Luminosity Monitor Status

MICE Collaboration Meeting 27
5 July 2010

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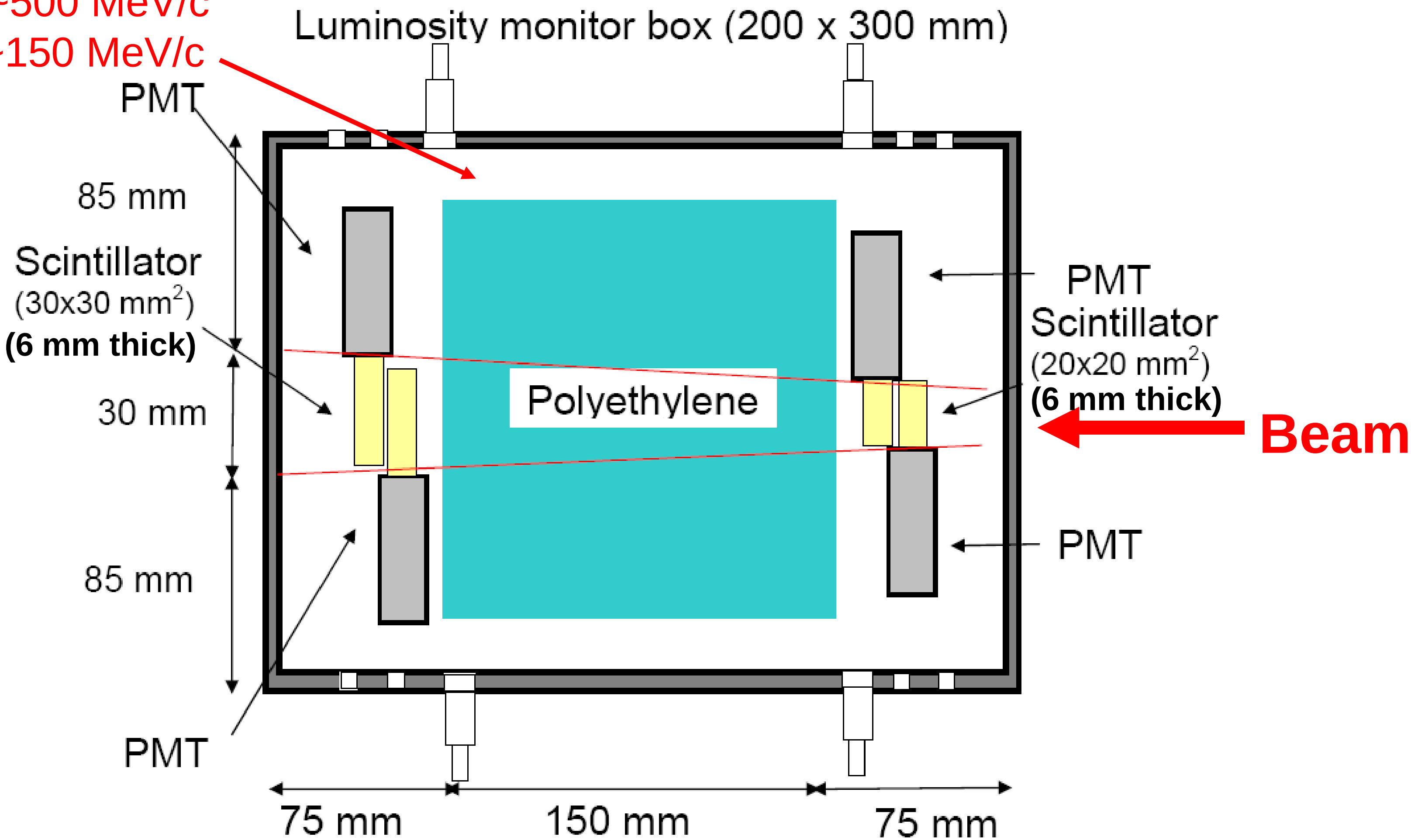
Purpose of Luminosity Monitors

- Luminosity monitor to determine particle rate close to target and extract protons on target as function of depth – independent of beam loss monitors.
- The luminosity monitor was installed and commissioned in the ISIS vault in January and February 2010
- Further test runs to validate the gate width were carried out in April 2010
- The luminosity monitor (LM) is now an integral part of MICE and has been taking data regularly since February
- The LM scaler information is now standard and can be used to normalise all future analyses with a measure that is proportional to the protons on target (POT) and independent of the beamloss (which is written on a separate data stream)
- Meanwhile, simulations to understand and normalise LM to POT are ongoing.

Luminosity Monitor Design

- Final design of luminosity monitor:

Cuts off:
protons ~500 MeV/c
pions ~150 MeV/c



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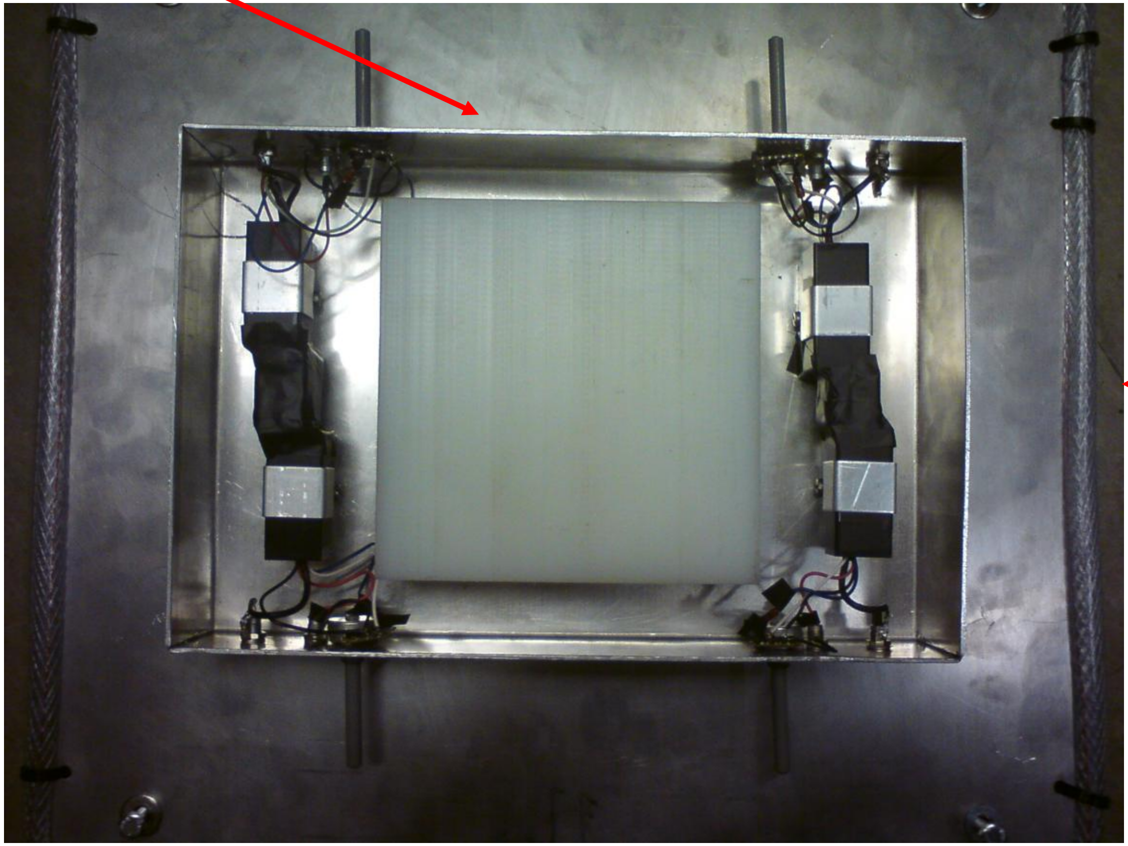
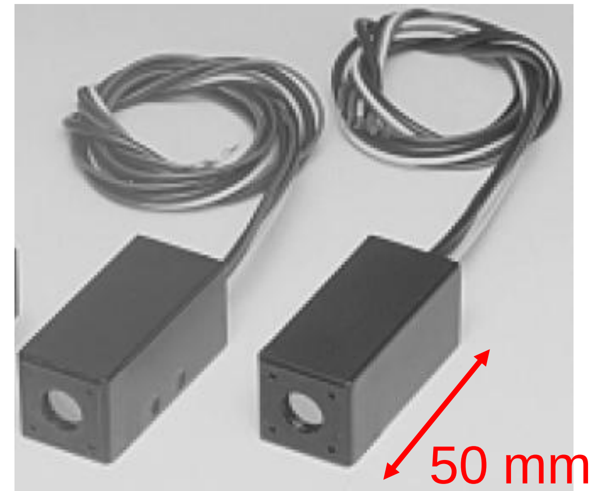
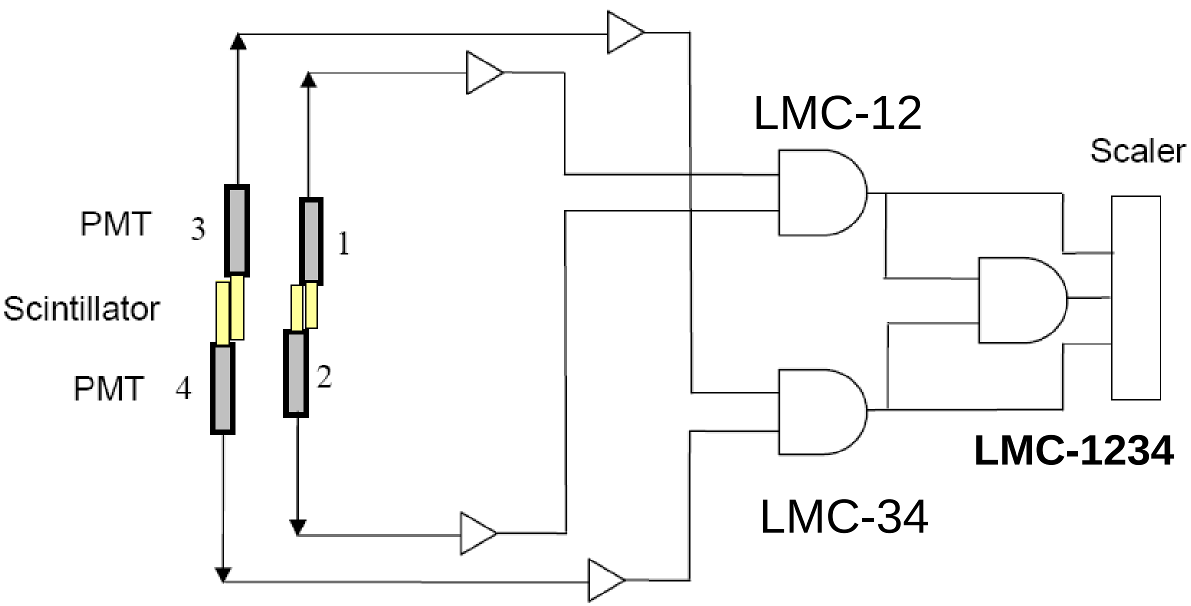


Beam

Photomultipliers

- Use four Hamamatsu H5783P PMTs
- Readout consists of three signals within the 3.23 ms MICE experimental gate:
  - Coincidence 12 (LMC-12) – scaler 08
  - Coincidence 34 (LMC-34) – scaler 09
  - Coincidence 1234 (LMC-1234) – scaler 10





Power provided by two low voltage power supplies:

PMT-1: 10.5 V

PMT-2: 10.7 V

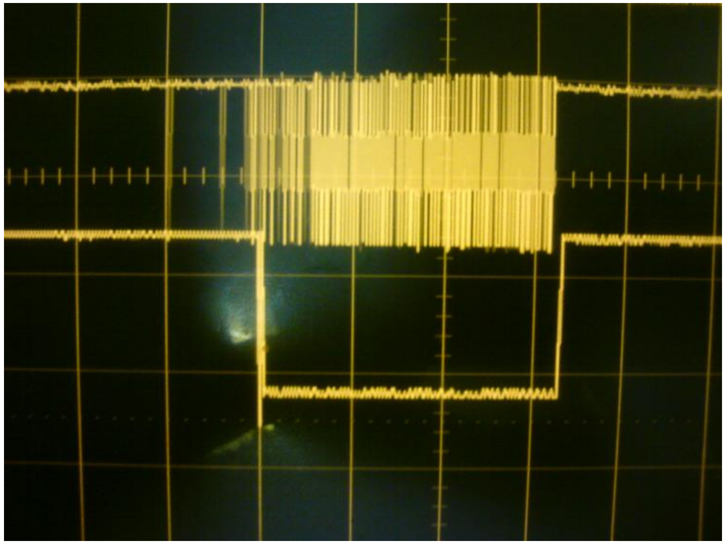
PMT-3: 10.7 V

PMT-4: 10.5 V

Discriminator set at 500 mV: very low noise!

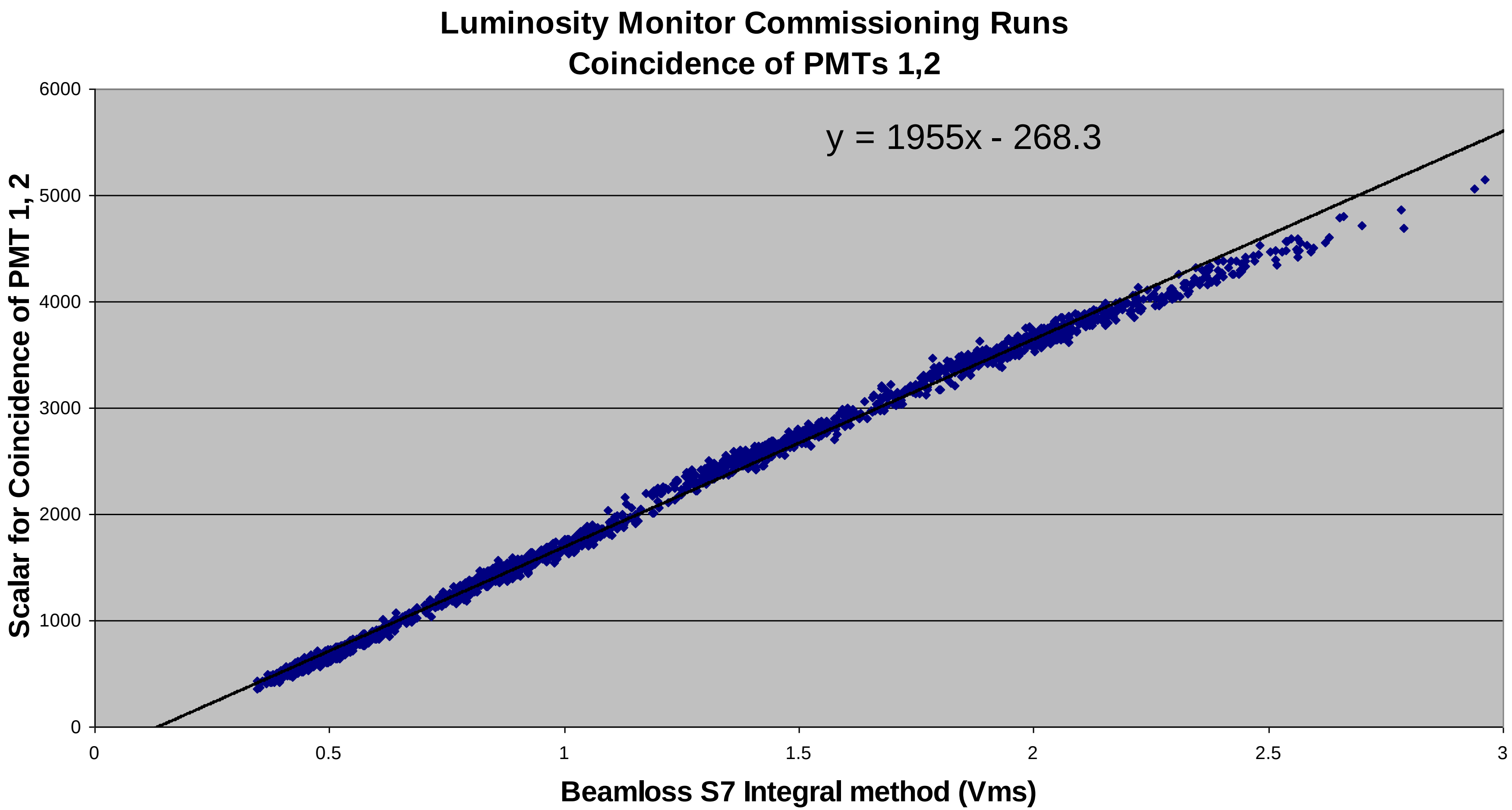
Commissioning Luminosity Monitors

- Commissioning mainly 7 February
- LM signals inside 3.23 ms experimental trigger gate

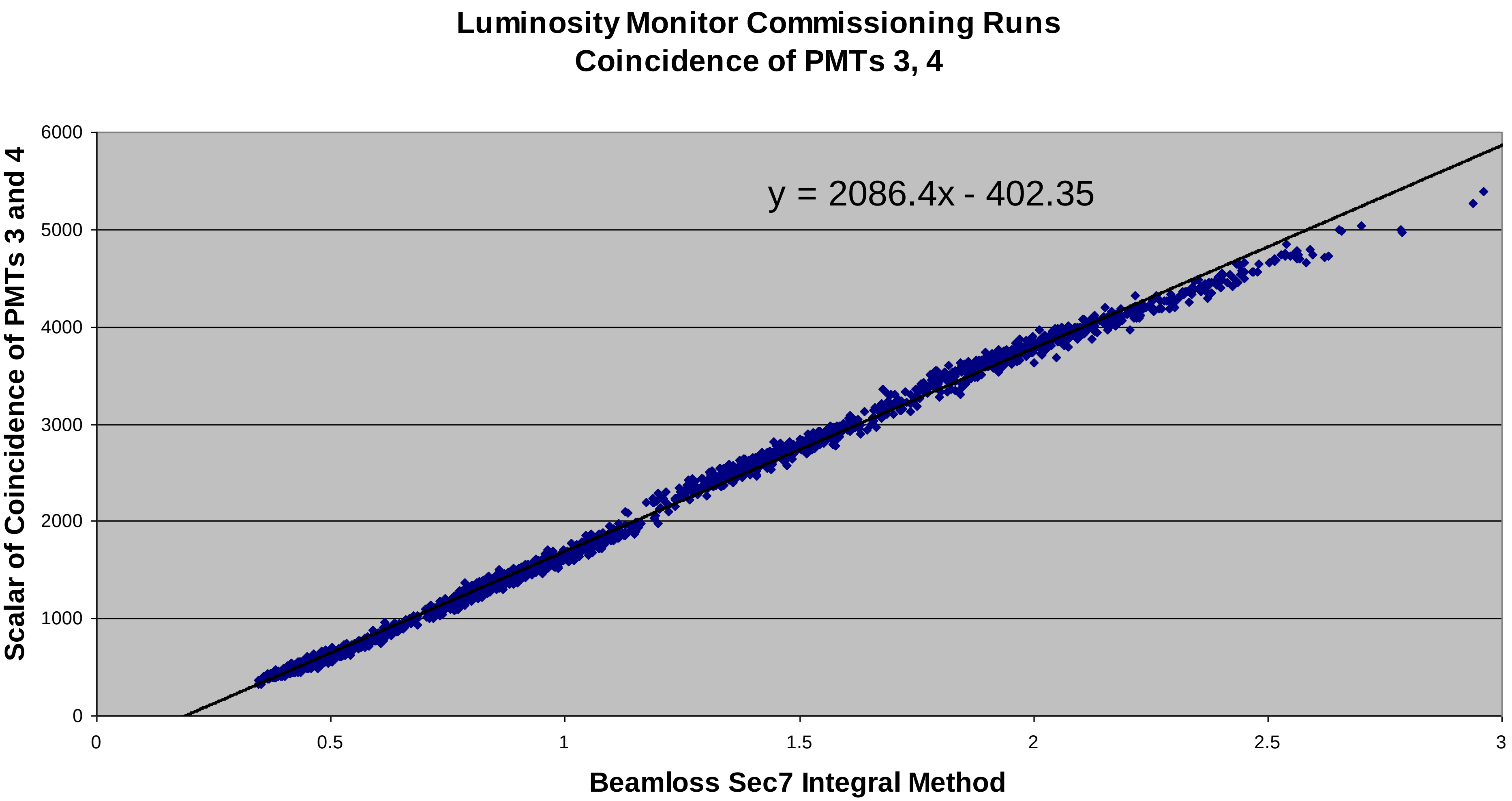


- ISIS bunches 100 ns long and 325 ns separation, so net gate width is 3.23x(100/325) = 1 ms
- In February, set width of LM signals to 40 ns, but concern that gate width too big and may cause saturation at high rate
- In April 20-21 performed runs as a function of gate width to check dependence with gate width (BL limited to <1.4 V)

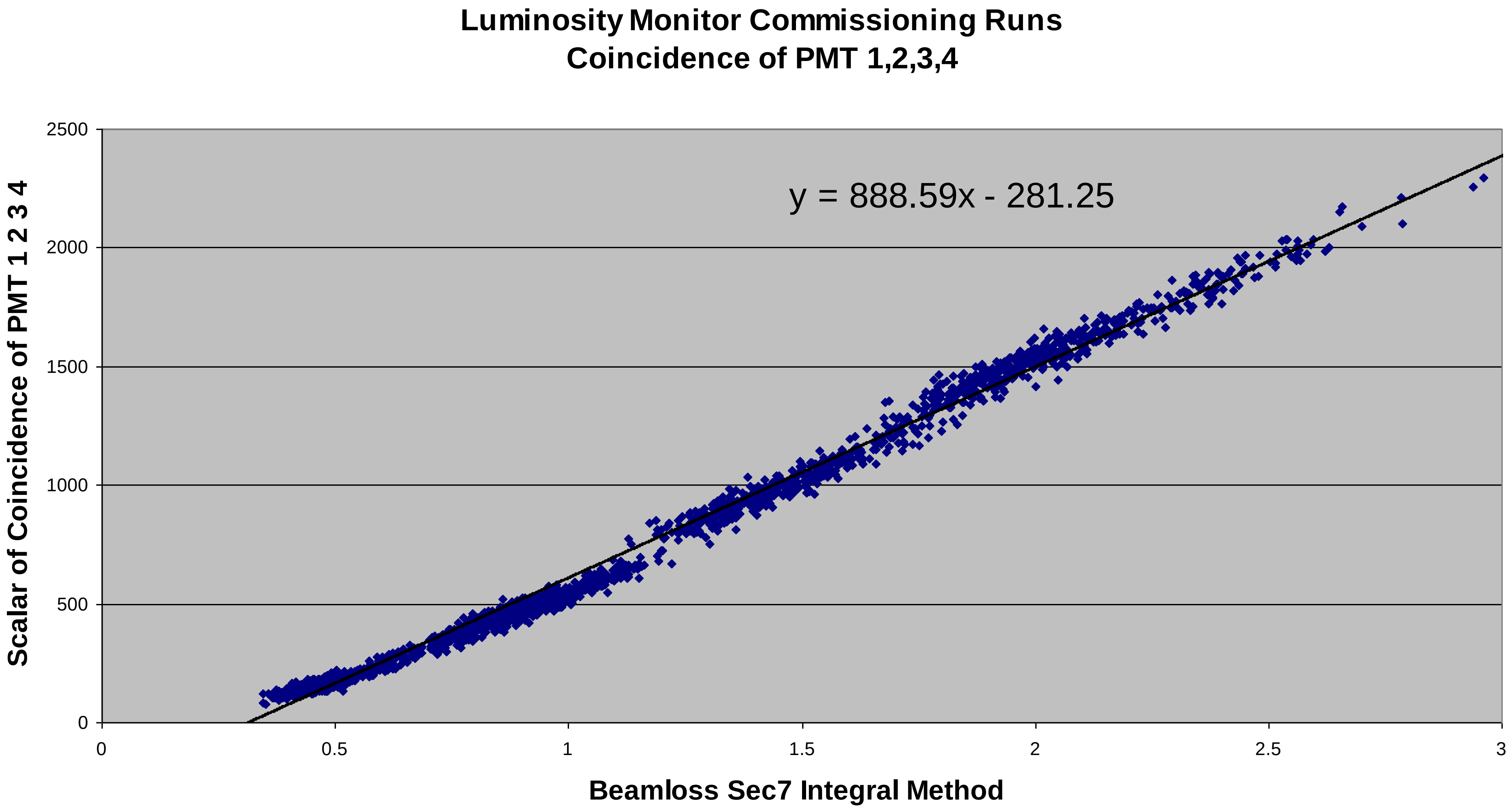
Data taken Feb 2010



Data taken Feb 2010



Data taken Feb 2010



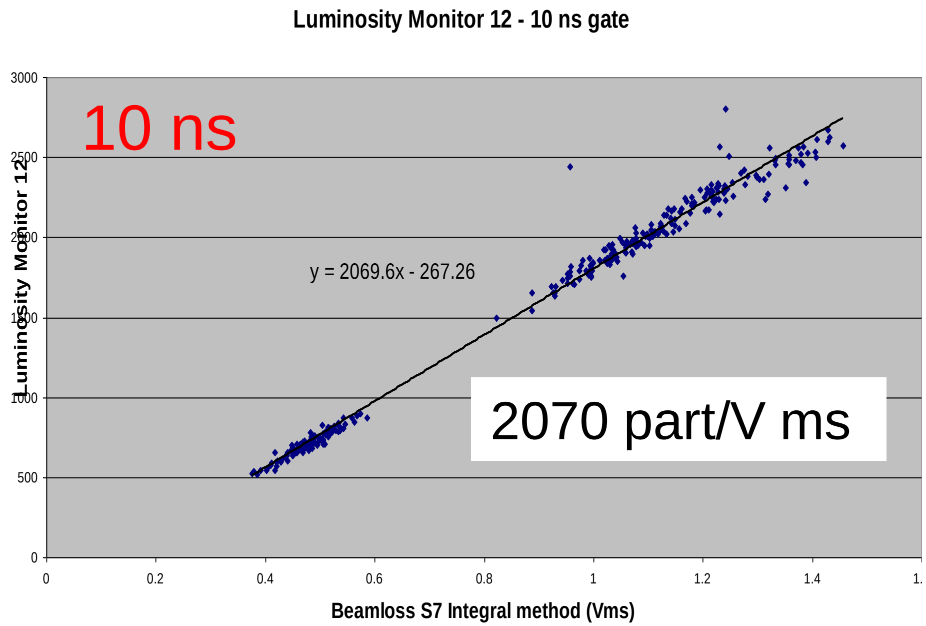
Data taken Feb 2010

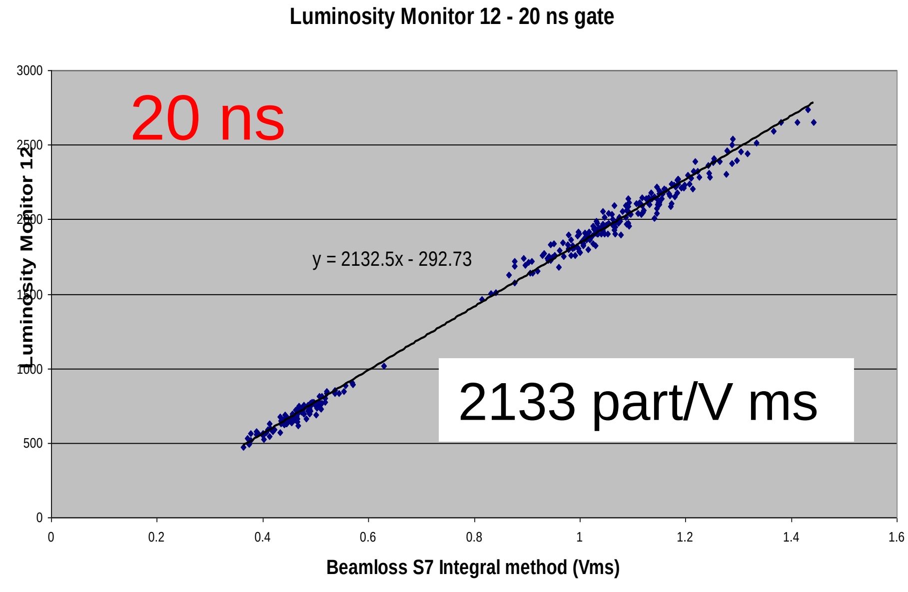
- Summary of results:
  - LMC-12: 1955 particles per V.ms / 4 cm^2
  - LMC-34: 2086 particles per V.ms / 9 cm^2
  - LMC-1234: 889 particles per V.ms / 4 cm^2

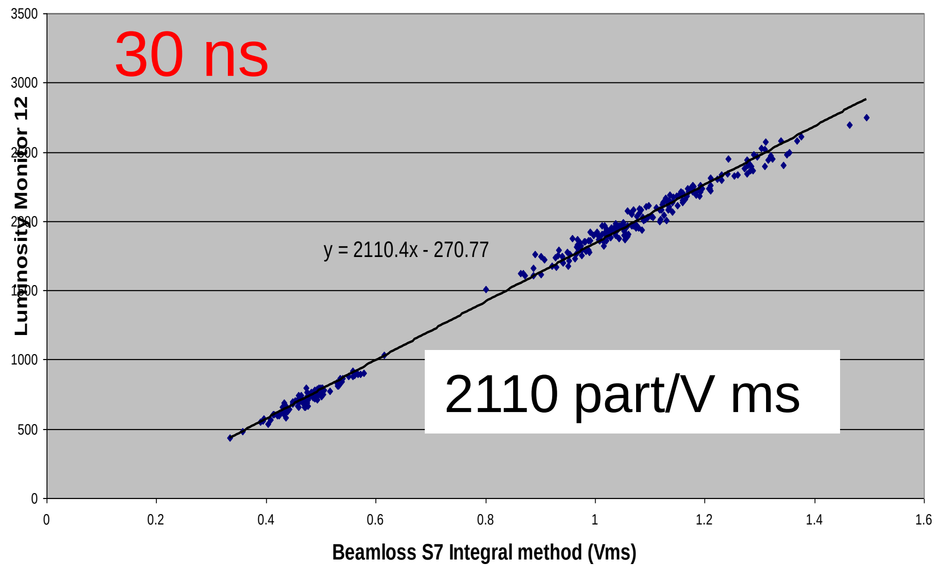
- Assume beamloss calibration of $3.5x10^{-14}$ V.s/pot at 9 ms, therefore: 1 V ms $=2.9x10^{10}$ pot
  - LMC-12: $1.71x10^{-8}$ particles/(pot . cm^2)
  - LMC-34: $0.81x10^{-8}$ particles/(pot . cm^2)
  - LMC-1234: $0.78x10^{-8}$ particles/(pot . cm^2)

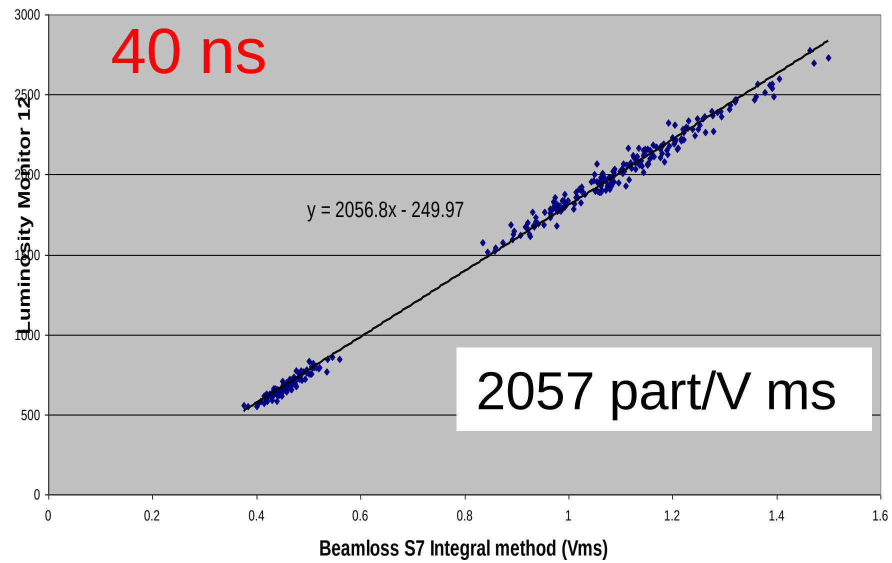
Coincidence 34 and 1234 have same rate per cm^2

Data taken April 2010 – LM12



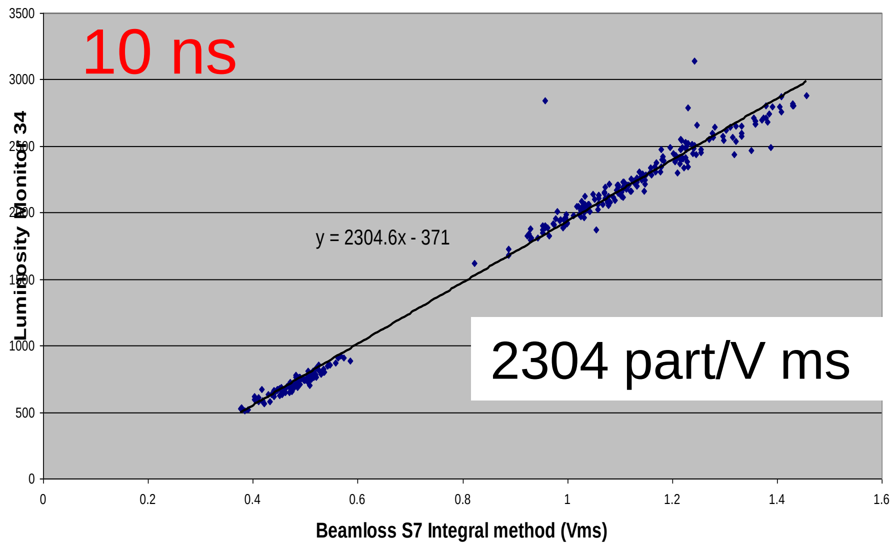




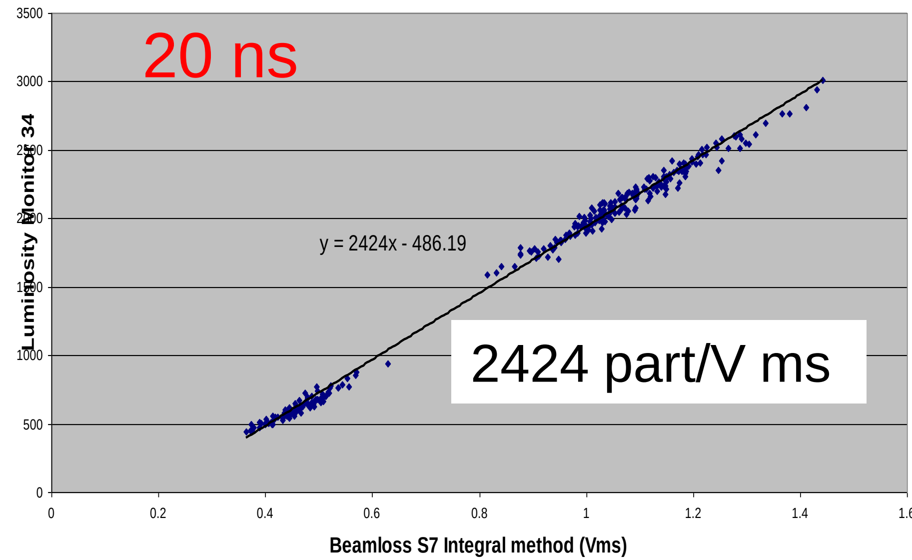


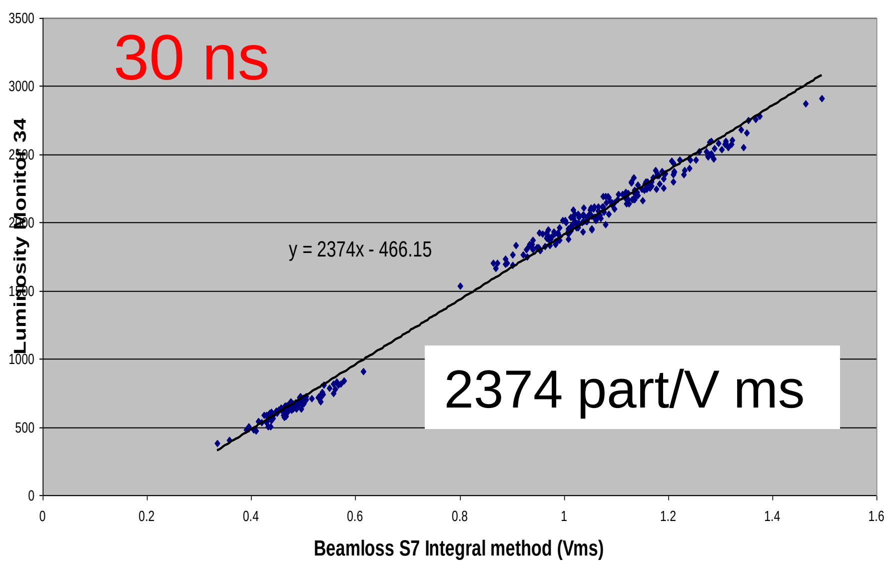
Data taken April 2010 - LM 34

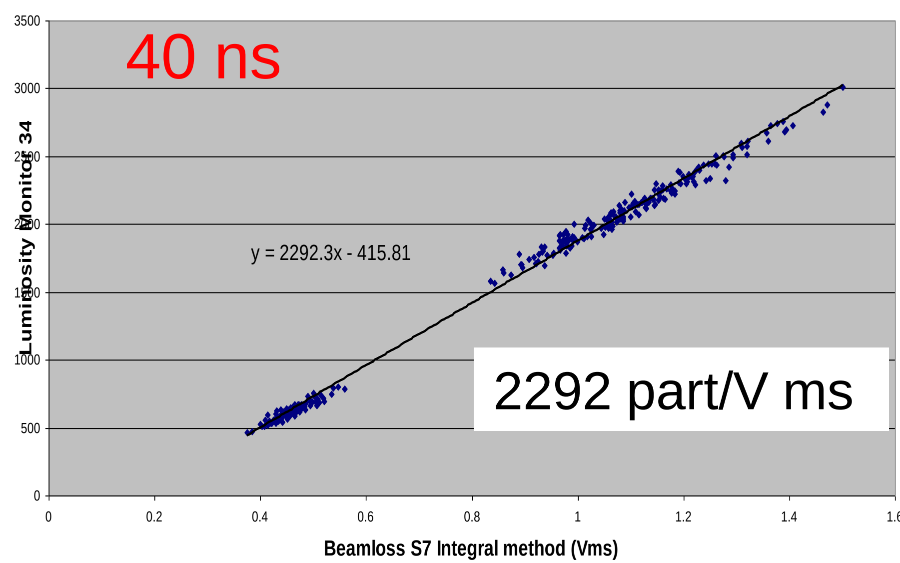
Luminosity Monitor 34 - 10 ns gate



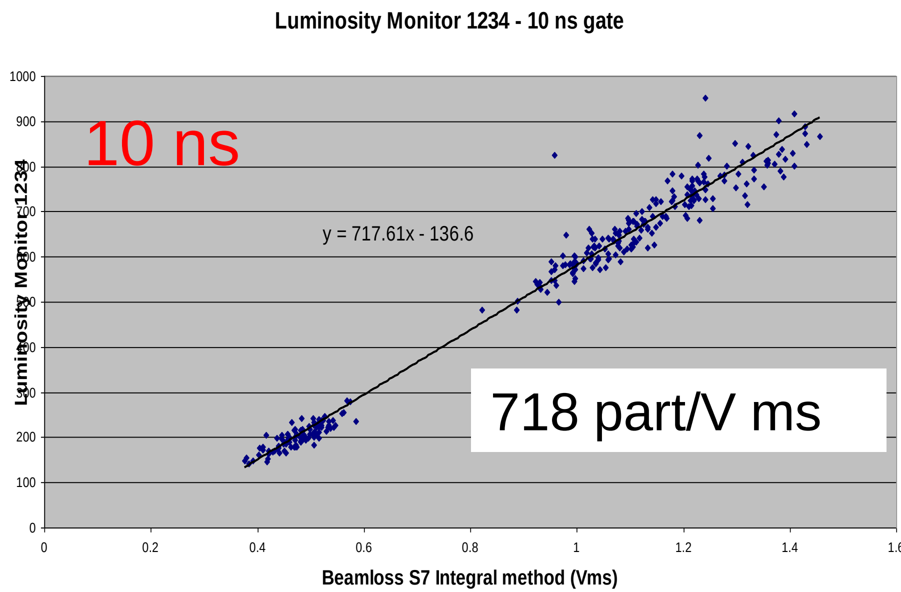
Luminosity Monitor 34 - 20 ns gate

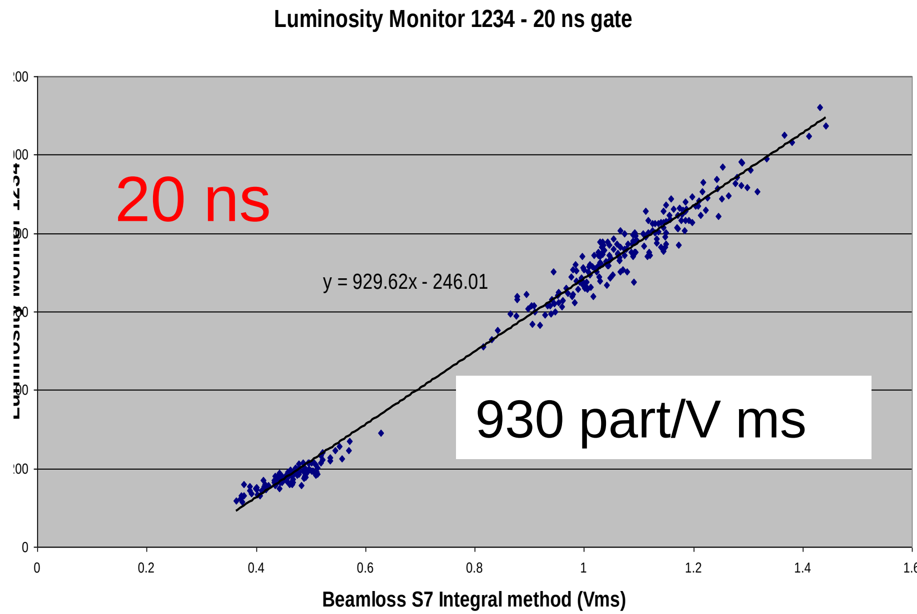


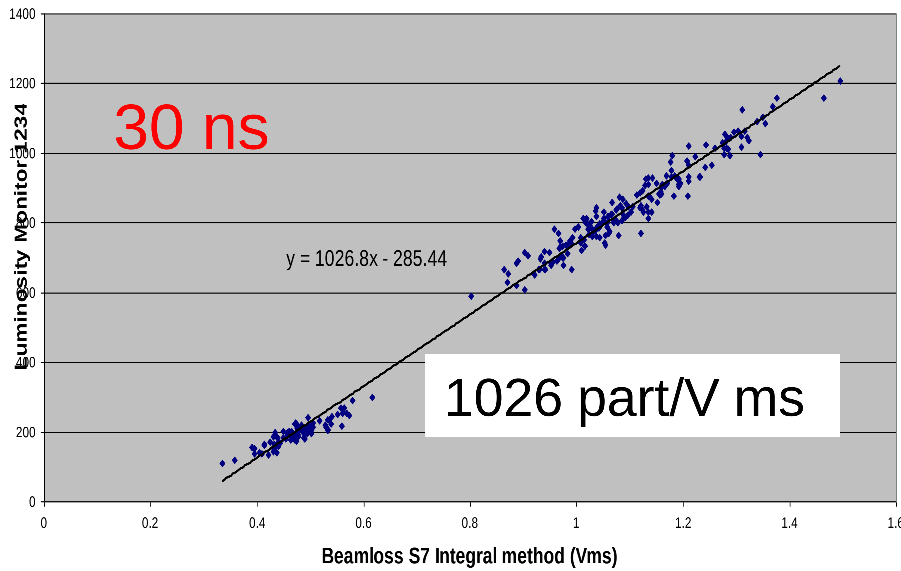


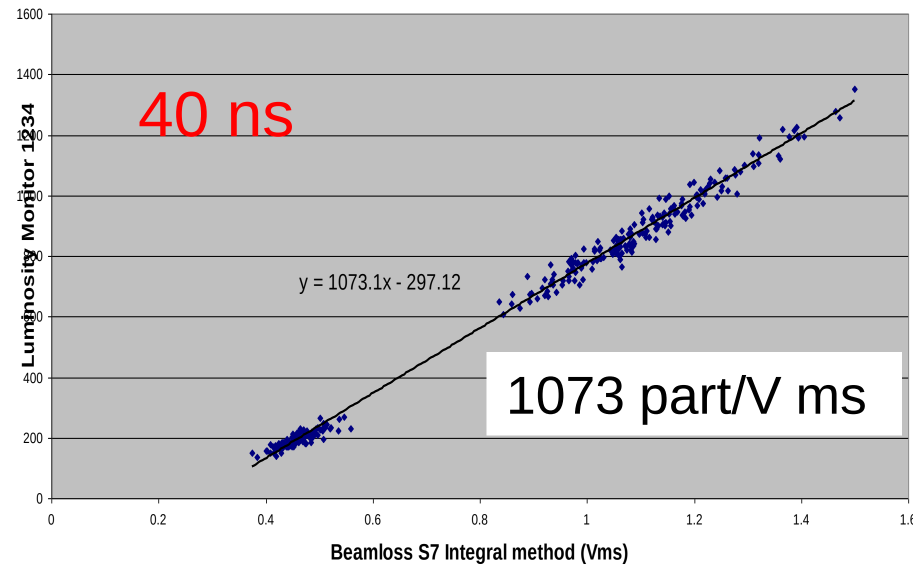


Data taken April 2010 - LM 1234









Data taken April 2010

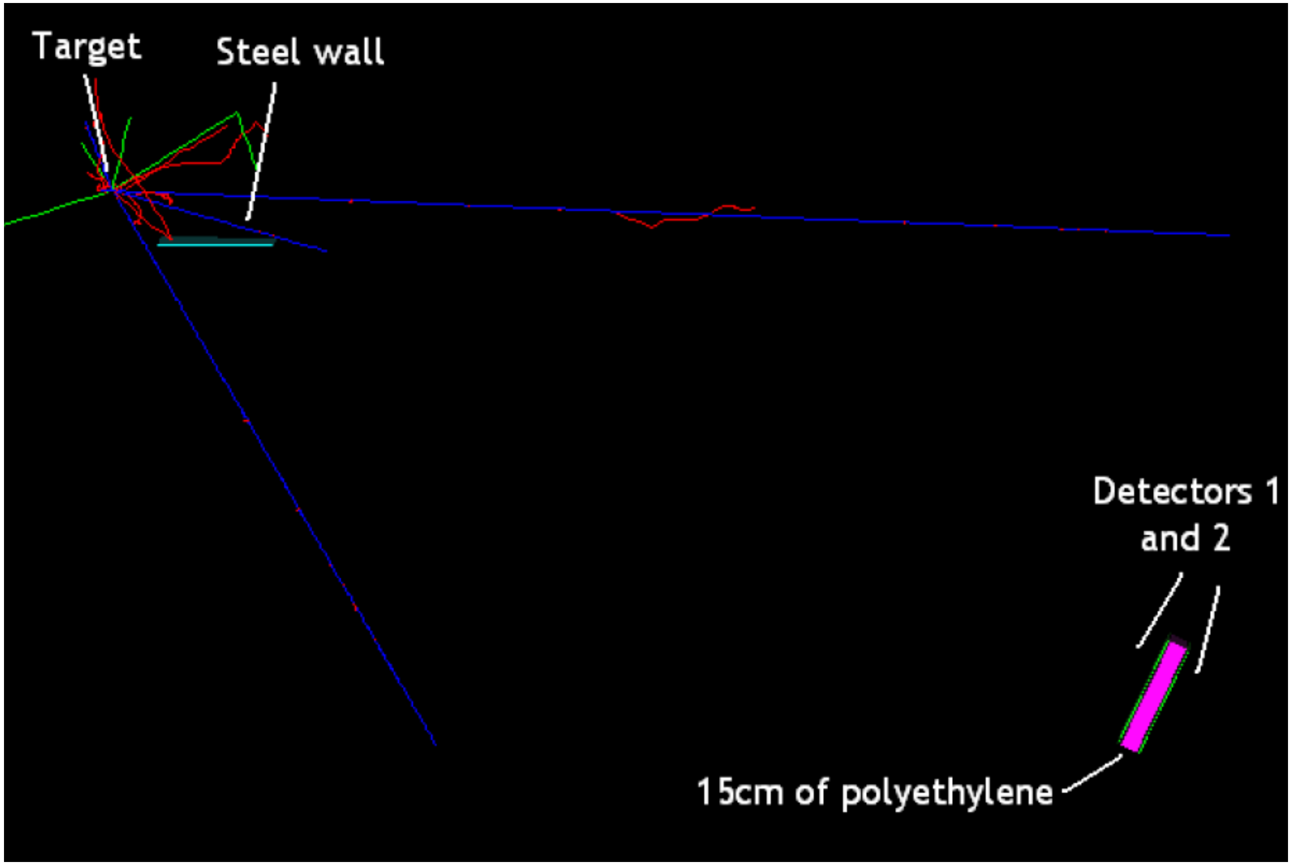
- Summary of results:

Rate vs gate width (ns)	LMC-12 (part/ V ms)	LMC-34 (part/ V ms)	LMC-1234 (part/ V ms)
10 ns	2070	2304	718
20 ns	2133	2424	930
30 ns	2110	2374	1026
40 ns	2057	2292	1073
Average	2092	2349	937
Feb 2010	1955	2086	889

- LMC-12 and LMC-34 seem to be independent of gate width, while LMC-1234 seems to increase with gate width
- Conclusion: set gate at 10 ns to minimise pile-up

Comparison to simulations

- We have run simulations using G4Beamline (D. MacLennan)
- Set up cylindrical target (R=3mm,r=2.3mm), and two detectors 100x100cm^2, separated by 15 cm plastic at 10 m and 25^o angle. Include 6 mm thick steel from target enclosure

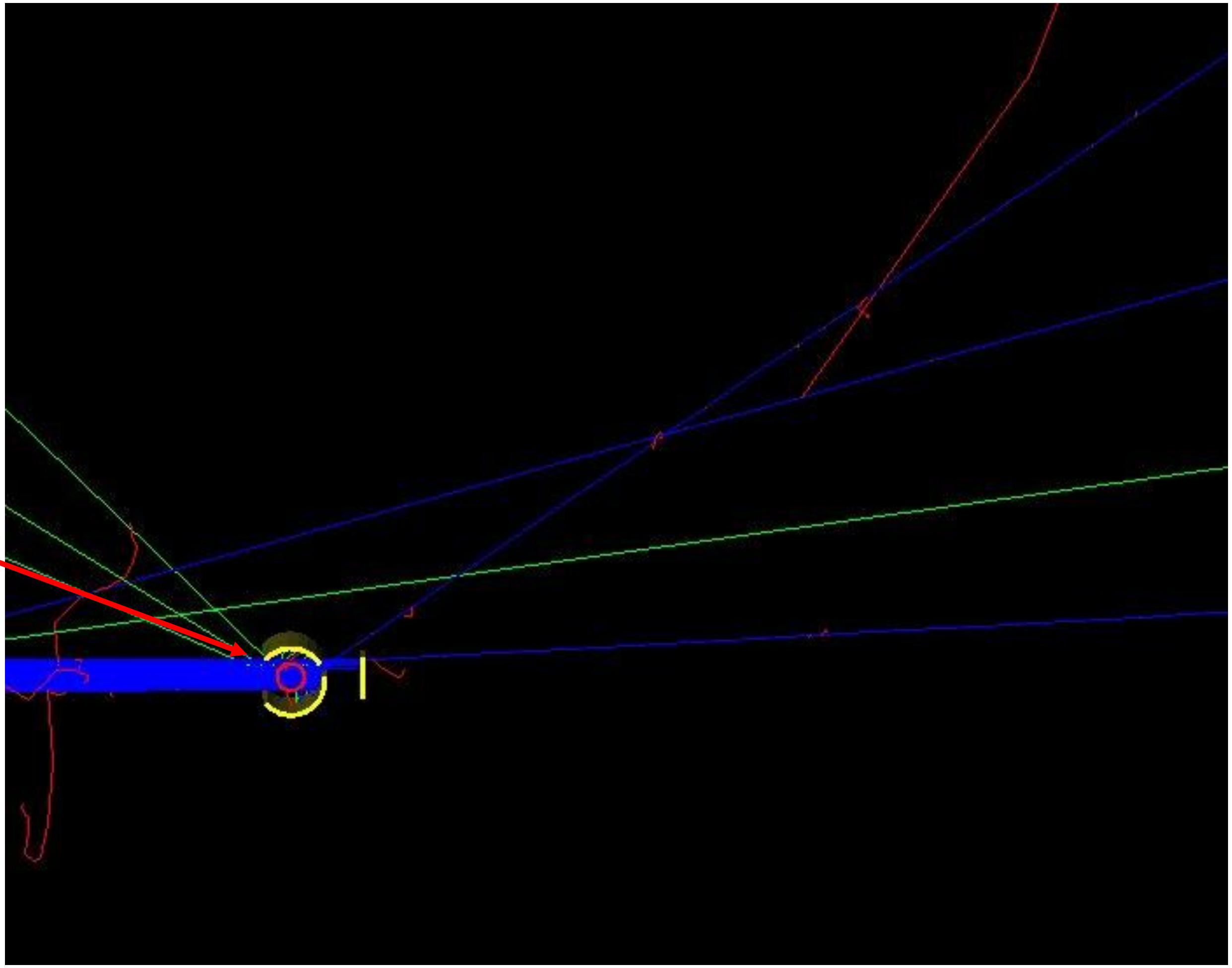


Comparison to simulations

- Only select particles within acceptance of detectors (100x100cm^2 at 10 m) and kill all other particles (yellow volumes)
- Test that we don't kill valid particles by changing kill volumes

Target

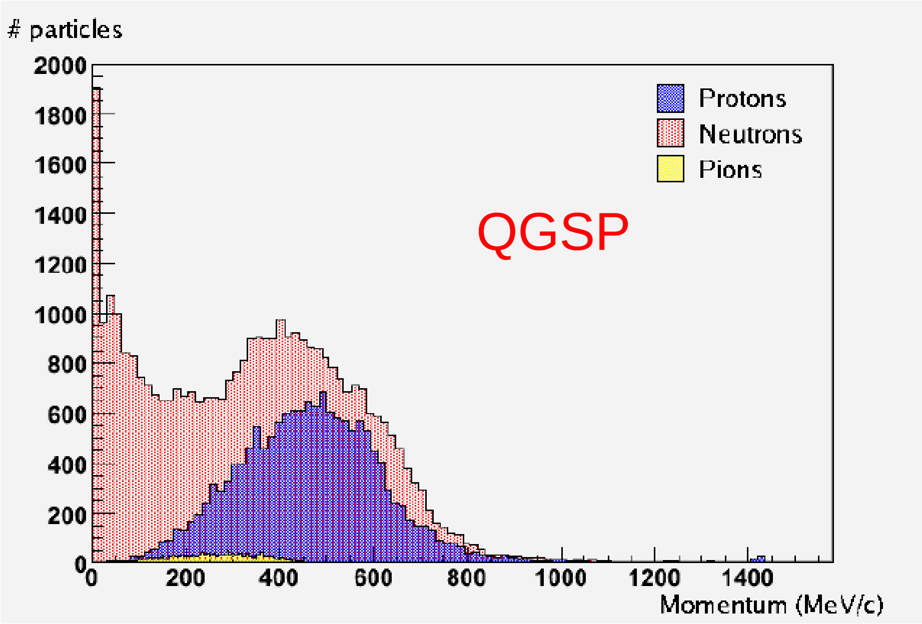
Proton Beam



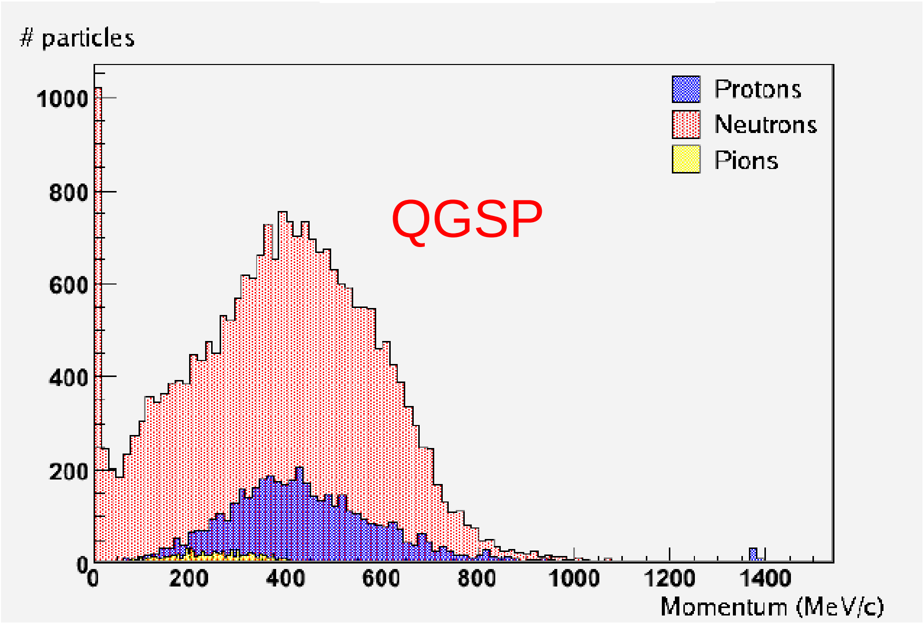
Comparison hadronic models

- Only select particles within acceptance of detectors ($100x100cm^2$ at 10 m) and kill all other particles
- First run with QGSP hadronic model

Unshielded detectors



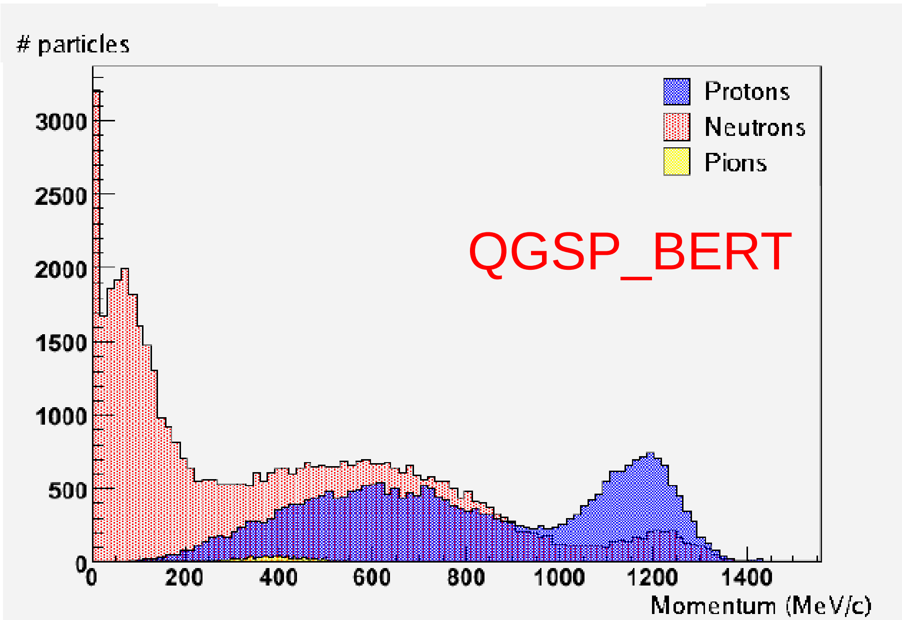
Shielded detectors



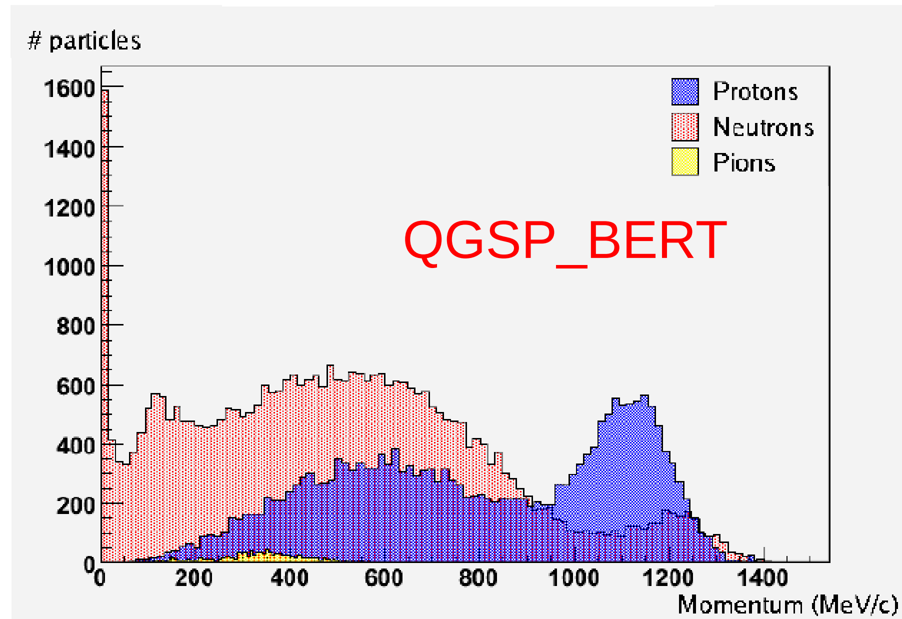
Comparison hadronic models

- Only select particles within acceptance of detectors (100x100cm^2 at 10 m) and kill all other particles
- Now run with QGSP_BERT (QGSP+Bertini cascade model) for comparison – shows proton peak at ~1200 MeV/c

Unshielded detectors



Shielded detectors



For total particle yields: assume neutron efficiency from GEANT4 simulations ~2.2%

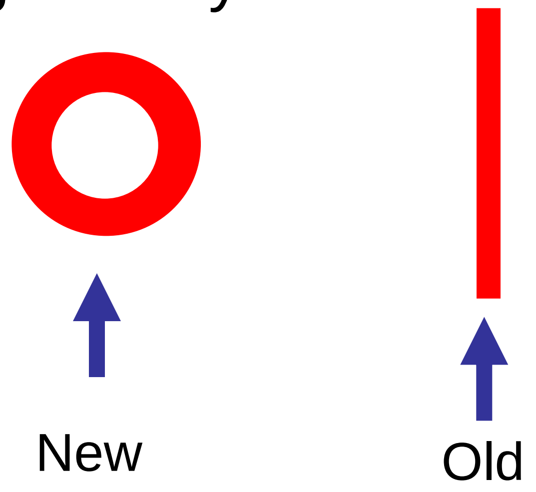
Comparison hadronic models

- Compare number particles (proton+pion+neutronx2.2%) crossing detectors for hadronic models (up to a factor 2):

Hadronic model	**Number particles in unshielded detector**	**Number particles in shielded detector**	**Particles/ (pot cm^2) Unshielded**	**Particles/ (pot cm^2) Shielded**
LHEP (10^7 pot)	183	74	(1.83 0.14)x10^{-9}	(7.40 0.86)x10^{-10}
LHEP_BERT (10^7 pot)	342	257	(3.42 0.19)x10^{-9}	(2.57 0.16)x10^{-9}
QGSC (10^7 pot)	192	67	(1.92 0.14)x10^{-9}	(6.70 0.82)x10^{-10}
QGSP (10^7 pot)	157	57	(1.57 0.13)x10^{-9}	(5.70 0.76)x10^{-10}
QGSP_BERT (10^9 pot)	31145	22911	(3.12 0.02)x10^{-9}	(2.29 0.02)x10^{-9}
QGSP_BIC (10^9 pot)	27380	21693	(2.74 0.02)x10^{-9}	(2.17 0.02)x10^{-9}

Comparison target geometry

- Compare number protons crossing unshielded detector (10^4 cm^2) for the new target (cylinder with outer radius 3 mm and inner radius 2.3 mm) compared to the old target (10 mm x 1 mm) geometry



- Volume material in each target is very similar (assume depth inside beam=10mm):
  - Old target: 10x1x10 mm^3
  - New target: $\pi(3.0^2-2.3^2)$x10=116.7 mm^3

Comparison target geometry

- Compare number protons crossing unshielded detector (10^4 cm^2) for two target geometries (using QGSP_BIC)

Target geometry	**Number particles in unshielded detector**	**Protons on target (pot)**	**Area detector (cm^2)**	**Protons/ (pot cm^2)** **Unshielded detector**
New	27380	10^9	10^4	(2.74 0.02)x10^{-9}
Old	3639	10^8	1600	(2.27 0.04)x10^{-8}

- There is a factor of 8.31 difference in normalisation,
- Old target has 10 mm thickness
- New target has variable thickness due to geometry of cylinder (effective average thickness 1.945 mm=116.7/60)
- Another simulation was run to determine fraction of particles interacting in each target:

$$\frac{Old}{New} = \frac{0.0422}{0.0051} = 8.27$$

(therefore net number of pot in new target is 8.27 times smaller!)

Comparison to simulations

- Assume all protons on target traversing 10 mm target are lost in ISIS (9 MeV E_{loss}), so for new target simply multiply by 8.27 (ratio of old/new)

Hadronic model	Particles/ (pot cm^2) Unshielded	Particles/ (pot cm^2) Shielded	Ratio Shielded/ Unshielded
LHEP	1.51×10^{-8}	6.12×10^{-9}	0.41
LHEP_BERT	2.83×10^{-8}	2.12×10^{-8}	0.75
QGSC	1.59×10^{-8}	5.54×10^{-9}	0.35
QGSP	1.30×10^{-8}	4.71×10^{-9}	0.36
QGSP_BERT	2.58×10^{-8}	1.89×10^{-8}	0.73
QGSP_BIC	2.27×10^{-8}	1.79×10^{-8}	0.79
Data	1.71×10^{-8}	8.10×10^{-9}	0.47

- No model describes data accurately (not even ratio is well described)
- However, to do normalisation more accurately would need to determine number of protons lost in ISIS when target is traversed by beam

Conclusion

- Luminosity Monitors have been installed in ISIS vault and are now working regularly for MICE analyses
- LM data scales very well with beam loss data
- Up to ~1.4 V.ms beamloss, LM rate independent gate width 10 ns-40 ns (have chosen 10 ns as final width)
- Comparison of yields for different hadronic models shows big differences in yields (about a factor of 2)
- Normalisation of simulations for cylindrical target are about a factor of 8 smaller than the data, due to the fact that not all protons interact in target.
- Need to understand how protons are lost to the beam better to do a proper comparison of LM data to simulations