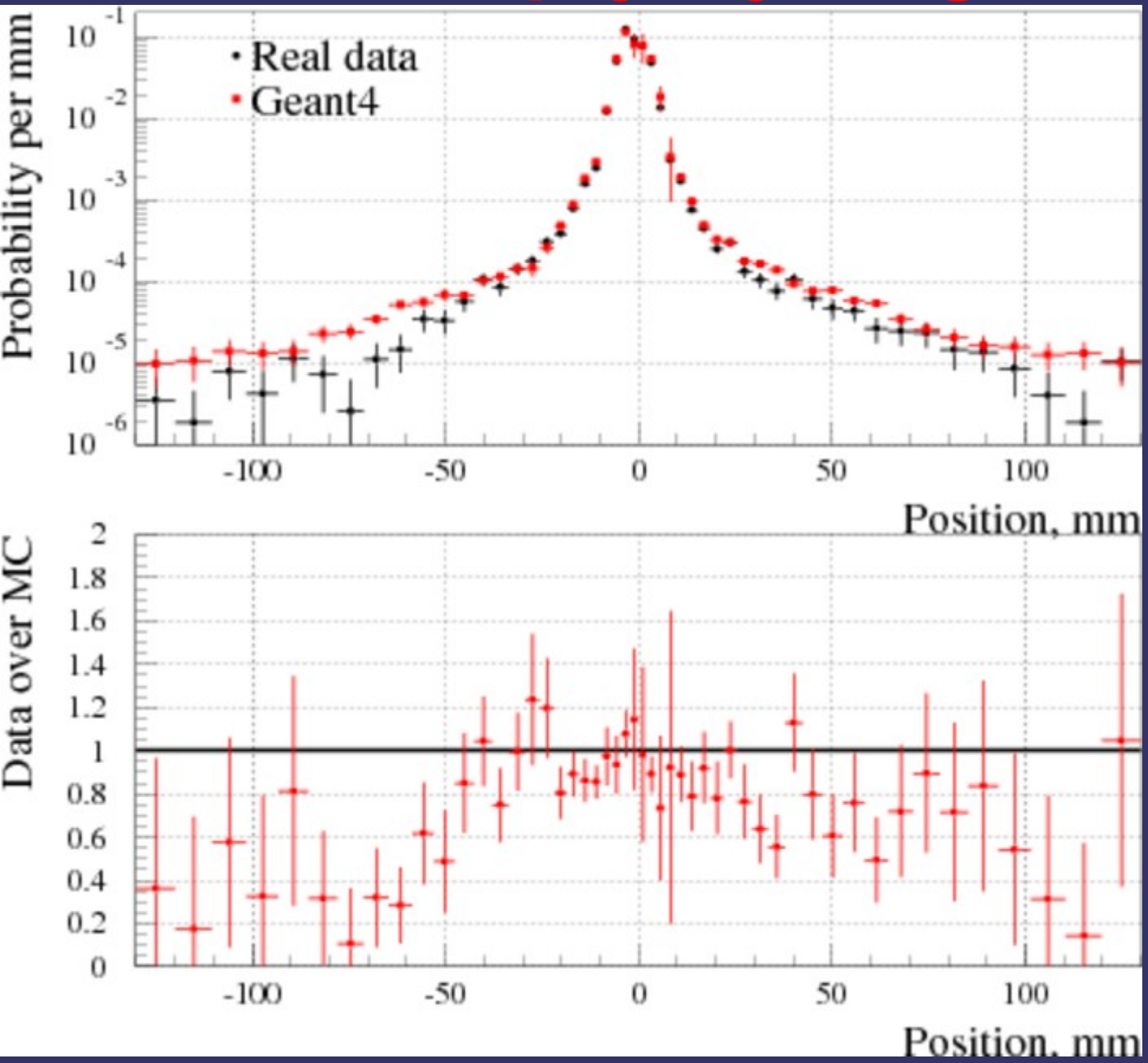
Thick Lithium, 0.81% X0



Tails lower in data

Very similar to the Beryllium

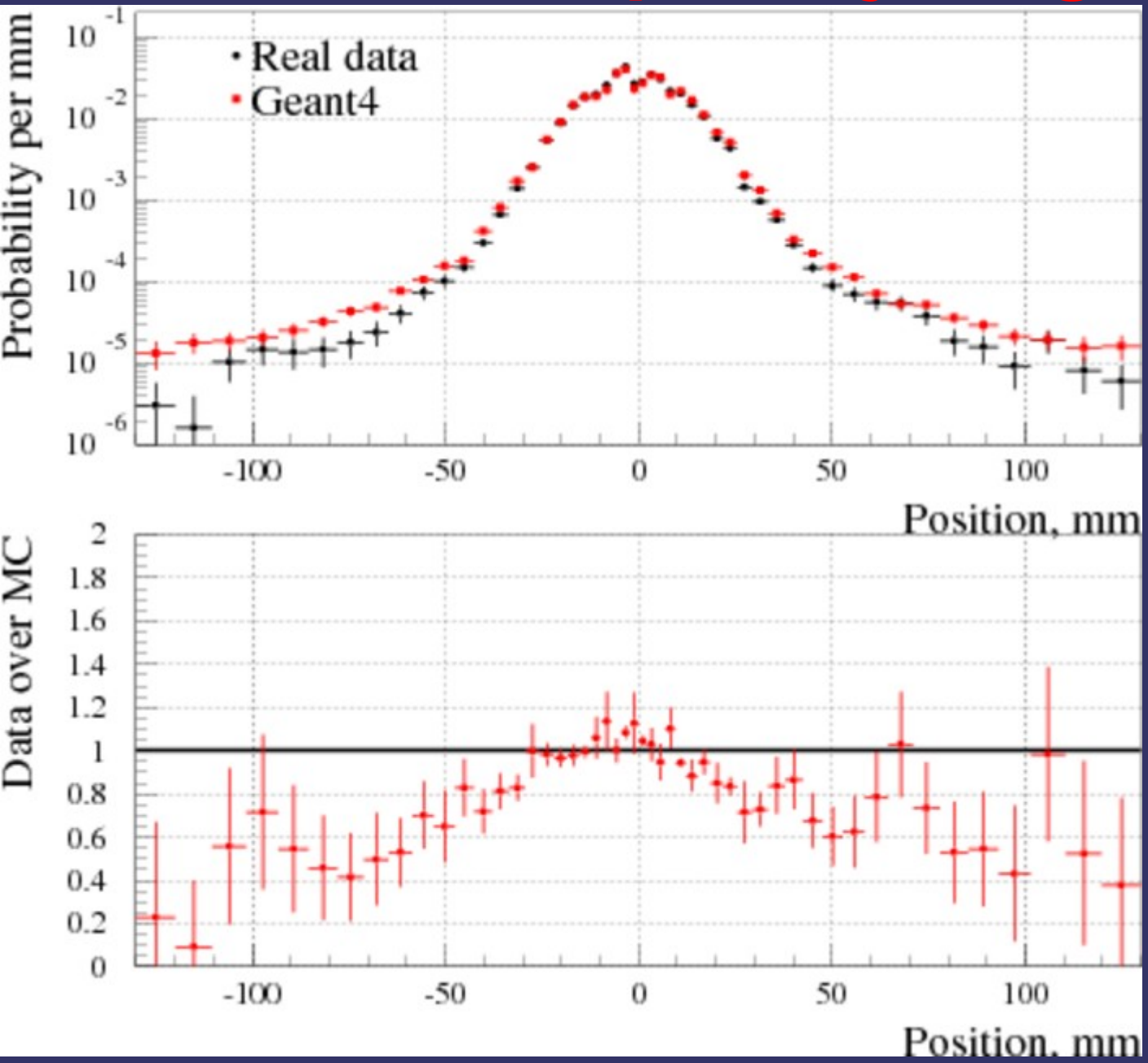
Empty Hydrogen vessel



Needs improved MC description

Difference propagated as a systematic

15cm liquid hydrogen, 1.53% X0



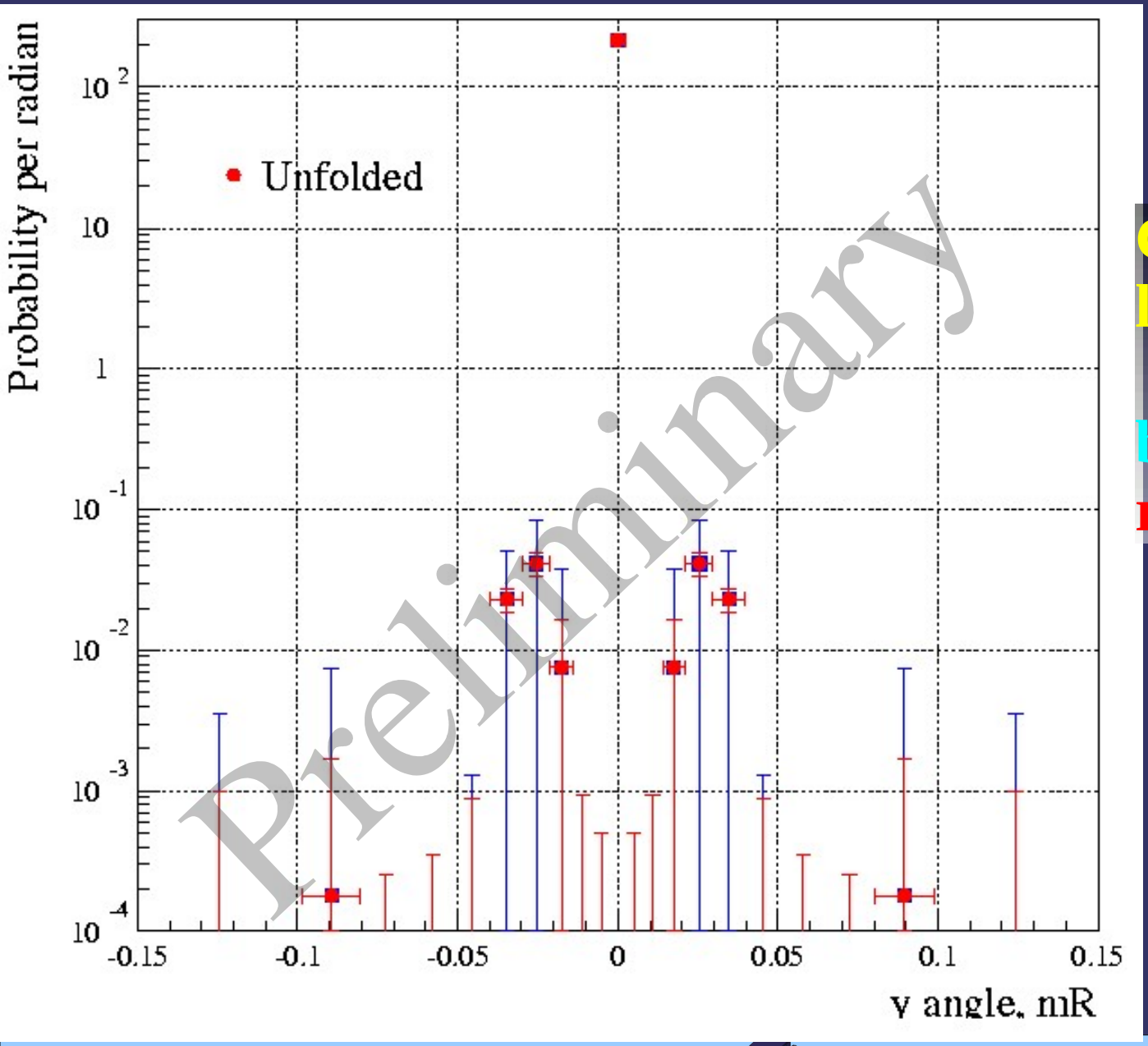
Tails noticeably lower in data

Target vessel description systematics *not* in this plot

Systematics Considered

- These are for all plots:
  - Y shift of tracker: 0.3mm
  - Z shift of tracker: 5mm
  - Steel plot efficiency correction
  - Unfolding collimator correction
  - Flat background subtracted from MC
  - Assume internal veto efficiency 100%
  - Tracking done with planes 1+3m not 1+2
- These only for deconvolution plots:
  - Unfold with wrong Geant target
  - Unfolding collimator residual
  - No-target difference

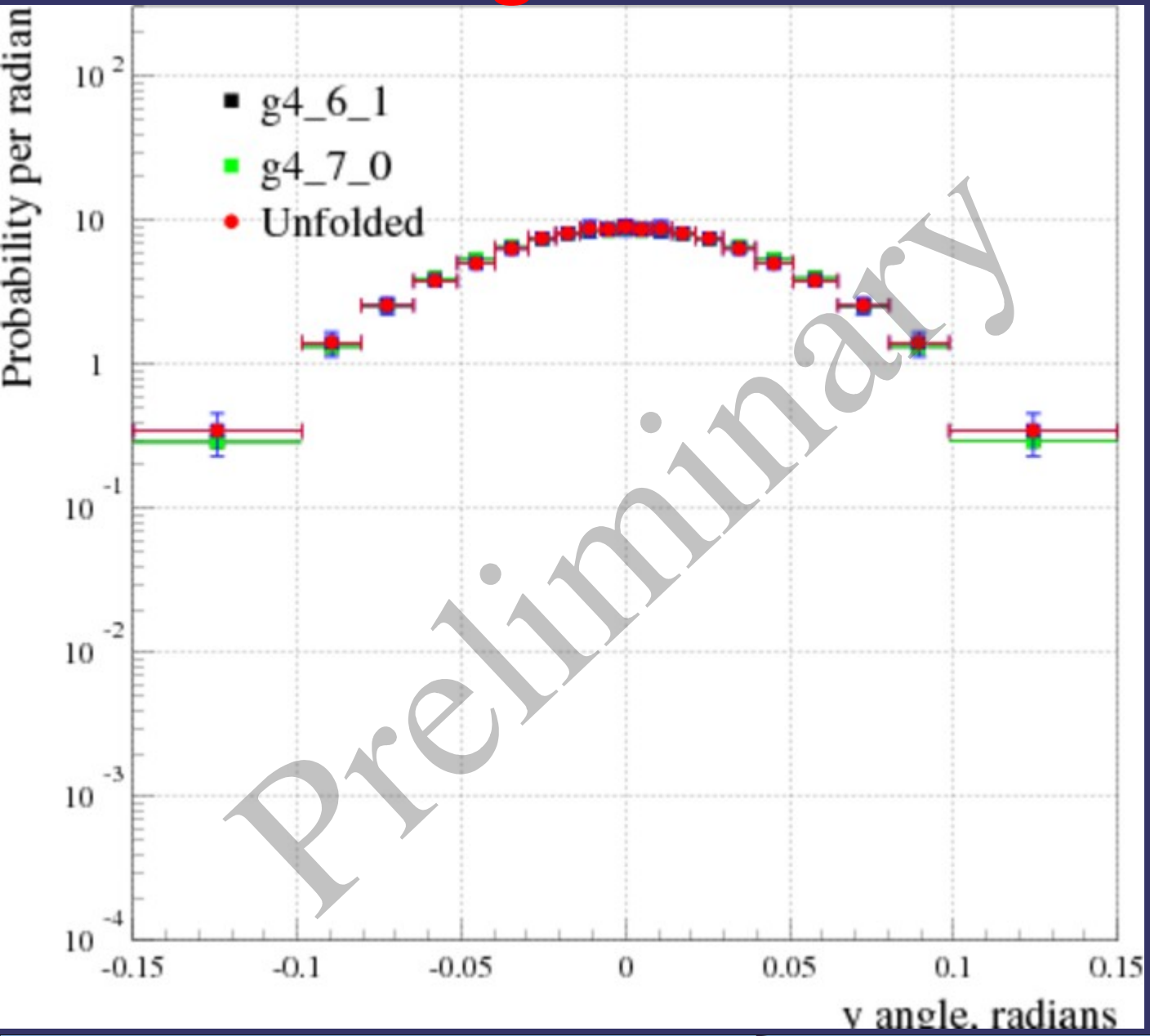
Unfolding test – delta function



G4.7.0 has tails 50% larger than G4.6.1

blue is systematics
red is statistics

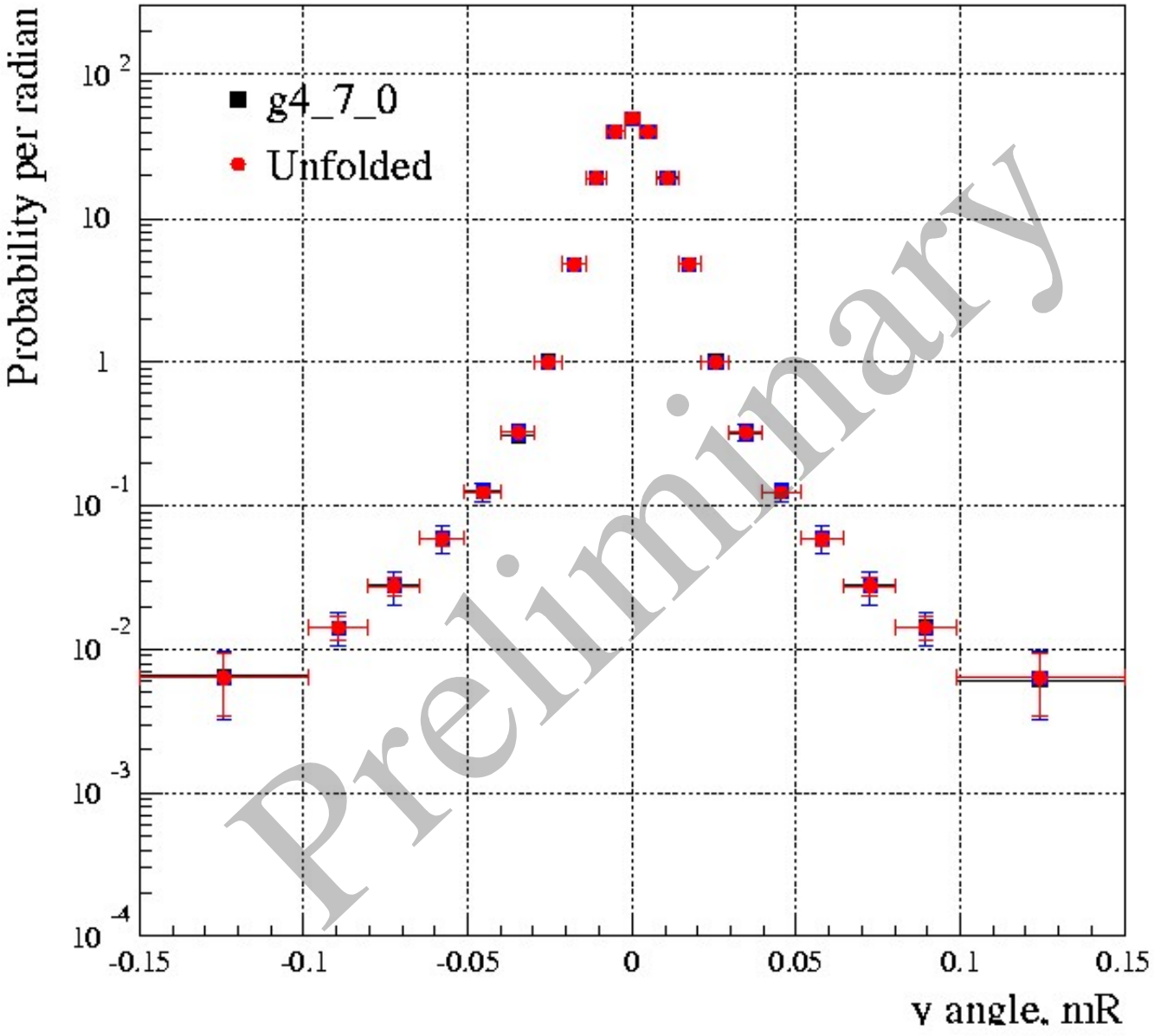
Unfolding test – thick steel, 28% X0



Geant model well reproduced here.

Central limit theorem region

Unfolding test – MC Lithium

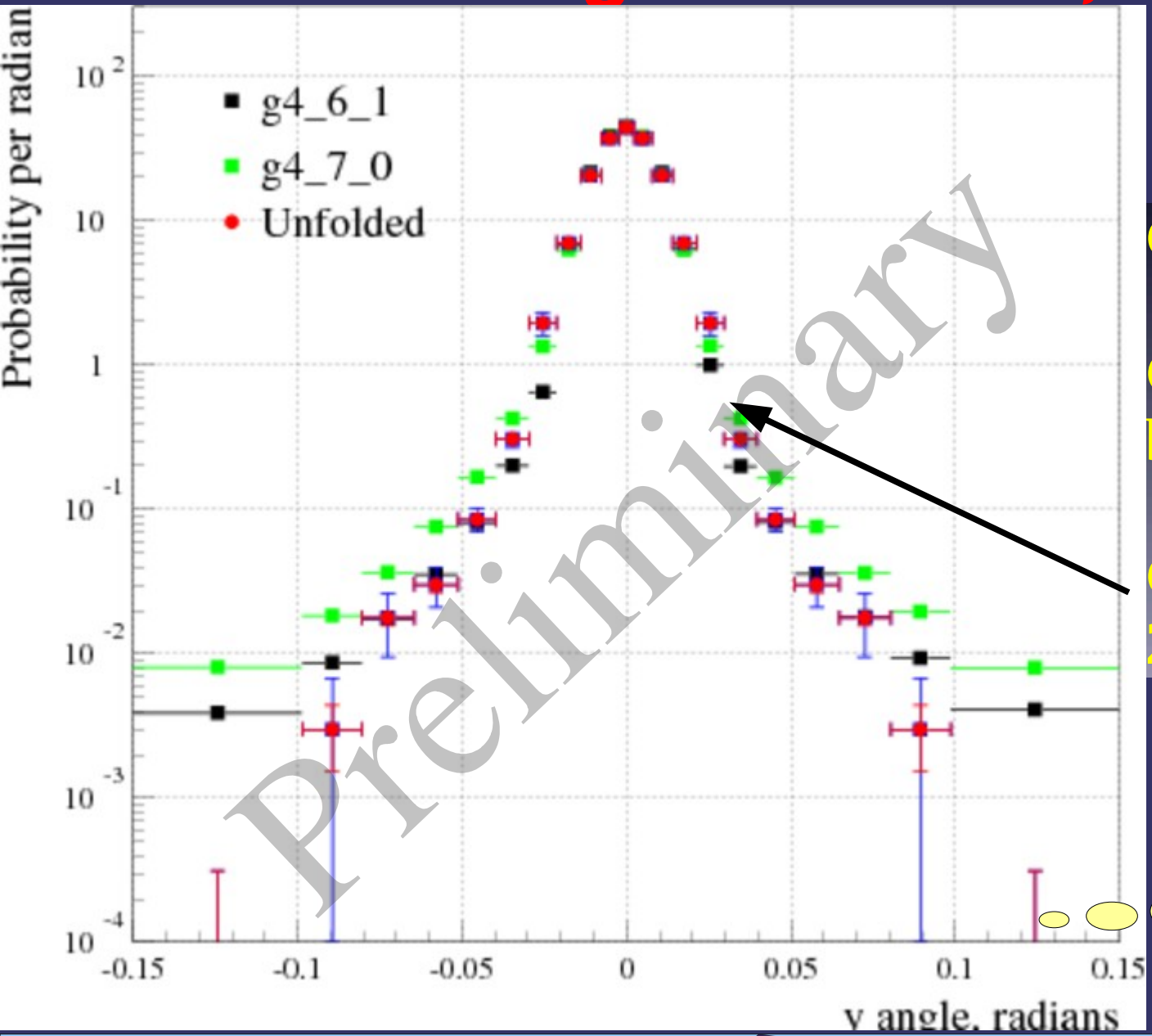


Using G4 results as the data the unfolded spectrum is perfect

Technical test of unfolding

Last bin is overflow

Unfolding: thin Steel, 1.36% X0



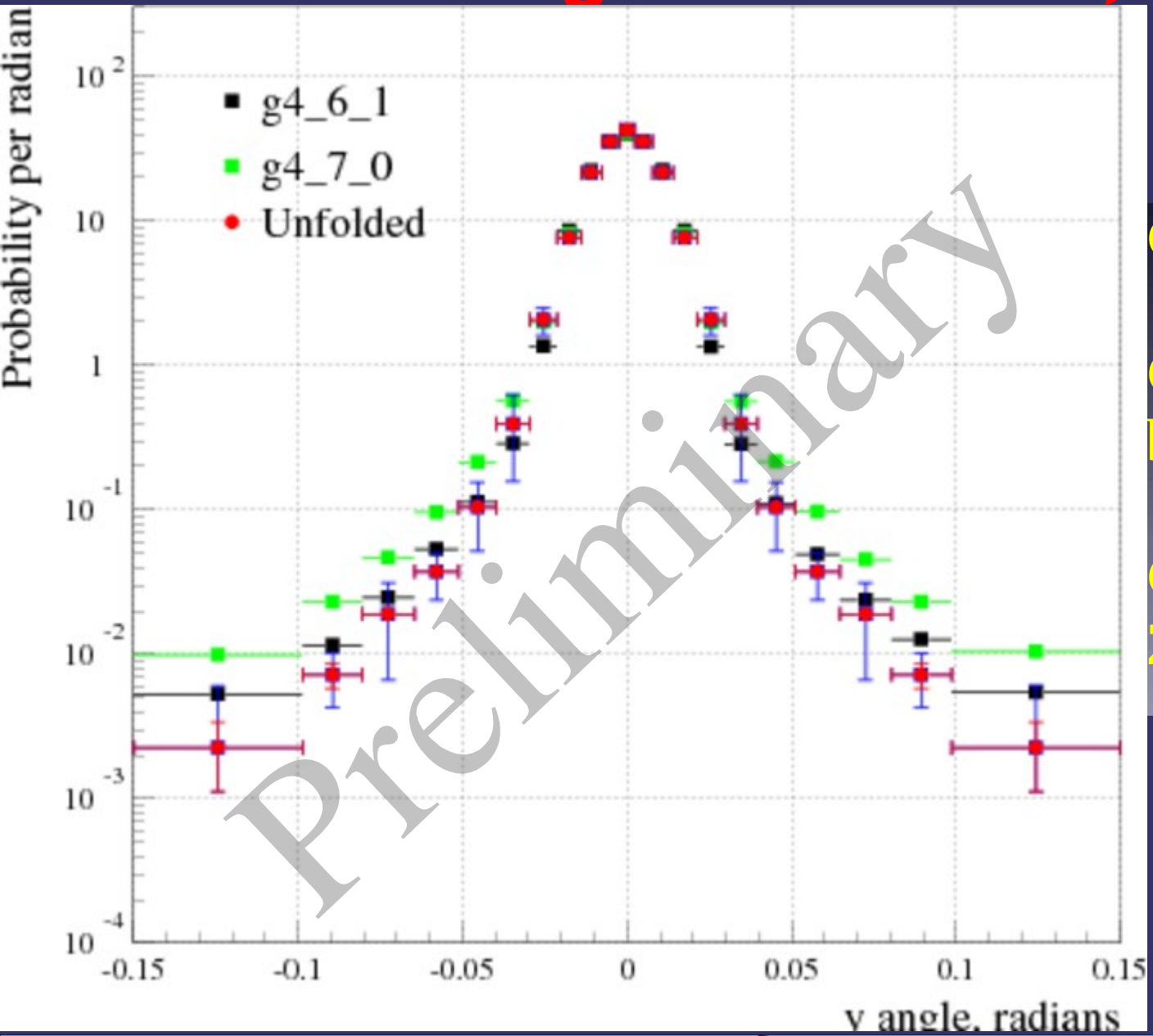
Geant 4.6.1 not bad

Geant 4.7.0 tails too big

Geant too low at 25mRads

Problems with systematics in zero bins?

Unfolding: aluminium, 1.69% X0

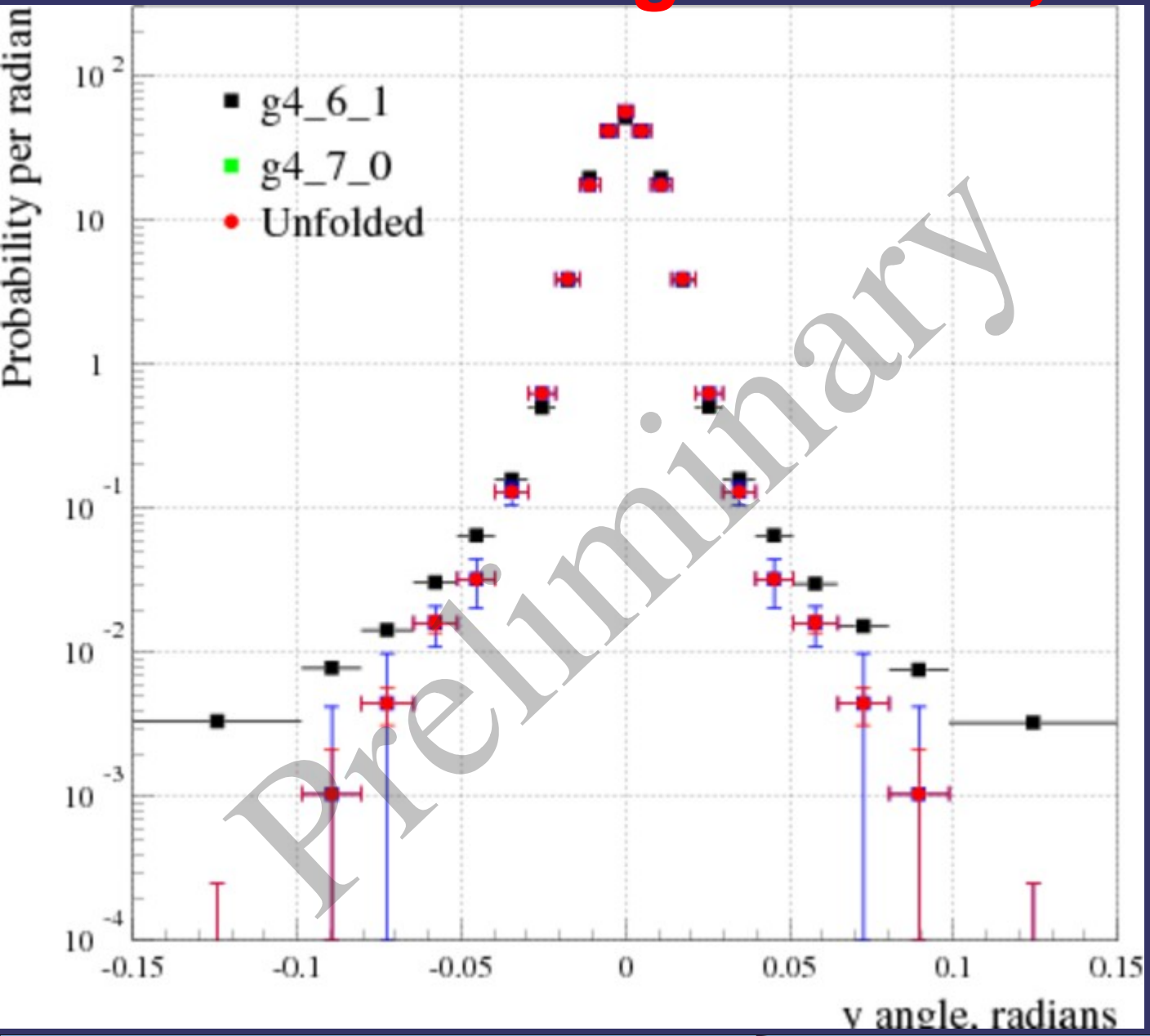


Geant 4.6.1 not bad

Geant 4.7.0 tails too big

Geant 4.6.1 deficit at 25mR still visible

Unfolding: carbon, 1.53% X0



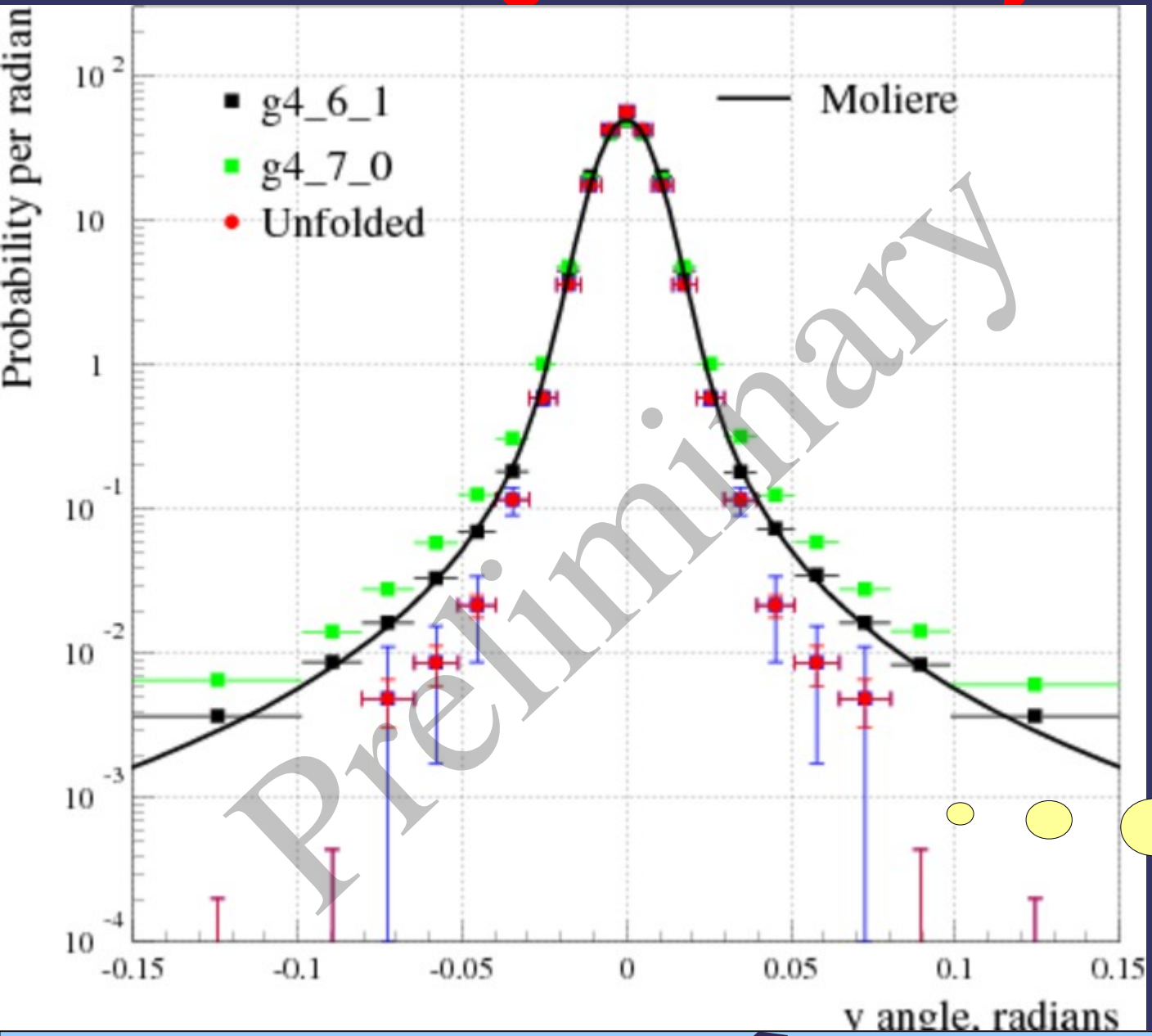
Geant model OK in Gaussian region -- tails too large?

Geant too low at 25mRads

Statistical

stat+sys

Unfolding: Thick Beryllium, 1.06% X0



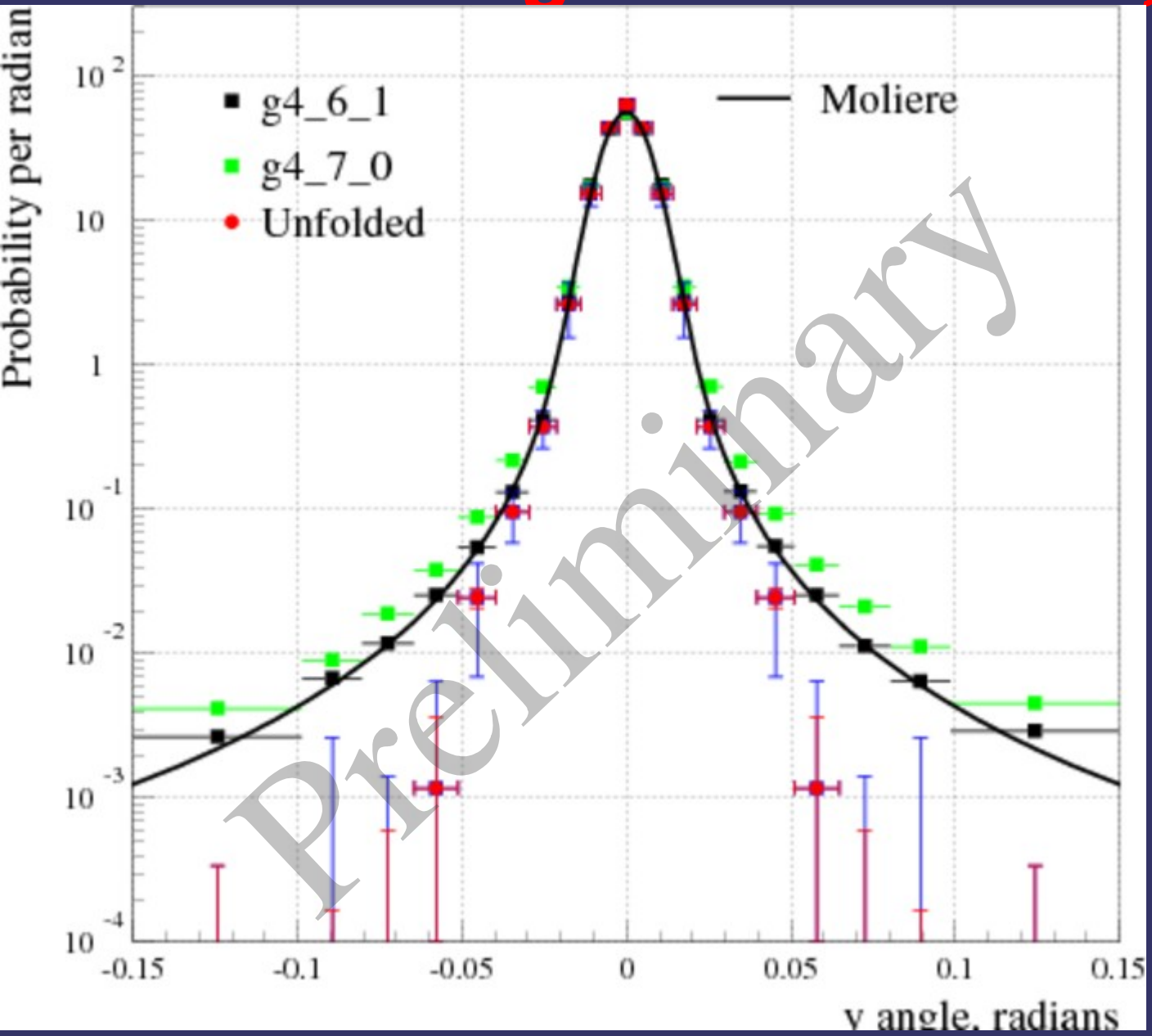
Geant 4.6.1 looks like Moliere

Geant 4.7.0 is above these

Data lies below

Have we understood background subtraction?

Unfolding: thick lithium, 0.81% X0

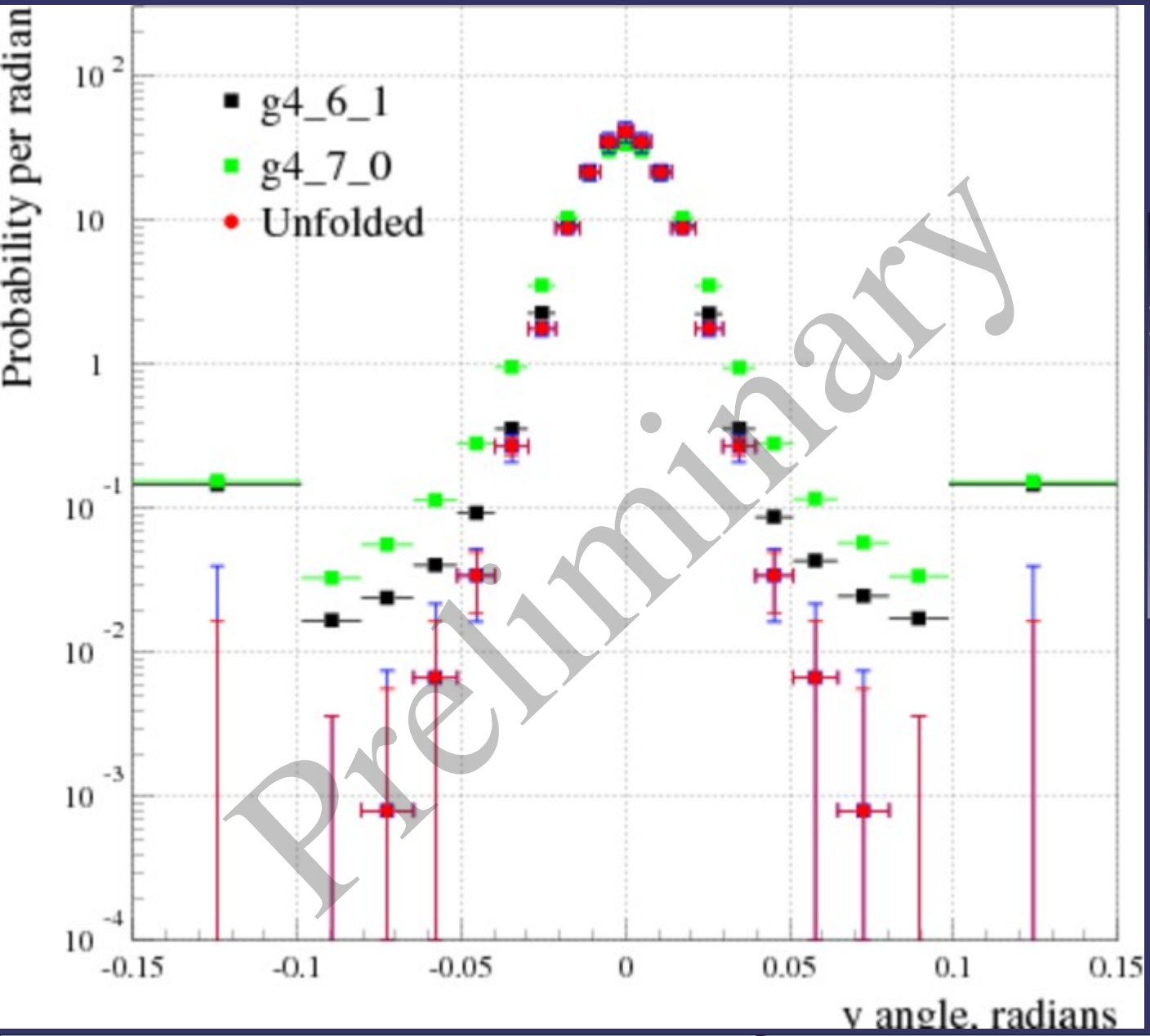


Rather like Beryllium

Andrievsky's factor 2 data excess at 1% not seen

Laszlo Urbain (G4) suggests that was delta rays

Unfolding: 15cm LH_2, 1.53% X0



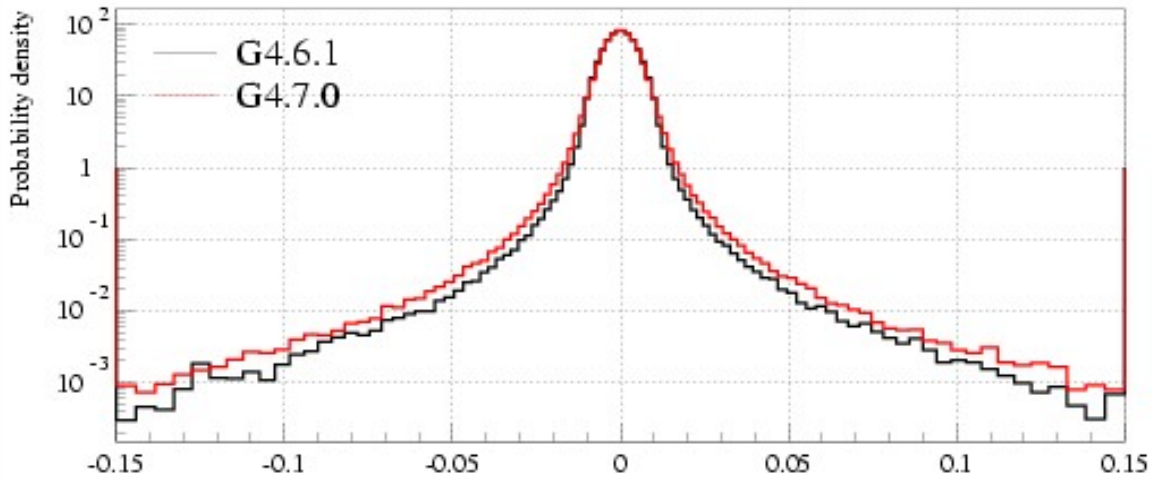
Geant 4.7.0 predicts more tails than observed

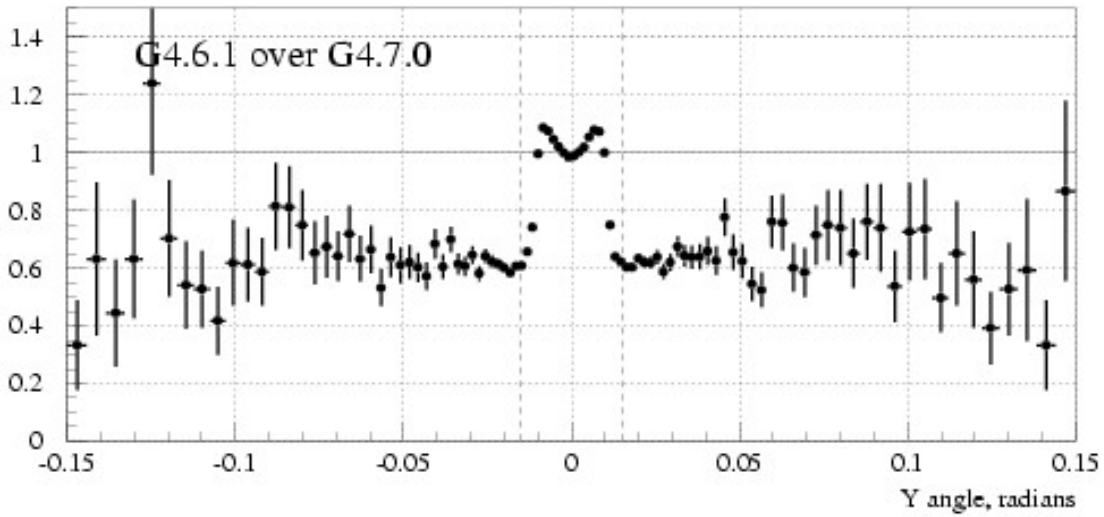
Geant 4.6.1 much closer to data

Conclusions and Outlook

- Analysis proceeding
  - Systematics well under way.
  - Publication 'soon'.
- Instability in Geant demonstrates value of this data
- Geant 4.6.1 is a reasonable description of multiple scattering in this region
  - Geant 4.7.0 has excessive tails
- Will attempt mini-Mice using Tina
- Andrievsky discrepancy for Lithium not confirmed

Geant instabilities





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