Wedge Absorber Plans

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Science & Technology Facilities Council

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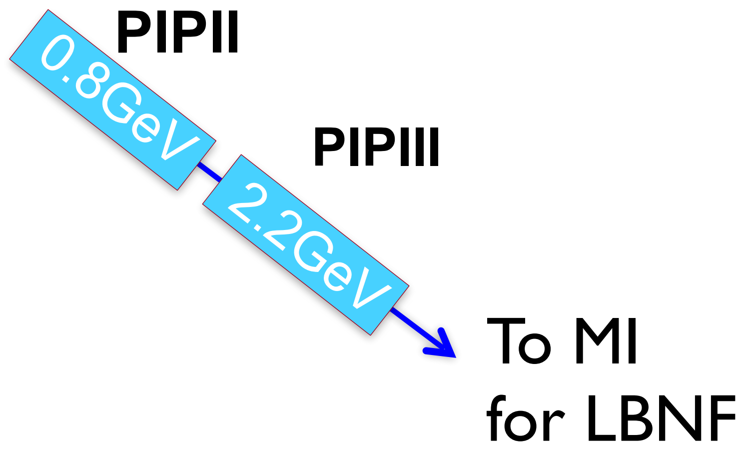
Why a Wedge?

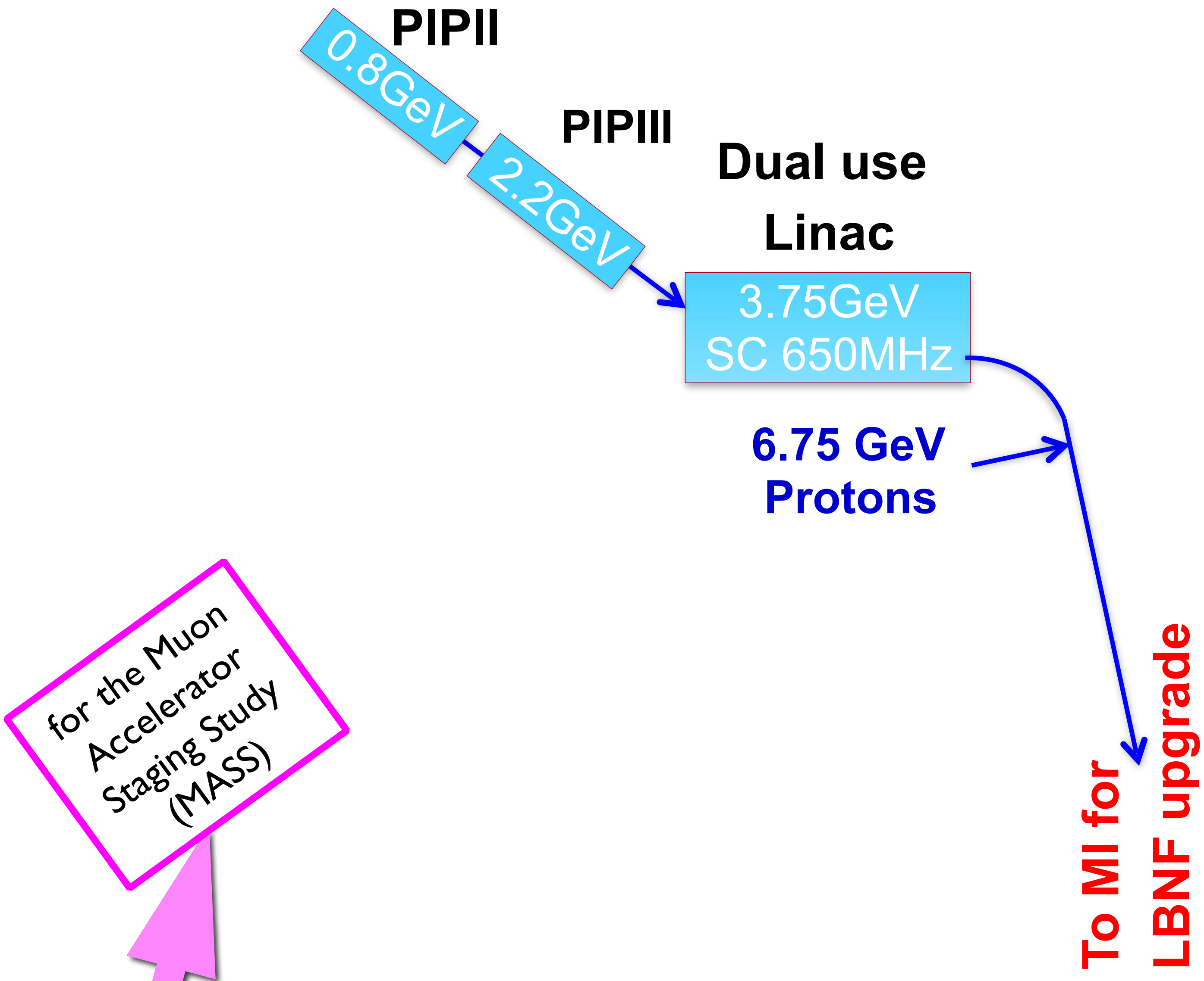
1. Both muon colliders *and neutrino factories* (new MASS result) require 6D muon cooling
   - accomplished via emittance exchange
   - MICE Step IV can make the first demonstration

Progressive installation in stages with Physics and technology validation at each stage

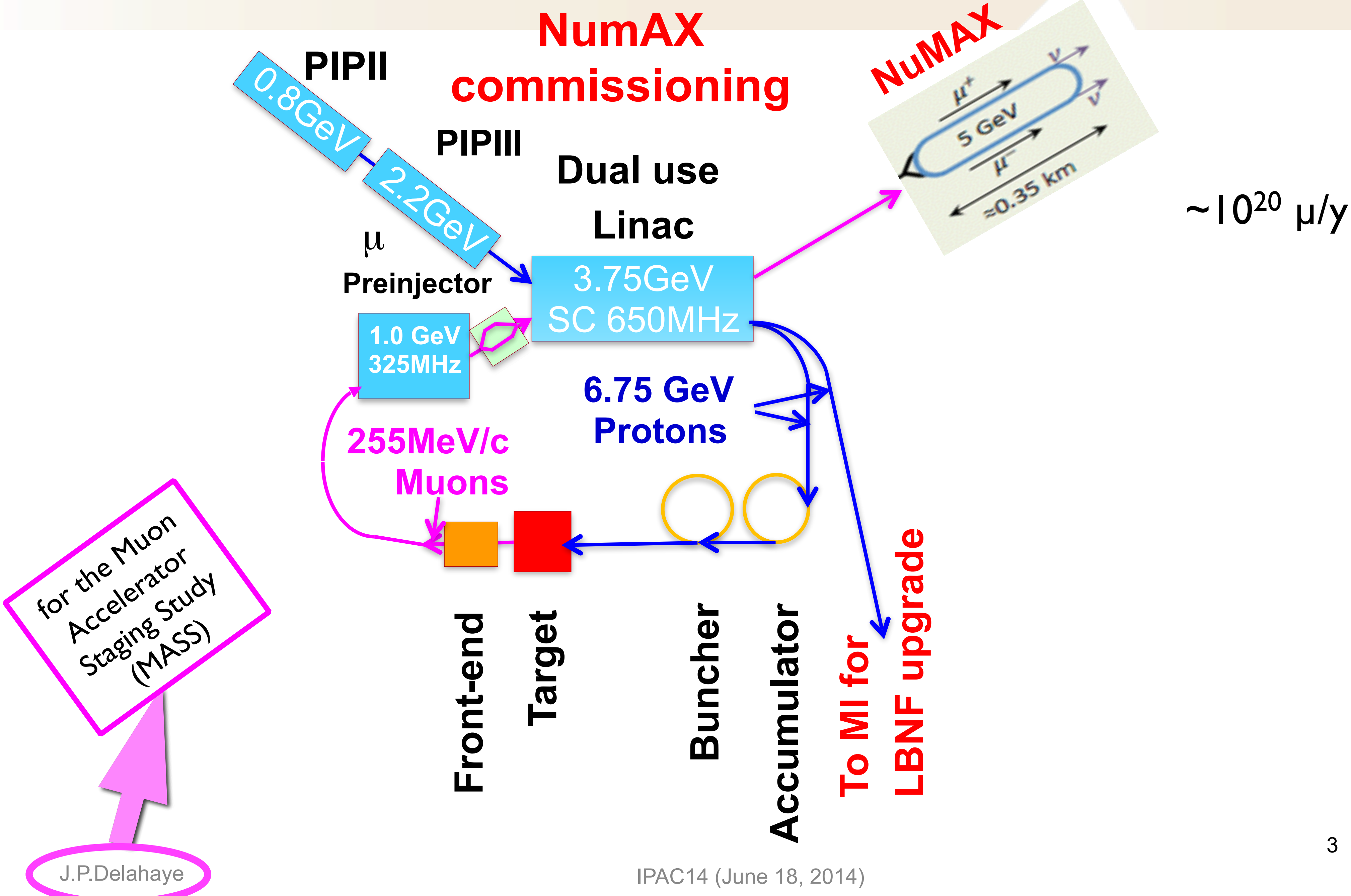


for the Muon Accelerator Staging Study (MASS)

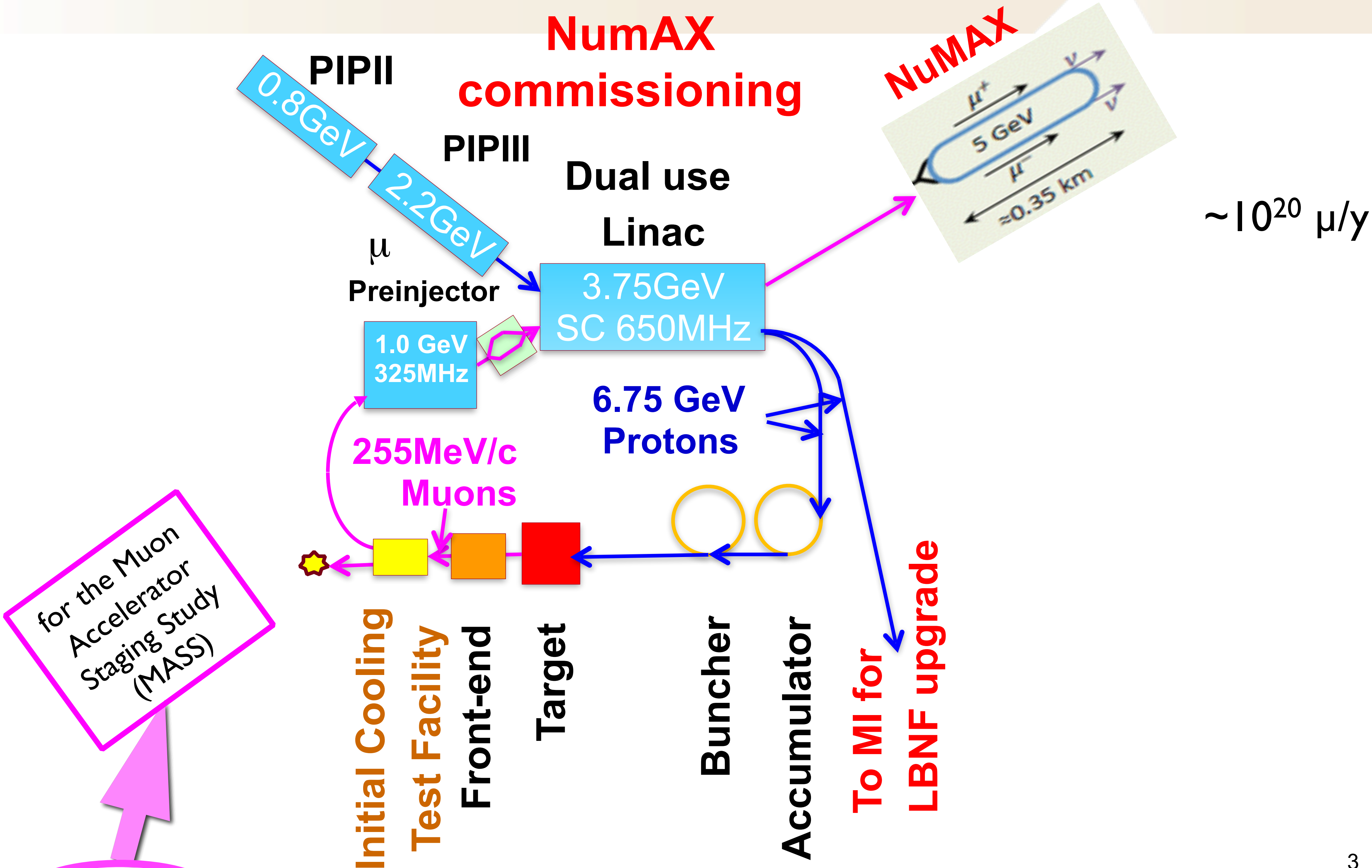
Progressive installation in stages with Physics and technology validation at each stage



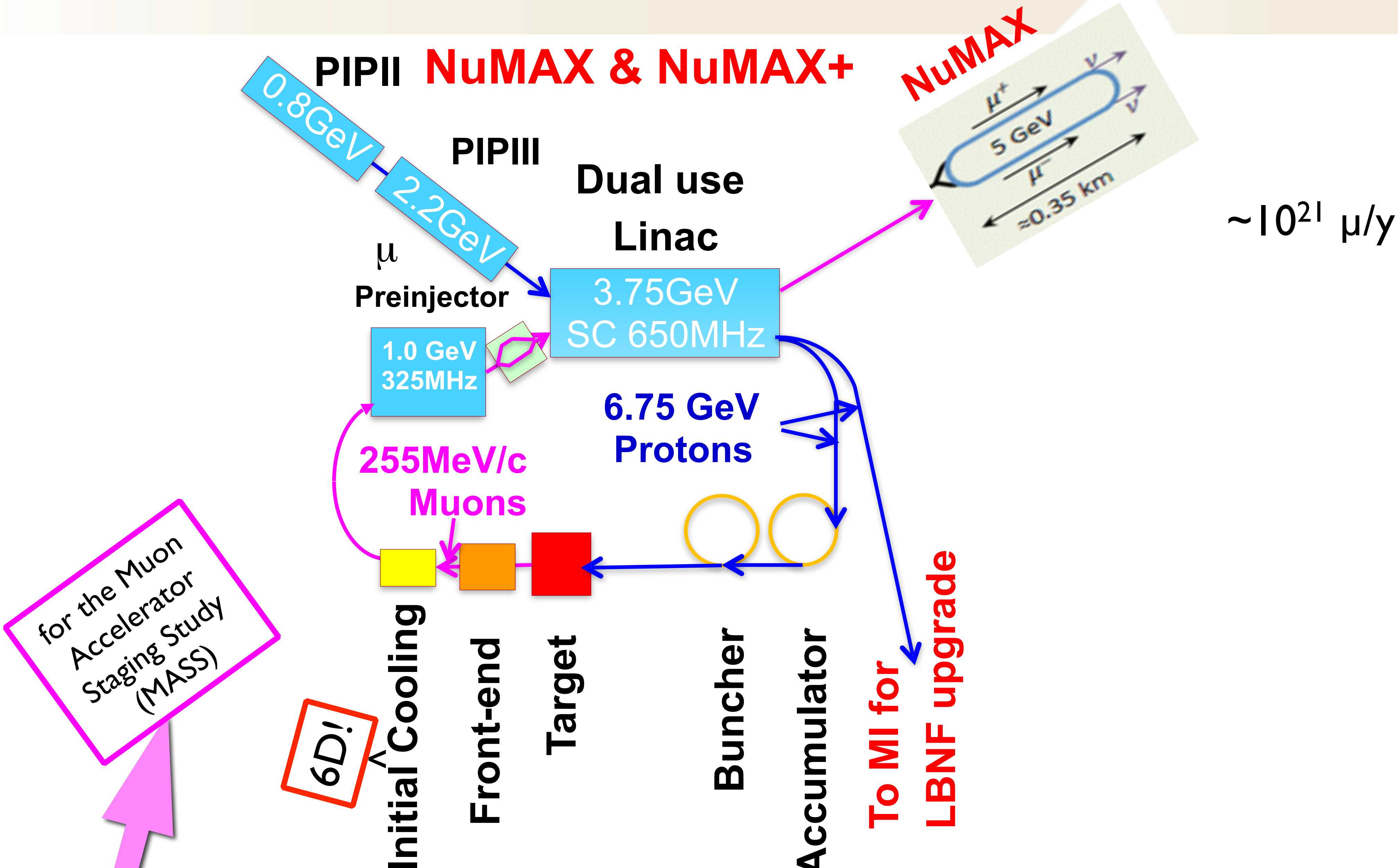
Progressive installation in stages with Physics and technology validation at each stage



Progressive installation in stages with Physics and technology validation at each stage



Progressive installation in stages with Physics and technology validation at each stage



Why a Wedge?

1. Both muon colliders *and neutrino factories* (new MASS result) require 6D muon cooling
   - accomplished via emittance exchange
   - MICE Step IV can make the first demonstration
2. How well are the models in our cooling simulation codes validated?
   - *dE*/*dx* and straggling data are old and low-statistics
   - want to predict MC luminosity to < factor of 2
   - expect this to be sensitive to "Landau" tail of *dE*/*dx*

☞ **Wedge absorber gives us *both* tests at once!**

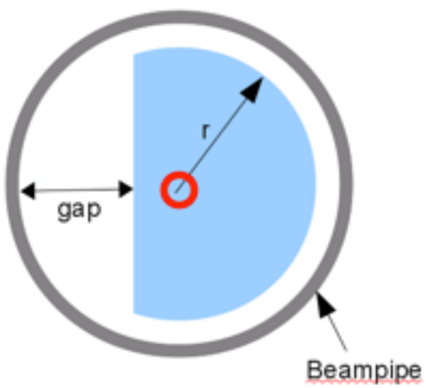
The Wedge Advantage

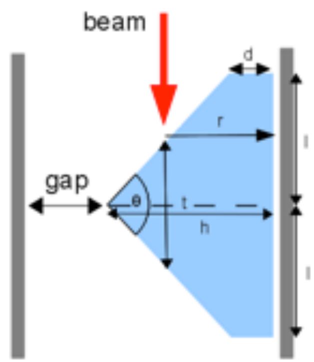
- Systematics minimization:
  - wedge not only allows *dE/dx* measurements with a range of thicknesses (needed to pin down Landau tail) all at once
  - also calibrates the optical magnification and possible position offsets all at once:
    - one can reconstruct the apparent positions of the wedge base and apex (P. Soler, public communication, CM38)
- MAP review committees consistently stress importance of validating the assumptions in our simulations!

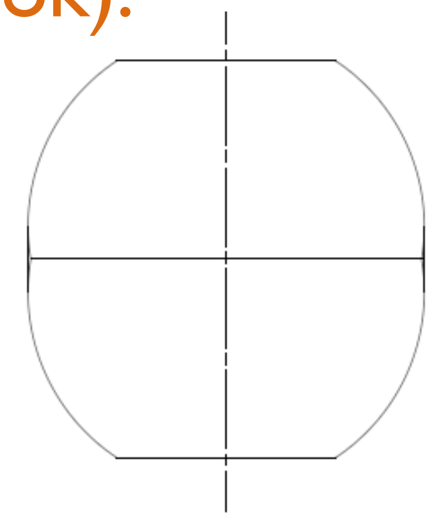
$\Longrightarrow$ wedge test is a *golden opportunity* we need to exploit!

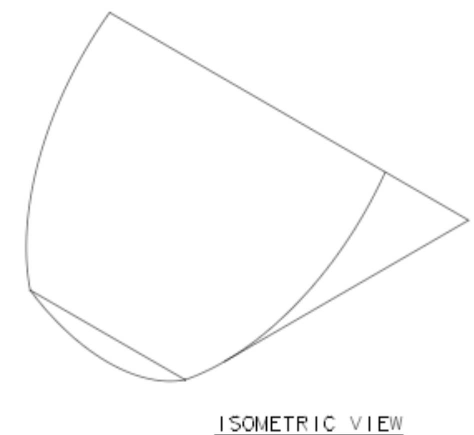
Wedge Designs

- LiH wedge (Rogers, Snopok):

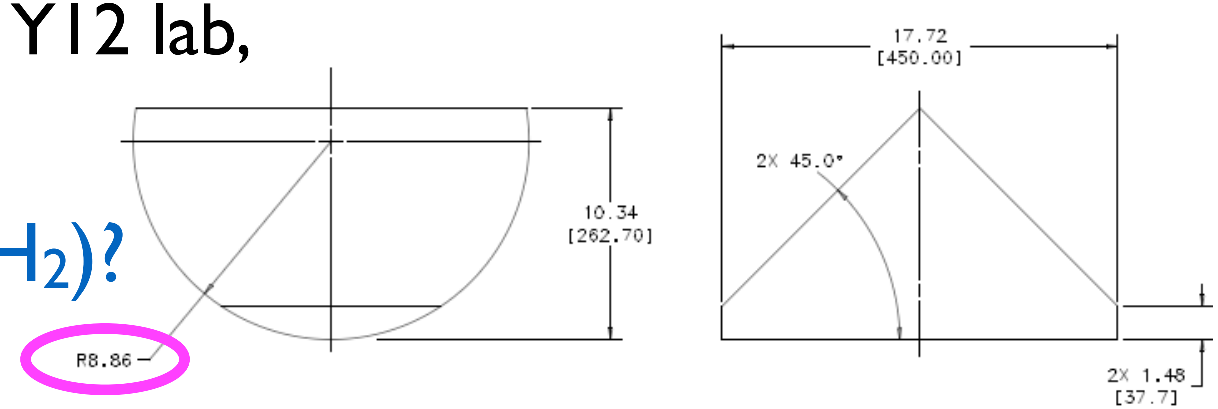








  - ordered by FNAL from Y12 lab, but too expensive!



- So why not plastic (CH_2)?

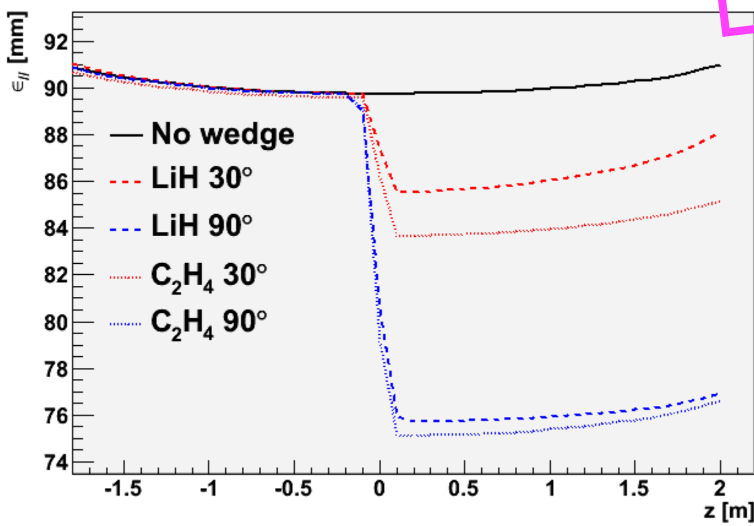
45 cm diameter CH_2 rod – not available!
But 30 cm is, and is good enough…

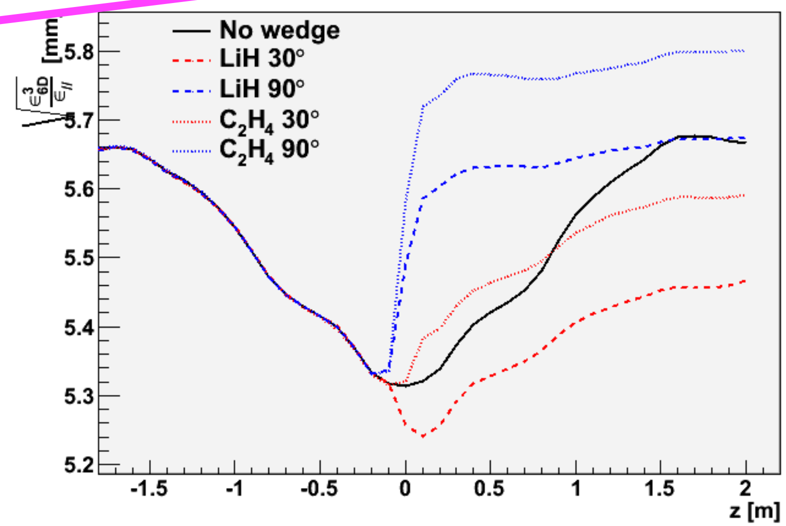
Emitt. Exch. Performance

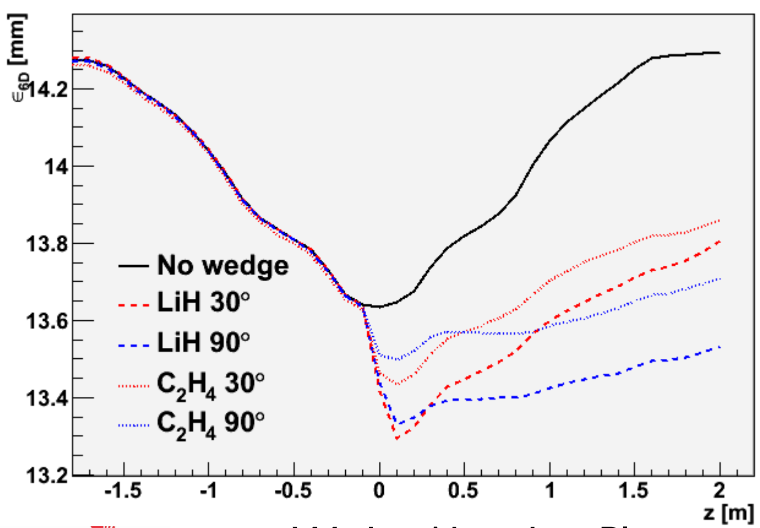
Cooling Signal at 6 mm

From Chris Rogers's Analysis || talk Wednesday

r = 225 mm





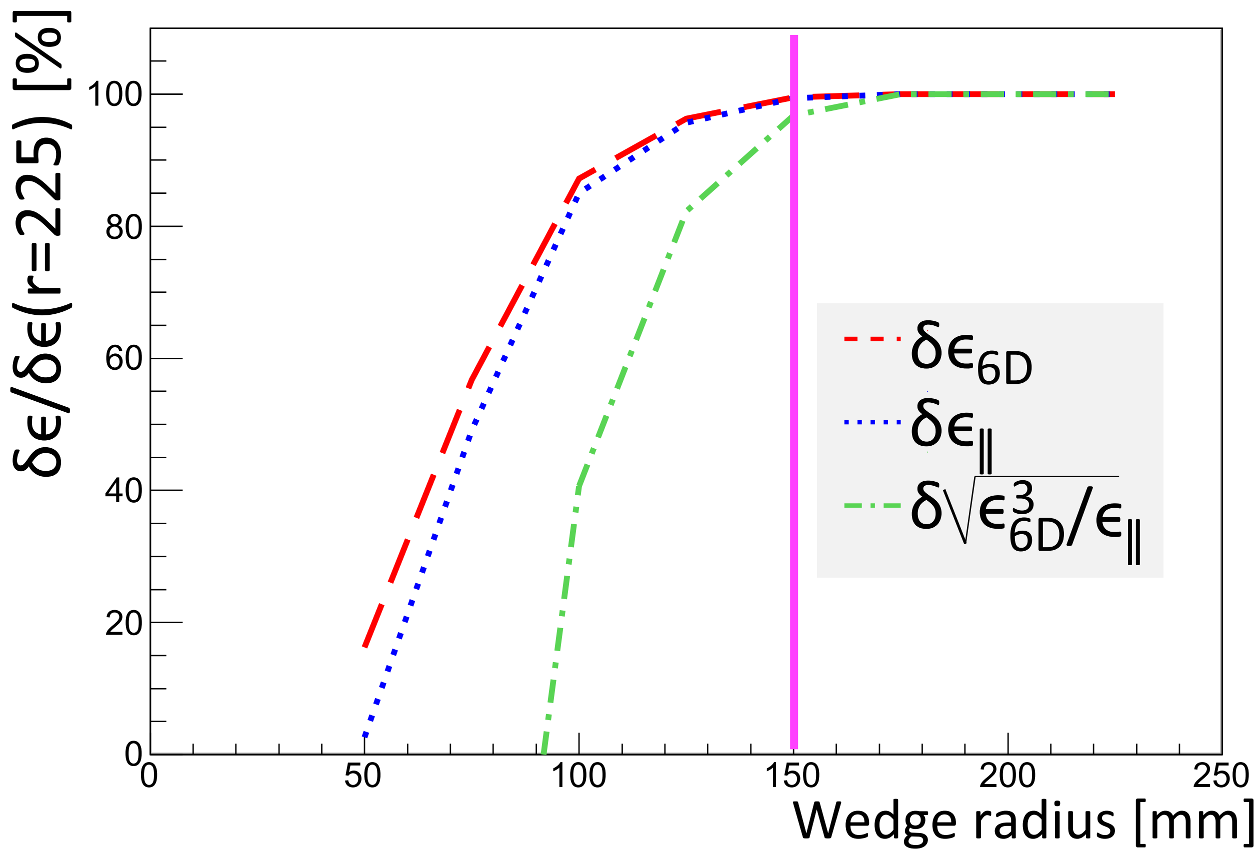


"Standard MICE beam"

- 6 mm transverse emittance
- Large 90 mm longitudinal emittance
  - 25 MeV energy spread
- 200 mm dispersion at the wedge

Radius Dependence

From C. T. Rogers, P. Snopok, MICE-CONF-SIM-0262 (IPAC'10, WEPE081):



- r = 150 mm hardly distinguishable from r = 225 mm

Wedge Designs

Good morning Dan, June 23, 2014

Per our discussion Friday I came up with a quote for the wedges based on the material cost and the time I estimate to machine the part(s).

12" diam x 24" long polyethylene rod - $1433.00

shop time $75/ hour x 48 hours - $3600.00

Total - $5033.00

The fixturing of this part would be the most time consuming because of the size & irregular shape.
I hope this information is helpful.

Regards,

Salomon Rodriguez
Lab Technician
BCPS / Idea Shop
Illinois Institute of Technology

From Chris Rogers's Analysis || talk Wednesday:

Required MICE Time

- Change absorber to wedge and back again (8 days)
- Transverse emittance and pz scan @ 420 mm, high statistics
  - 3 emittance settings * 3 momentum settings
  - Standard SC magnet currents
  - 1 hour (100k triggers) per run + 3 hours set up time
  - 1 (12 hour) day
- P_z, Beta function at absorber scan with lower statistics
  - Vary beamline to produce 3 emittance settings and 3 momentum settings, keep SC magnets constant, 10k triggers per run
  - 90 minutes to do all that
  - 120 minutes to change magnet currents
  - 3 SC magnet settings per day + 3 hours set up time
  - 10 beta functions => 3 days
  - 10 pz values => 3 days
- 2 days spare
- 17 days total

- We think this is conservative:
  - need ~ 1 week run time

References

1. Solid Absorber Support Verification, J. Tarrant, P. Lau, MICE-NOTE-GEN-0369, 2012-03-20

2. Wedge Absorber Position Analysis, P. Snopok, MICE-NOTE-SIM-0398, 2012-12-31

3. MICE wedge absorber support specifications, Pavel Snopok, MICE-NOTE-GEN-0354, 2011-08-20

4. Wedge Absorber Design and Simulation for MICE Step IV, C.T. Rogers, P. Snopok, L. Coney, G. Hanson, MICE-CONF-SIM-0339, 2011-03-28

5. Wedge Absorber Design for the Muon Ionisation Cooling Experiment, C.T. Rogers P. Snopok, L. Coney A. Jansson, MICE-CONF-SIM-0290, 2010-05-13

6. Wedge Absorber Simulations for the Muon Ionisation Cooling Experiment, C.T. Rogers, P. Snopok, MICE-CONF-SIM-0262, 2009-09-01

7. R. Palmer, public communication, MICE CM38: "It's worth a Phys. Rev. Letter!" (or words to that effect)

From Chris Rogers's Analysis || talk Wednesday:

Conclusions

- Demonstration of emittance exchange is a valuable contribution to the muon collider R&D
- The MICE beamline can be used to propagate the appropriate dispersive beam through Step IV
  - Needs extensive beam sampling
- A plastic wedge will give more longitudinal emittance reduction than LiH
- The MICE detector systems can make a measurement of emittance exchange
- Provisionally, 17 days of MICE time are required
  - 8 days+support staff for an absorber exchange
  - 9 days+physicists for data taking
  - Needs further Monte Carlo to check

My Conclusions

- MICE can quickly make some unique & useful measurements of *dE/dx* in Step IV…

…and demonstrate emittance exchange at the same time!

  - both rated important by MAP & review committees

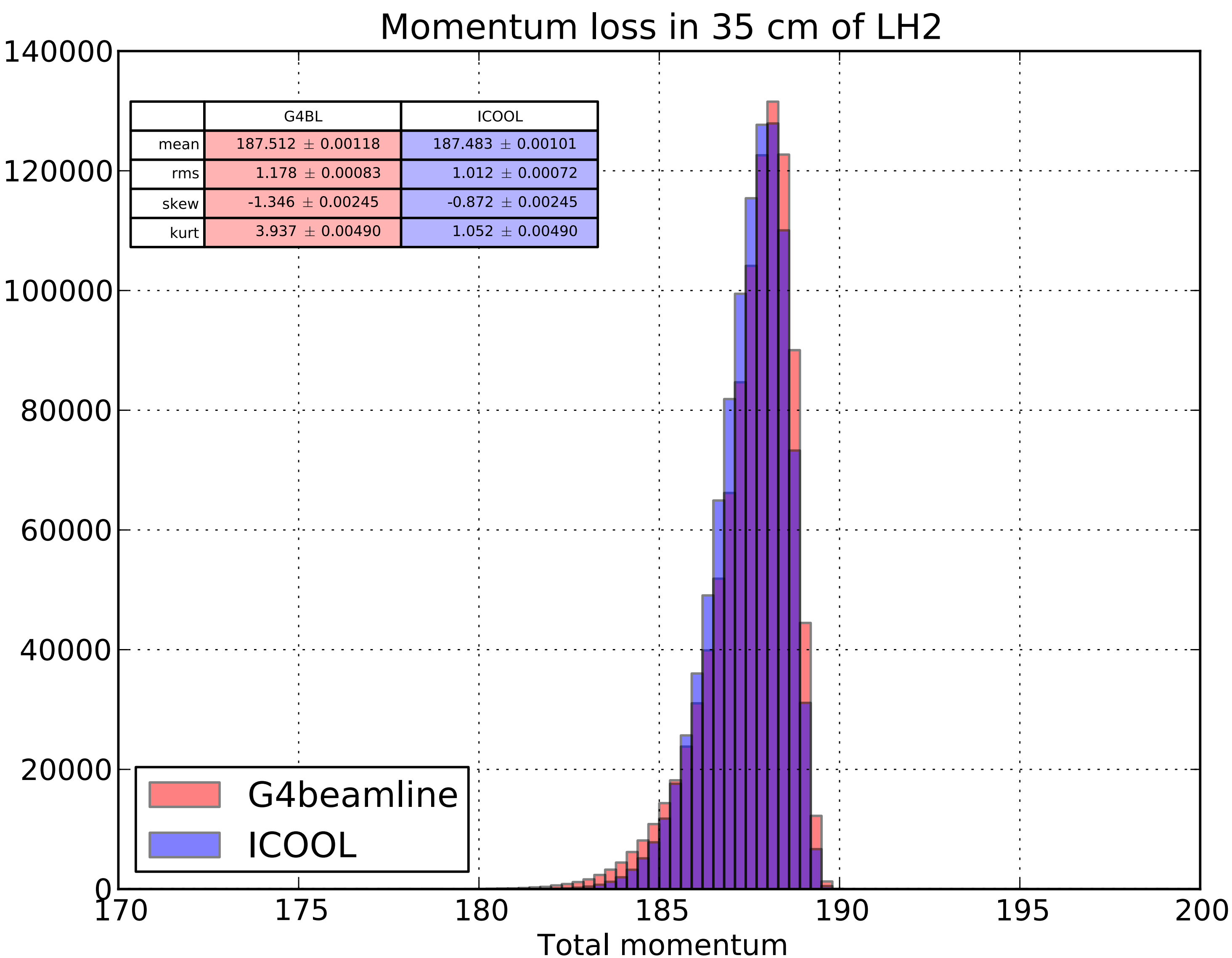
- Understanding achievable precisions will take more simulation work

- Hope to put a new IIT student on this (Tanaz Mohayai) under Pavel's direction
  - she has started learning MAUS
  - hope to present more at CM40

Why Not?

1. "Rutherford scattering is well understood"
   - but exact wave functions known only for H
2. "ELMS computes it from 1st principles and has been thoroughly tested in MuScat"
   - yes, but only for scattering, not *dE/dx*
   - and applies only to H, not Li, Be, C,…
   - and we (and our reviewers) can't be sure code implementation is correct without validating it
3. Too small an effect for us to measure?
   - see below…

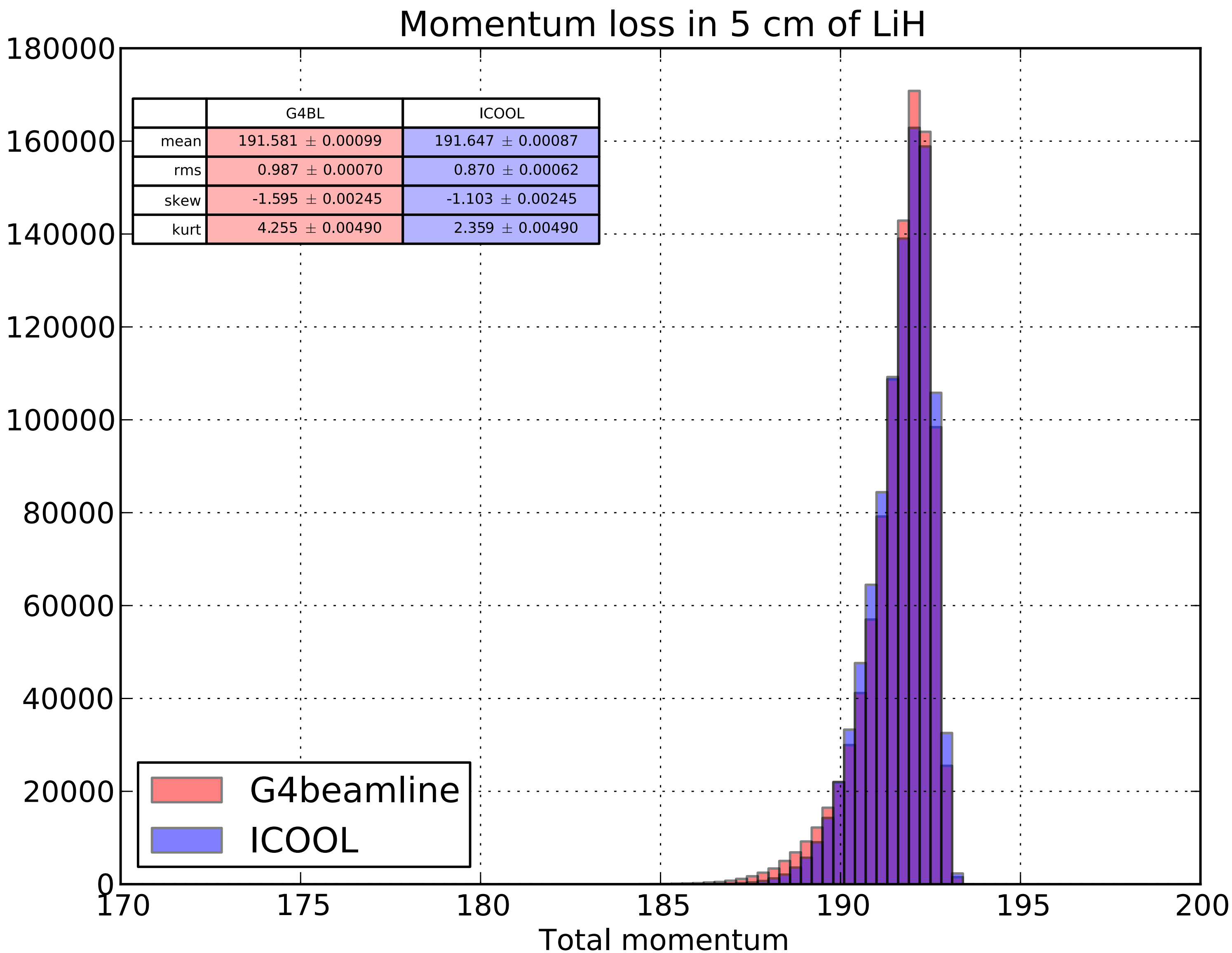
Too small to measure?



	G4BL	ICOOL
mean	187.512 ± 0.00118	187.483 ± 0.00101
rms	1.178 ± 0.00083	1.012 ± 0.00072
skew	-1.346 ± 0.00245	-0.872 ± 0.00245
kurt	3.937 ± 0.00490	1.052 ± 0.00490

- G4BL & ICOOL runs, 10^6 evts each, p = 200 MeV/c
- 1 MeV/c (10% of ΔE) RMS width vs < 5 MeV/c MICE resolution
- 2 model's predictions differ significantly

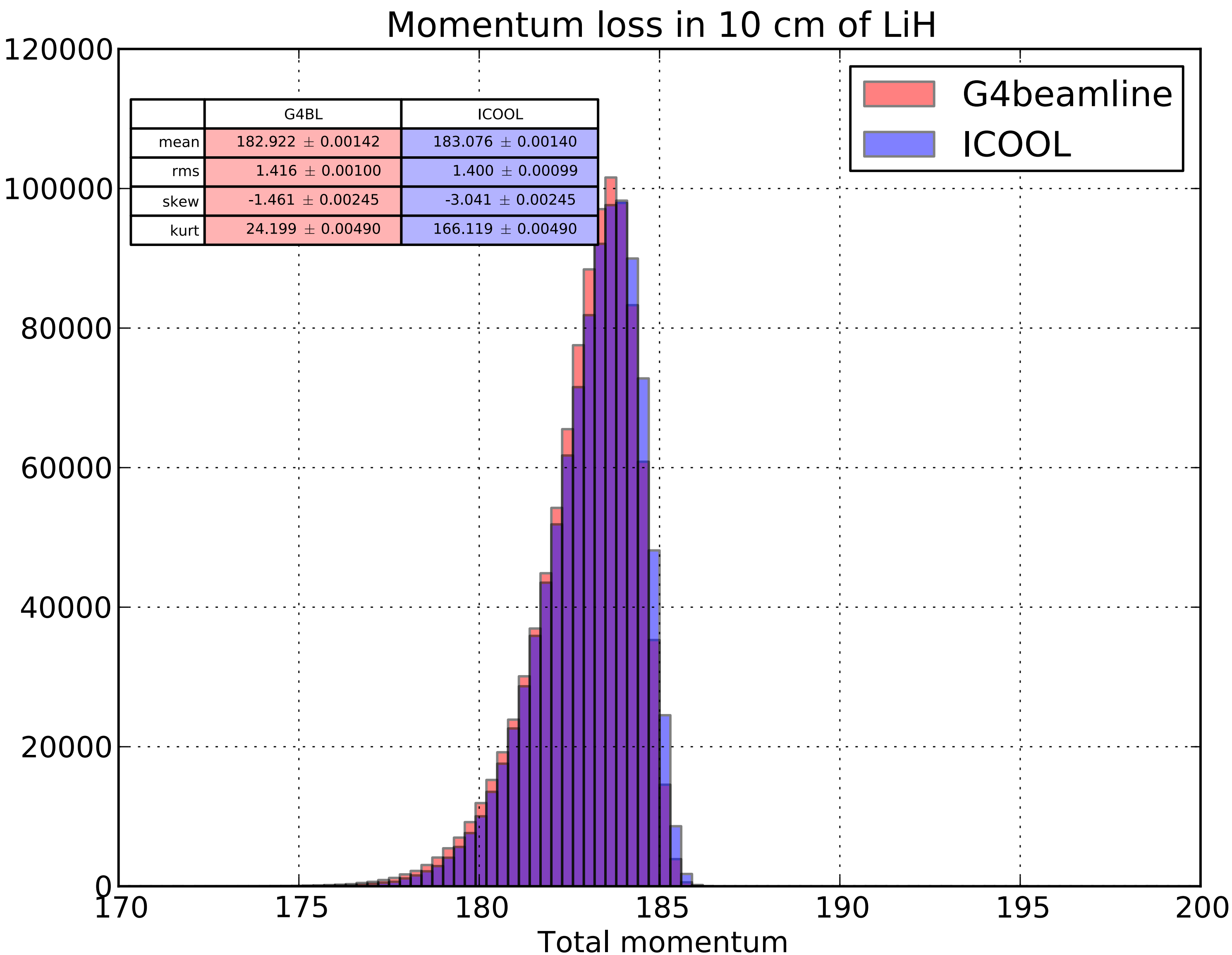
Too small to measure?



	G4BL	ICOOL
mean	191.581 ± 0.00099	191.647 ± 0.00087
rms	0.987 ± 0.00070	0.870 ± 0.00062
skew	-1.595 ± 0.00245	-1.103 ± 0.00245
kurt	4.255 ± 0.00490	2.359 ± 0.00490

- G4BL & ICOOL runs, 10^6 evts each, p = 200 MeV/c
- 1 MeV/c (10% of ΔE) RMS width vs < 5 MeV/c MICE resolution
- 2 model's predictions differ significantly

Too small to measure?



	G4BL	ICOOL
mean	182.922 ± 0.00142	183.076 ± 0.00140
rms	1.416 ± 0.00100	1.400 ± 0.00099
skew	-1.461 ± 0.00245	-3.041 ± 0.00245
kurt	24.199 ± 0.00490	166.119 ± 0.00490

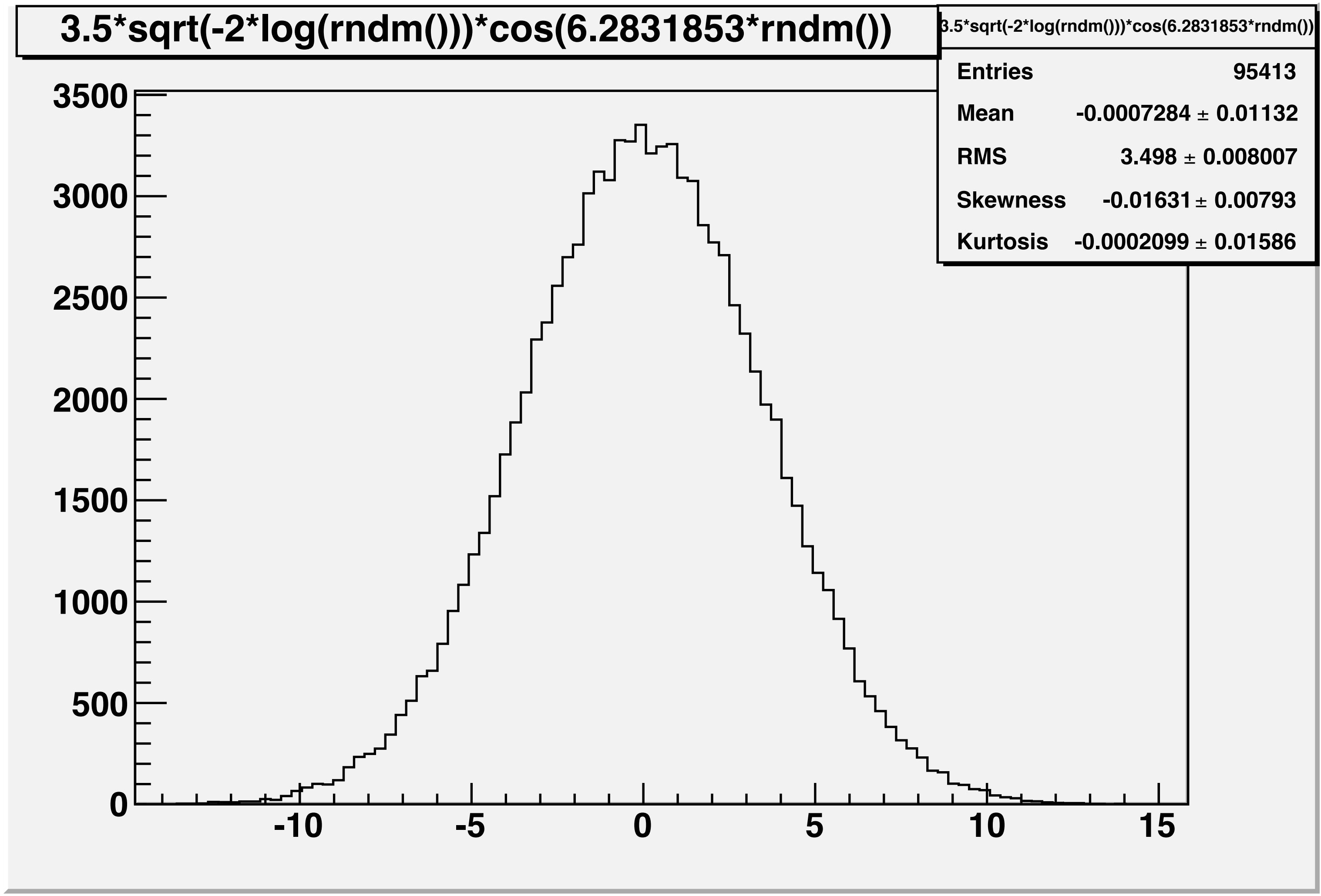
- G4BL & ICOOL runs, 10^6 evts each, p = 200 MeV/c
- 1 MeV/c (10% of ΔE) RMS width vs < 5 MeV/c MICE resolution
- 2 model's predictions differ significantly

Too small to measure?

- MICE Note 90: p_z resolution ≈ 4.6 MeV/c
  - improves with larger beam angles / emittance
- TOF resolution may be comparable to this
- Certainly sufficient resolution to measure mean dE/dx vs energy for several materials
- Can we usefully measure the Landau tail?
  - multiple absorber thicknesses for systematics?
  - more study required

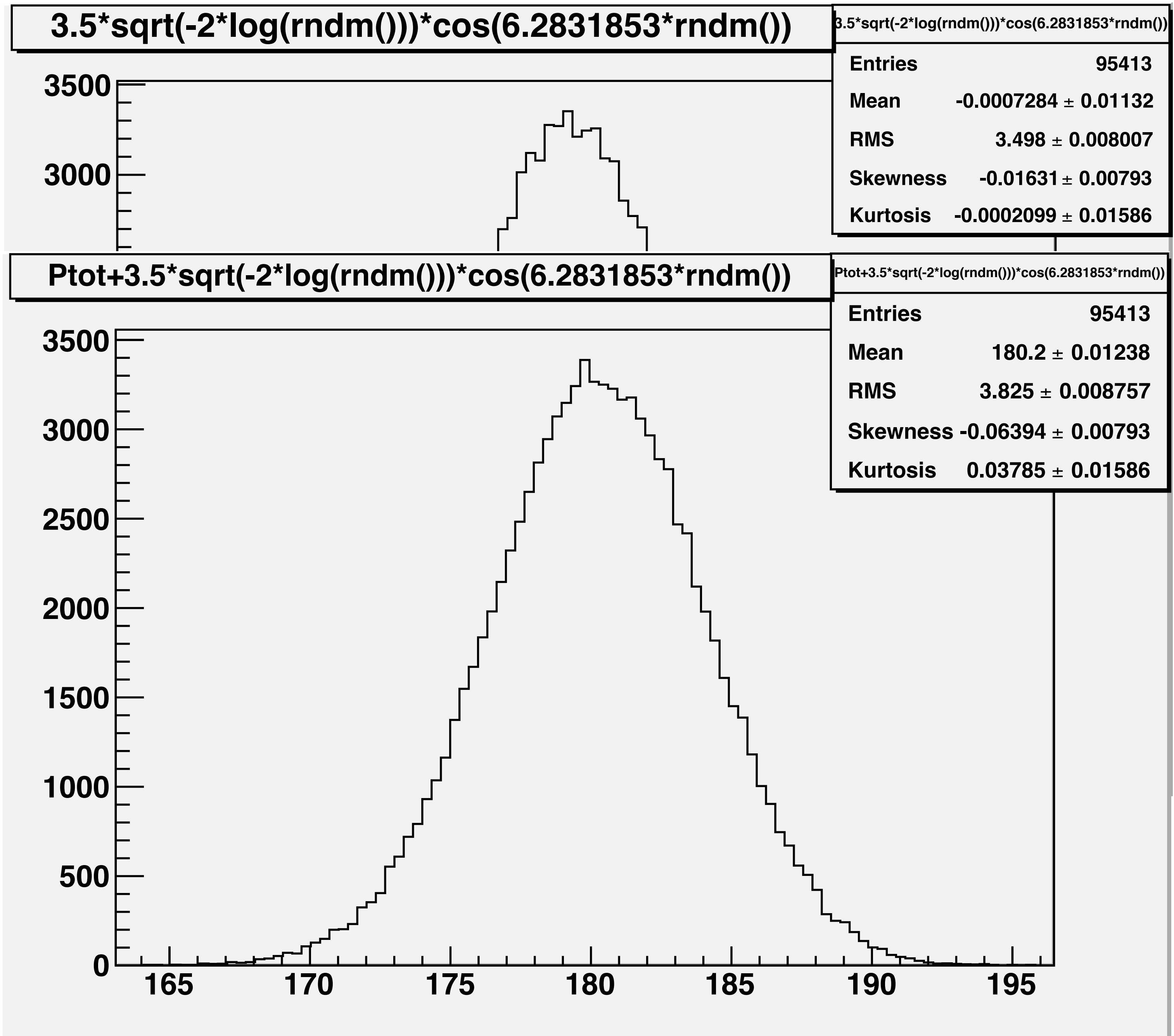
First Look at Precision:

- 100k sample, Gaussian smearing function
  - guess σ ~ 3.5 MeV/c



First Look at Precision:

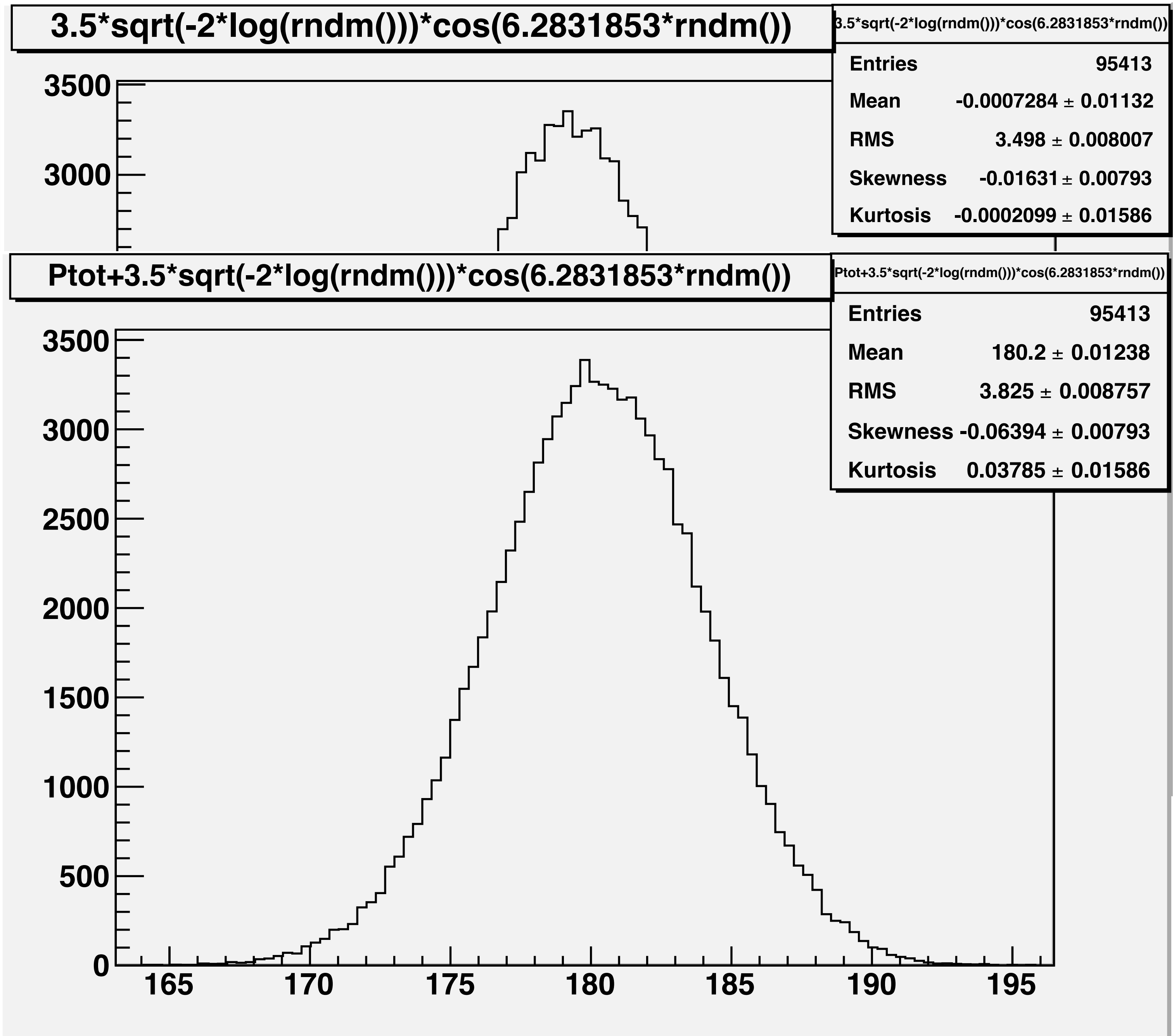
- 100k sample, Gaussian smearing function
  - guess σ ~ 3.5 MeV/*c*
- \+ G4BL "Landau" for 10 cm LiH at p_μ = 200 MeV/*c*
  - RMS, skewness, kurtosis all *significantly* increase



First Look at Precision:

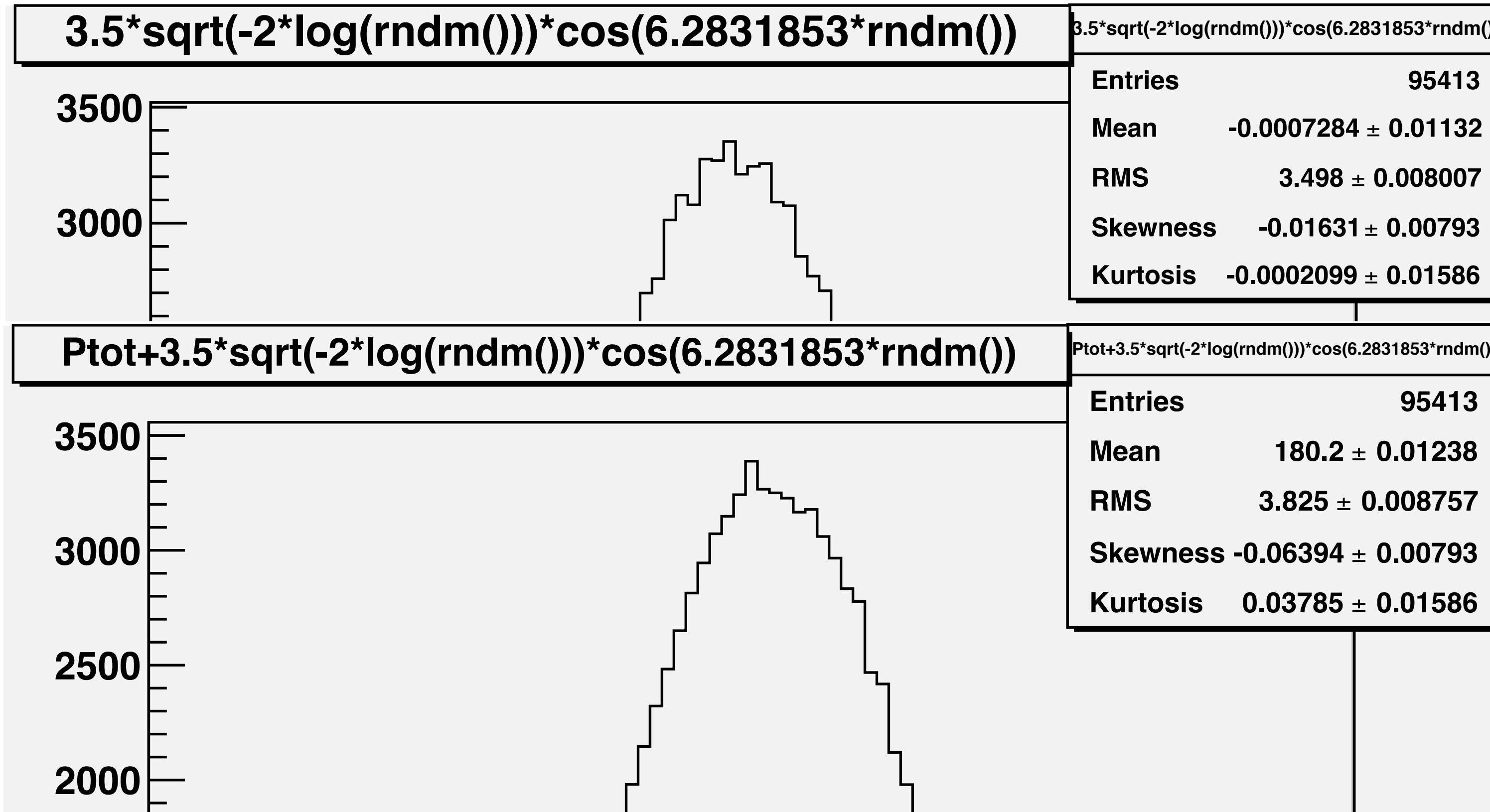
- RMS, skewness, kurtosis all *significantly* increase

Note: Root uncertainty estimates are too simplistic…



First Look at Precision:

- To estimate uncertainties more reliably, threw 5 100k-event samples:



Sample #:	1	2	3	4	5	RMS	
RMS	3.825	3.821	3.813	3.813	3.817	5.22E-03	smaller
Skewness	-0.06394	-0.05331	-0.04494	-0.07102	-0.05477	1.01E-02	bigger
Kurtosis	0.03785	0.03538	0.02587	0.03449	0.02832	5.06E-03	smaller