Beam-Line Status

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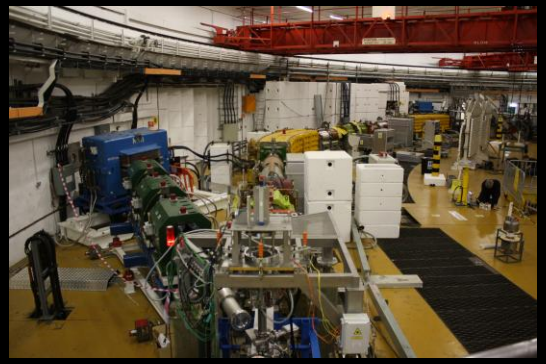
- Beam Line
    - detectors used in BL characterization
- Data Taking
- Software
- STEPI
- Remarks
    - post partum
    - 5 months to go …
- Paper Plans
- Conclusions

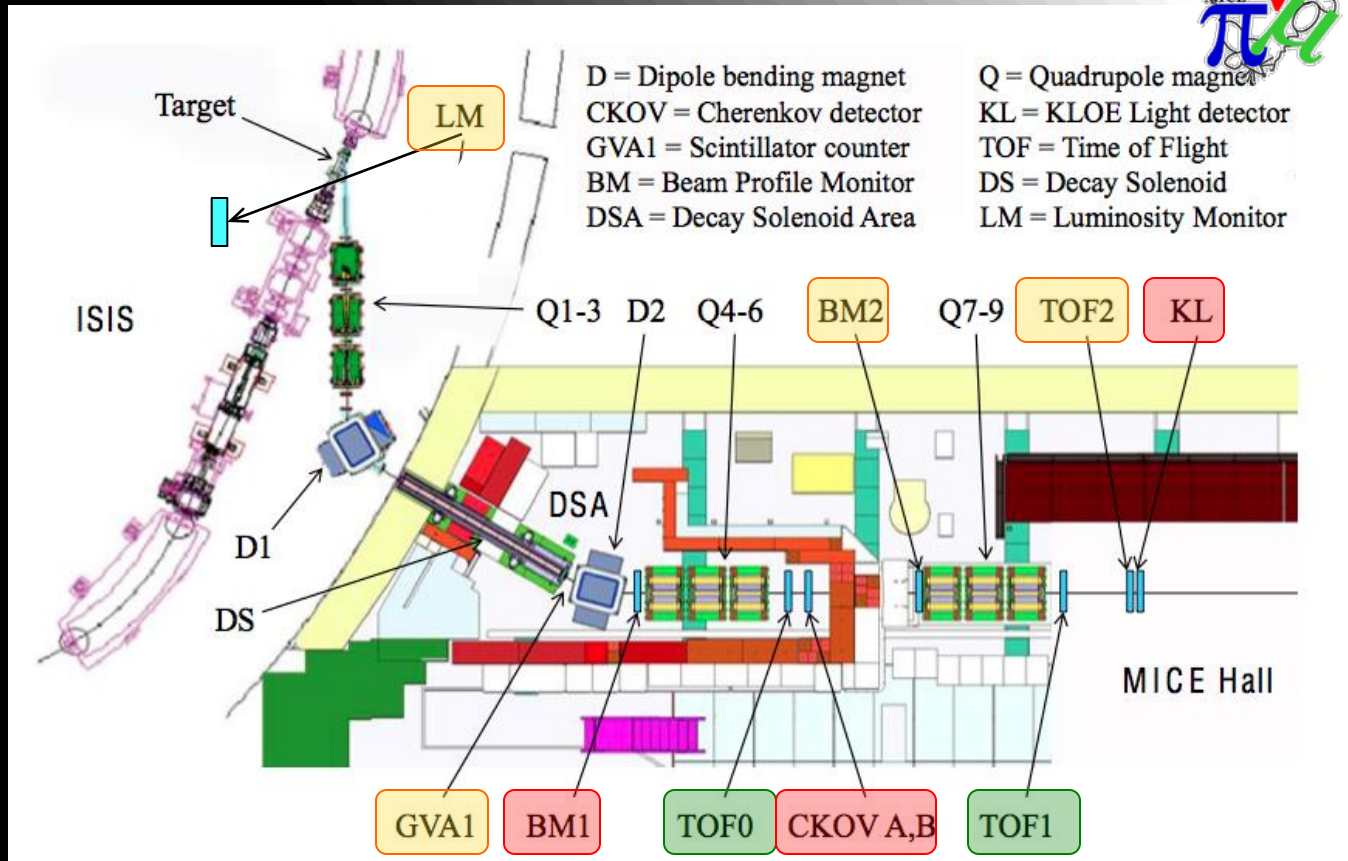


- TOF0, 1
beam characterization (shape, phase space)

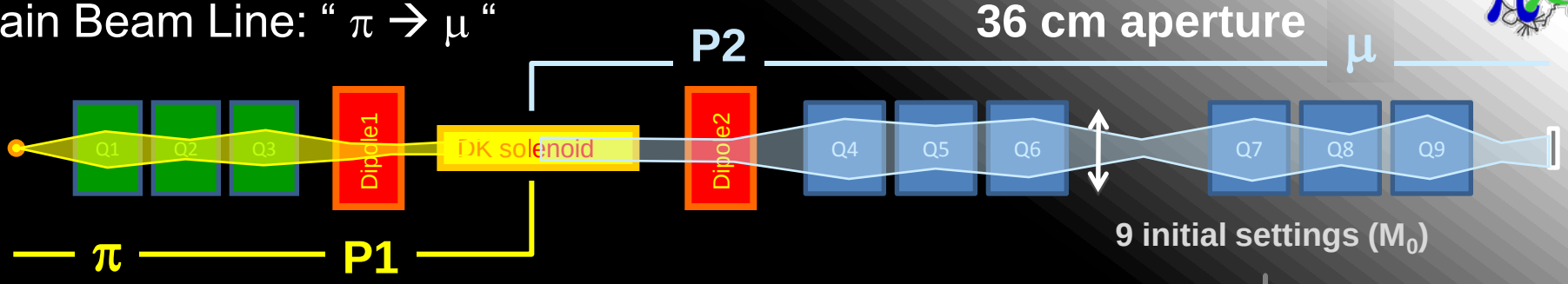
- LM, GVA1, BM2, TOF2
beam rate

- BM1
unused for this analysis
- CKOVa,b, KL
MICE PID

Observations:
TOF2 can be naturally introduced in this characterization
Any scope for KL/CKOV?
Any need for BM1?



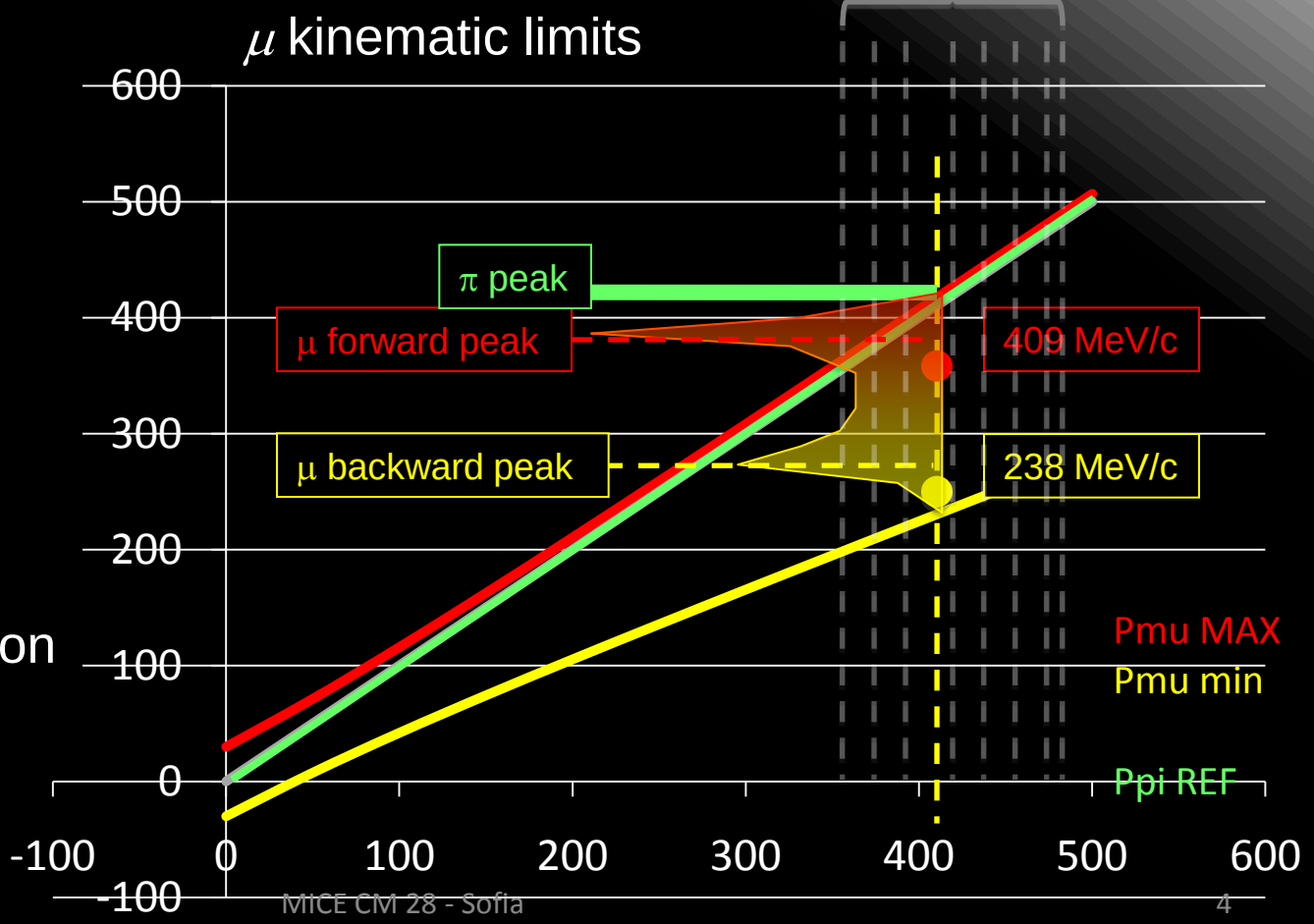
Main Beam Line: " π → μ "



Combine D1 & D2:
P1 ~ 2 x P2

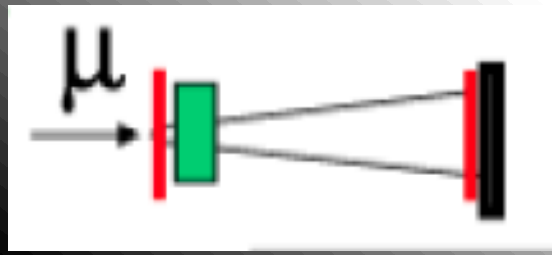
used to enhance
μ purity

P1 ~ P2 for pion/electron
beam calibrations



Data Taking Campaign [15/6/2010 – 15/8/2010]

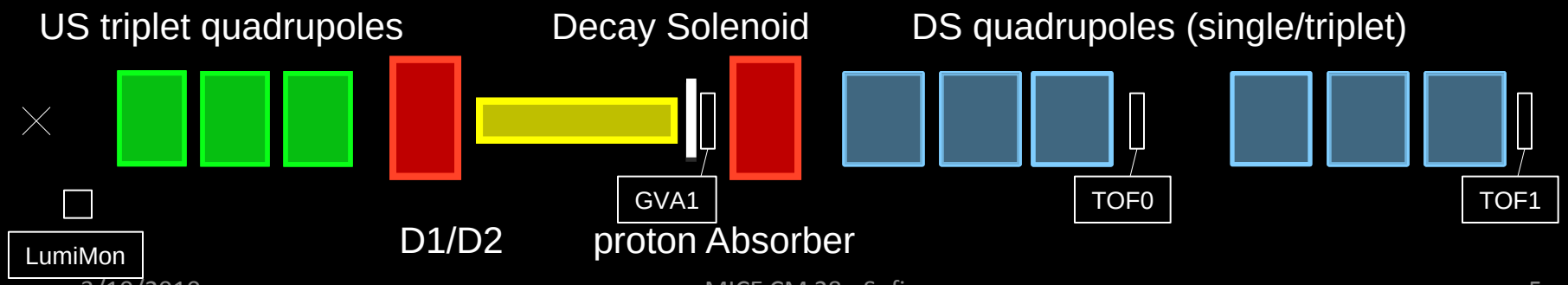
- *STEP I completion*
- Machine Physics [15/6 – 16/6]
  - Beam Rate vs. Target Depth studies [$V_{MAX} \approx 4V$]



- Users Run [19/6 – 12/8]
  - US quadrupoles/triplet scans [optimization of π production]
  - DS quadrupoles/triplets scans
  - dipoles scans (check momentum scale) <<< not as many as we would like to D2[2270-2278]
  - Decay Solenoid scan
  - single DS-quadrupole scan [phase advance study]
  - (ε,P) matrix runs
  - DAQ tests
  - OnLine optimization tests

Over 340000 target actuations / over 11M triggers / 917 runs
Beam Line set at several optics configurations

- Machine Physics [13/8 – 15/8]
  - Beam Rate vs. Target Depth studies [$V_{MAX} \approx 10V$]



Logbook Sanity
- how things can go wrong with cut ‘n’ paste

Run Numbers	Momentum at Tgt (MeV/c)	Momentum at D1 (MeV/c)	Momentum at D2 (MeV/c)	Q1	Q2	Q3	D1	DS	D2	Q4	Q5	Q6	Q7	Q8	Q9	Beamline Polarity	
2275	408.60	405.27	238.00	102.38	127.91	89.00	323.15	668.63	94.15	158.10	212.02	140.57	138.67	209.82	179.18	-	Reference settings with Q3
2276	408.60	405.27	238.00	102.38	127.91	89.00	323.15	668.63	94.15	158.10	212.02	140.57	138.67	209.82	179.18	-	Reference settings with Q3
2277		405.27	238.00	102.38	127.91	89.00	323.15	668.63	94.15	158.10	212.02	140.57	138.67	209.82	179.18		
2278	408.60	334.94	194.86	84.65	105.74	73.56	257.79	552.52	77.77	129.23	173.30	114.82	108.58	164.18	140.05		140 MeV/c 10pi beam
2279	408.60	334.94	194.86	84.65	105.74	73.56	257.79	552.52	77.77	129.23	173.30	114.82	108.58	164.18	140.05		140 MeV/c 10pi beam

- this case is simple: D1 allows to work back the right momentum
  - if we believe D1 reported here is correct
  - otherwise we need to access the DB
  - in this specific case, PD1 (DB) is also worng (405)
- there are 9/51 cases in some of the matrix runs
- we took 917 runs …
- we need to go report/correct and fix the right optics
  - we need to version the xcel file …
- don’t have a clear efficient idea

Analysis Topic	description	person	comments
QUALITY			
TOF0, 1 quality	calibration stability over time	MR, EC	ongoing
DQ: μ-peak	μ peak shape for reference runs	EC	done?
DQ: e-peak	e peak position and width for all runs	MR, EC	done?
DQ: neutrals	beam composition study	RF	done?
DQ for Reference Runs	Study of PMT response on TOF0,1,2	SB	ongoing
BEAMLINE SETUP			
Proton Absorber	effect of polyethylene slabs on (+) BL	CR	done?
SCANS (understanding the beamline)			
DS Q scan	Ph.Sp. evolution vs single quad excitation	EC, MA	ongoing
DK Sol scan	Effect of DK excitation on d.s. line	EC	done
Q456 / Q789 scan	beam variation with current	SB, MA, CR	ongoing
Response Matrix	Twiss Parameters dependence from Q-currents	?	to be started
MATRIX STUDIES			
M0 / M1 / M2	Impact of (ε,P) matrix on MICE	MA, MR, …	ongoing
SIMULATION			
MC production	G4beamline simulation of the beamline	MA,CR,MR	ongoing, to be optimized
G4MICE - BL	Extension of G4MICE code to the beamline region	ML, …	ongoing

Analysis of DATA (G4MICE)

-TofTree.cc :

extract basic info from raw data
create .root file for next step
cards: *geometry* & trigger station

-TofTrace.cc:

build the PhaseSpace
reconstruct Momentum
cards: *geometry & trigger station & Q7.8.9 currents (*)*

Comparison with MC (G4Beamline)

simulate BL from TGT to diffuser
current conversion to T or T/m via script
(CR script can also read directly from the RunSummary)
produce output at z-planes (e.g. TOF1US)

(*) reproducibility is an issue
PhSpace depends on P-cuts !

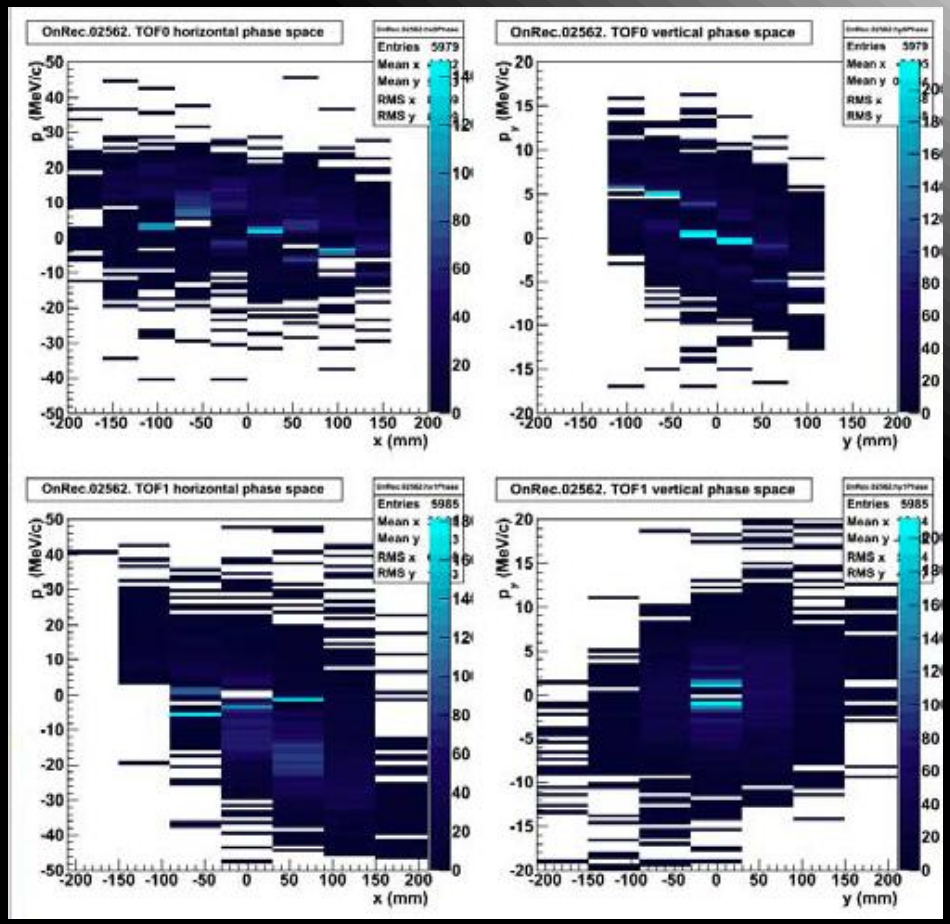
On Line Reconstruction

- Based on TOF0,1
- tracks reconstructed
- phase – space incrementally displayed on-line

(x,Px) (y,Py)

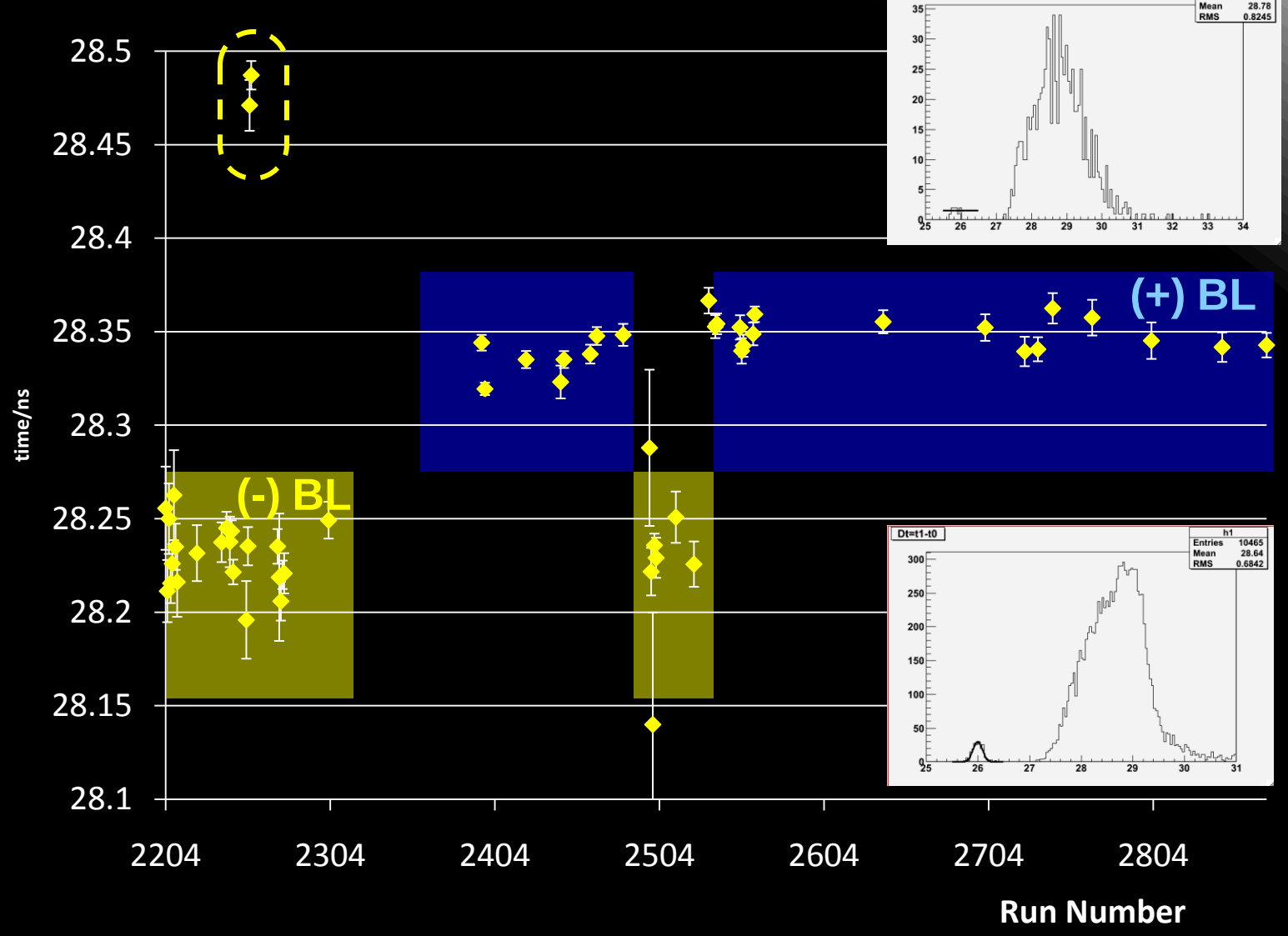
TOF0

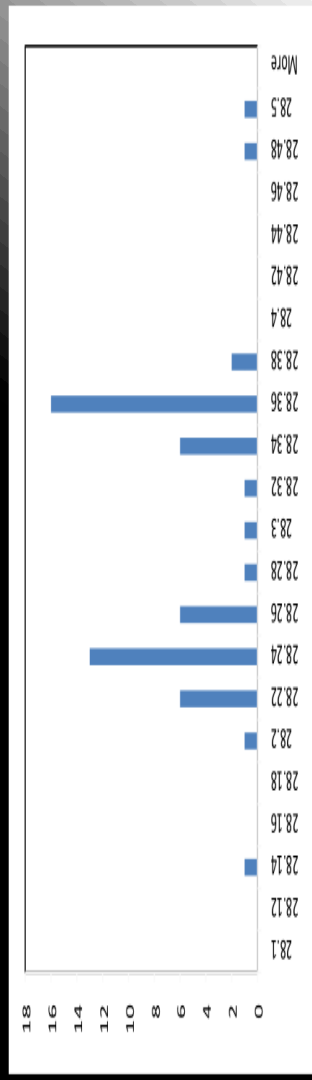
TOF1



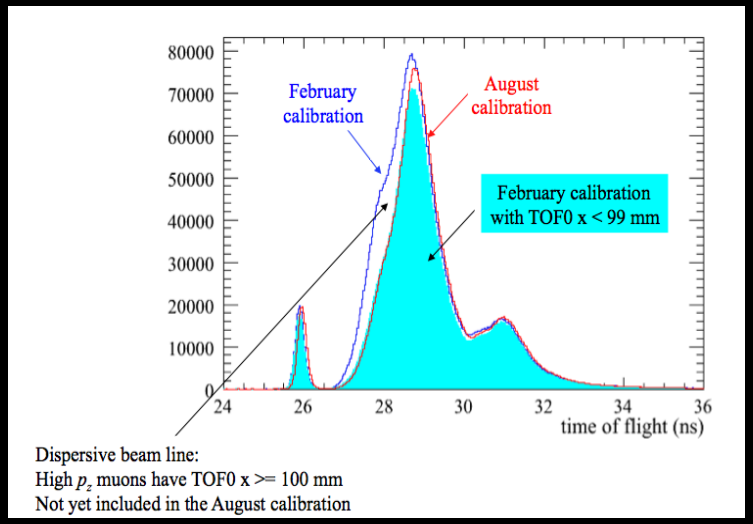
Data Quality

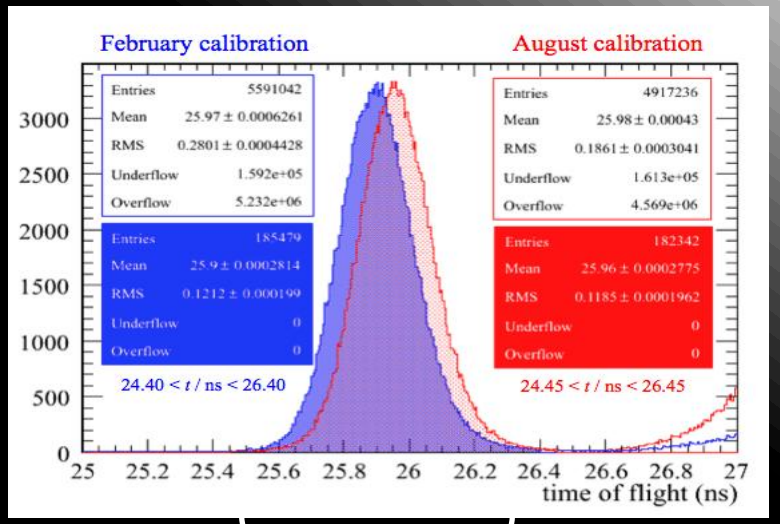
- study of muon peak position in Reference Runs (defined optics)



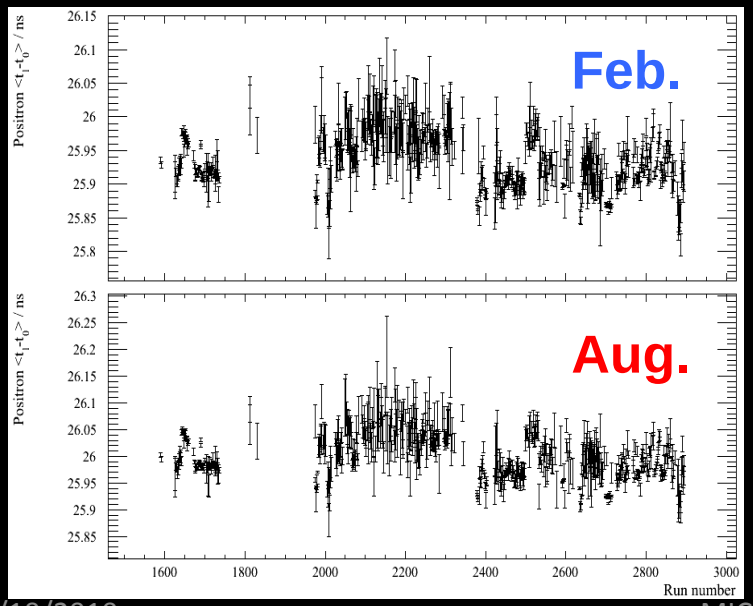


Data Quality
- Systematic Check of TOF0,1 calibration over the entire run sample



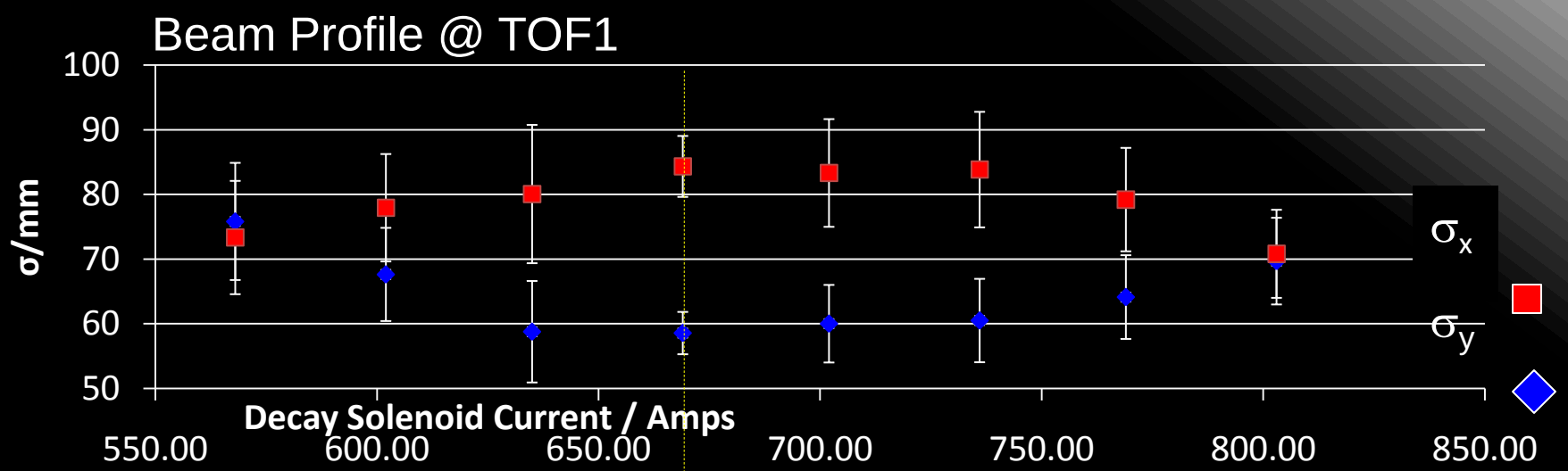


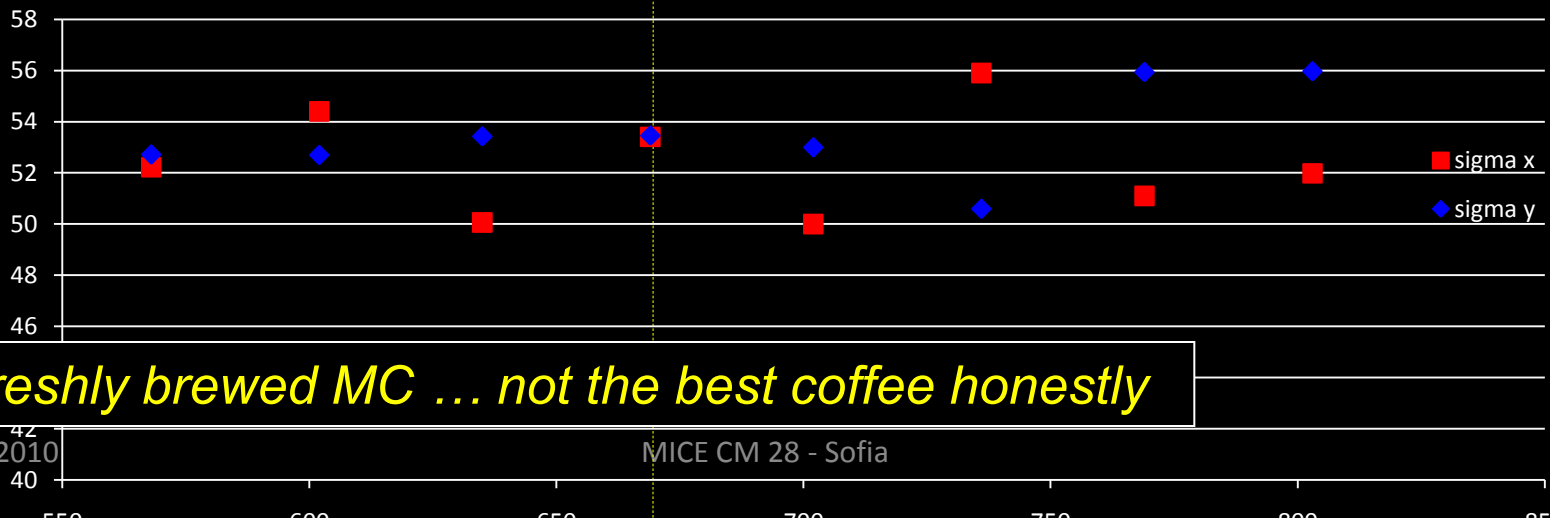
electron peak



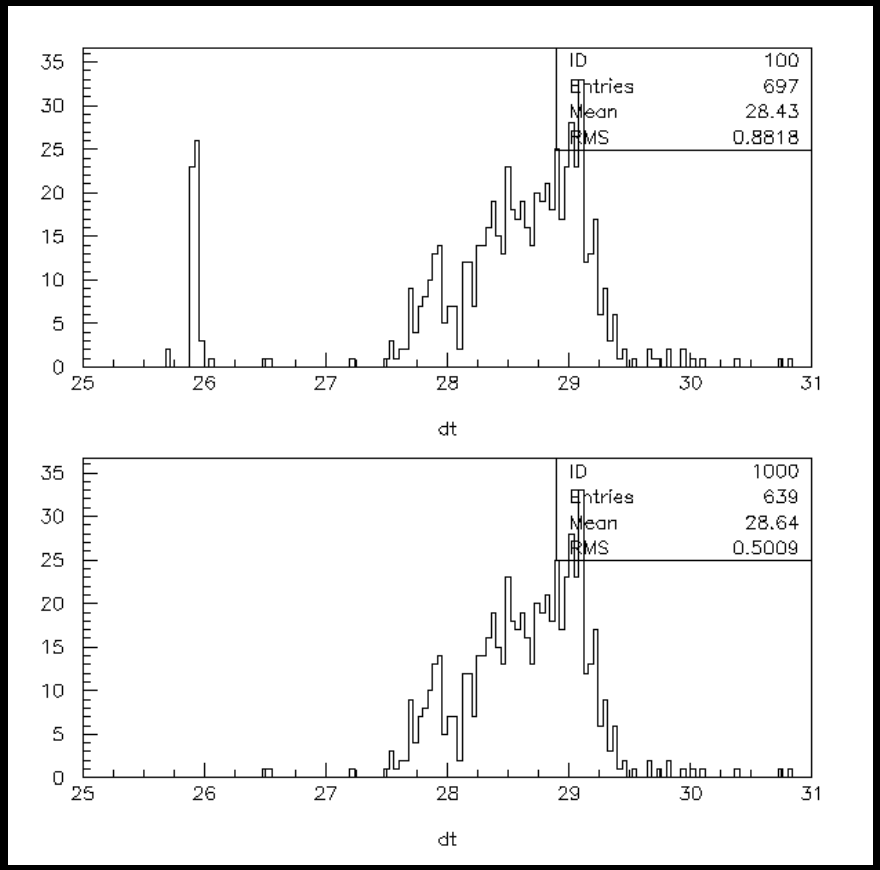
Data Analysis
- Decay Solenoid Scan

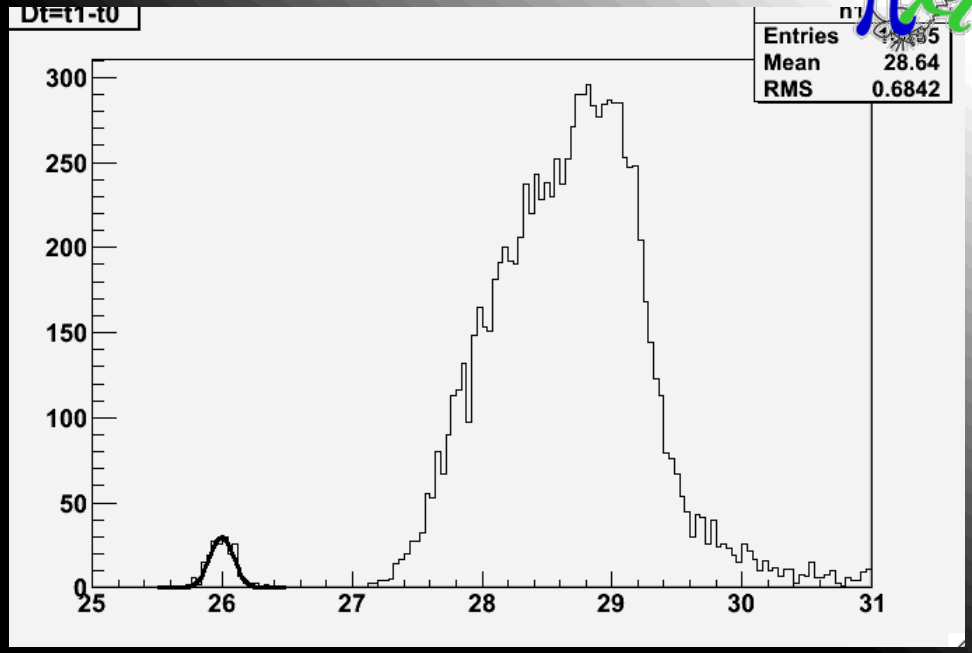
Run Number	2191	2192	2193	2195	2196	2197	2198	2200
Current / Amps	736	602	803	769	702	635	568	669





Freshly brewed MC … not the best coffee honestly





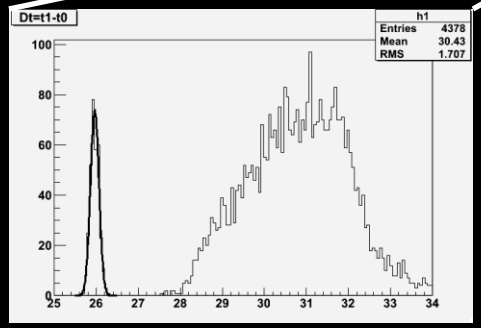
DATA: run 2244

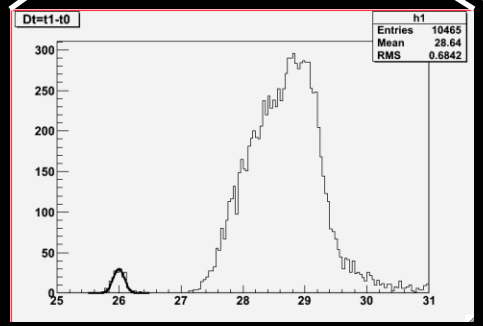
G4Beamline: run 2244

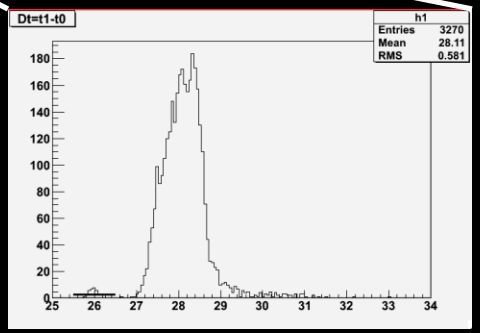
Why so many electrons?

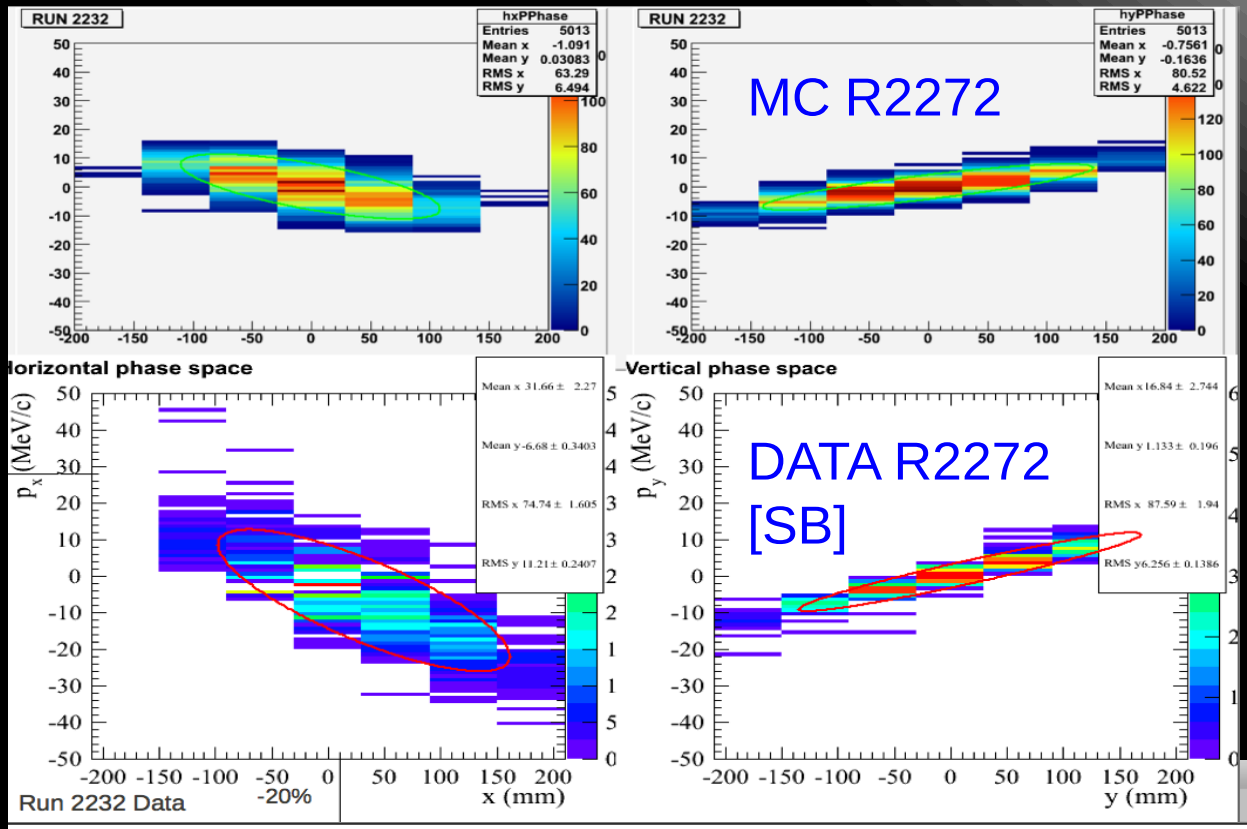
Good agreement on Δt_μ
28.64 (MC) / 28.68 (data)
e-peak = 25.9 ns
Old Geometry … what with new survey?

MATRIX (-)				OPTIMIZATION GRADE
	140	200	240	
3	2300	2266	2297	M0
				M1
				M2
				M2+
6	2271	2244	2269	M0
	2519	2503	2510	M1
				M2
				M2+
10	2279	2284	2280	M0
	2515	2507	2508	M1
				M2
				M2+





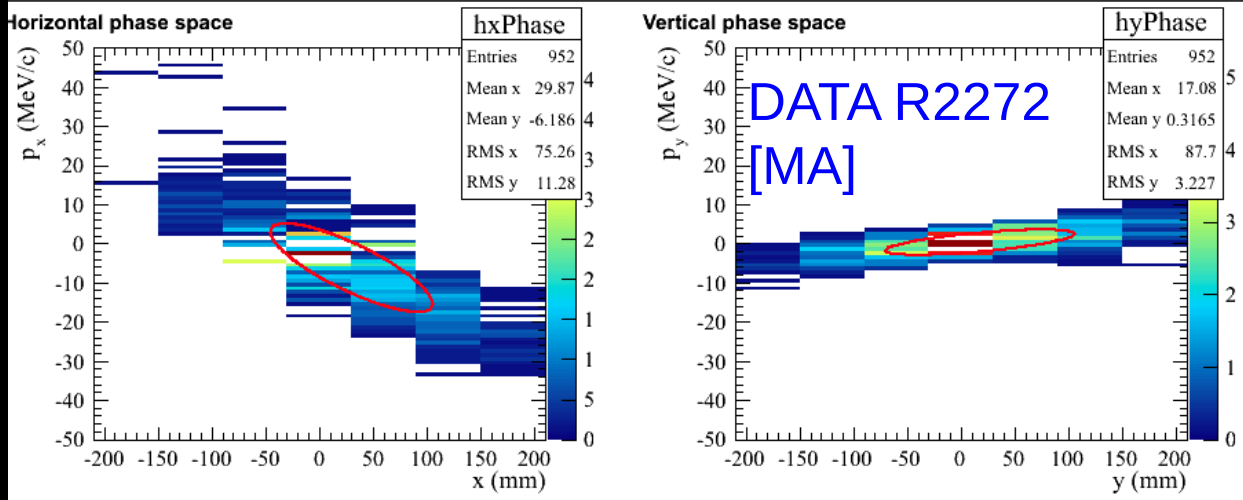


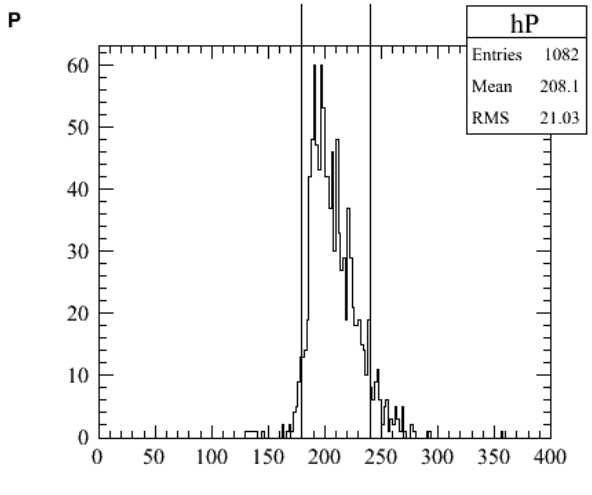


Need to freeze a geometry / calibration set of cuts

reproducibility: R2272 (august) which cuts?

R2272(october)





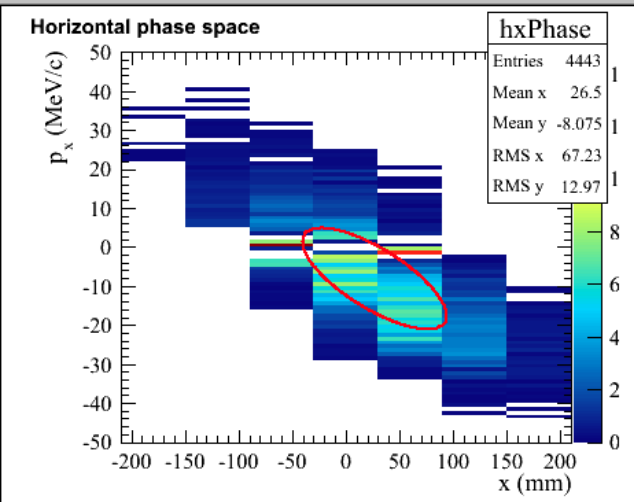
DATA

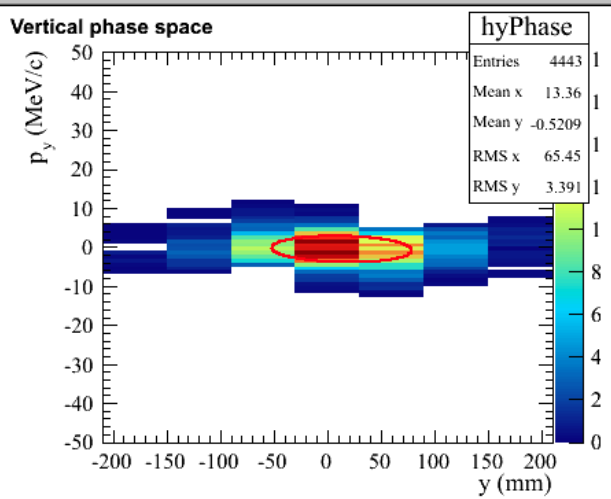
BeamLoss (mV)	Trig/spill	# of Triggers	Trig. Type	Spill gate (ms)	ISIS RepRate
1500	14	18984	TOF1	3.2	50 Hz

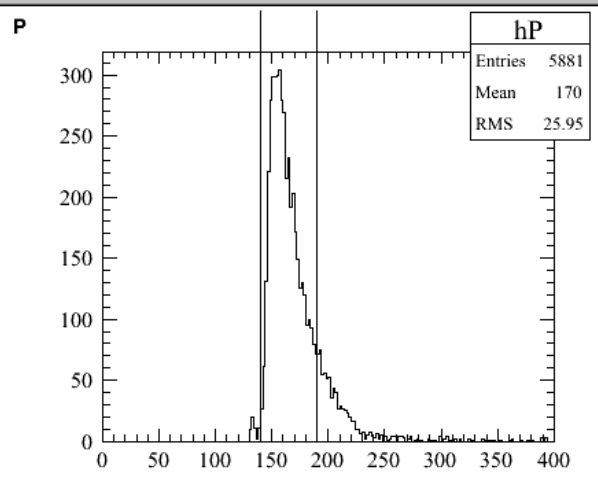
M0 3-140 R2300

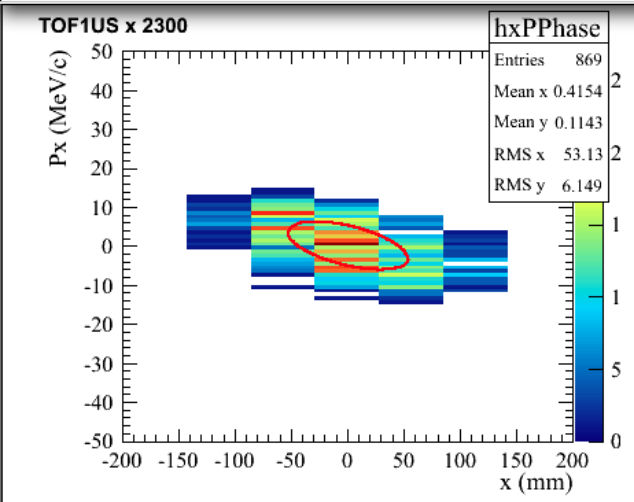
TOF1US 2300

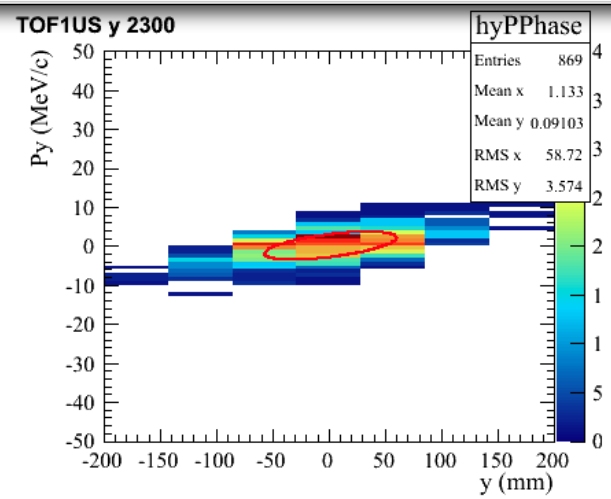
File Edit View Options Tools Help

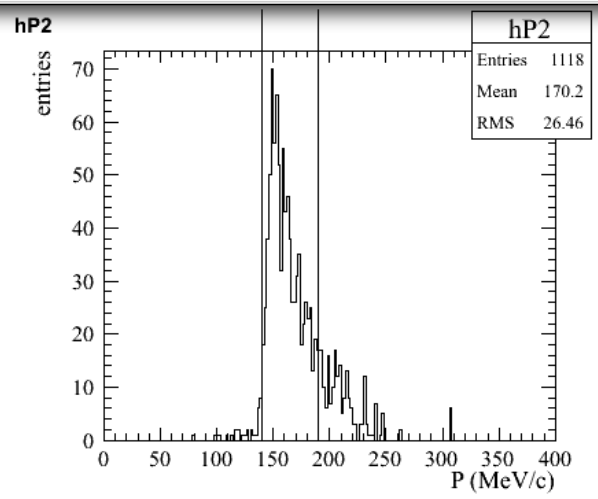












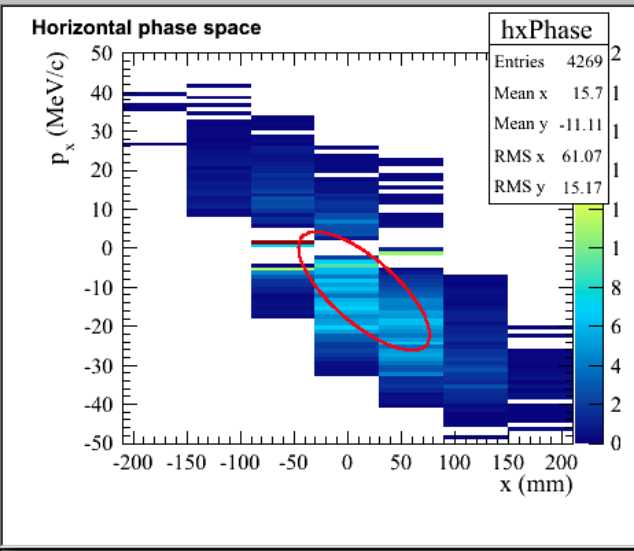
DATA

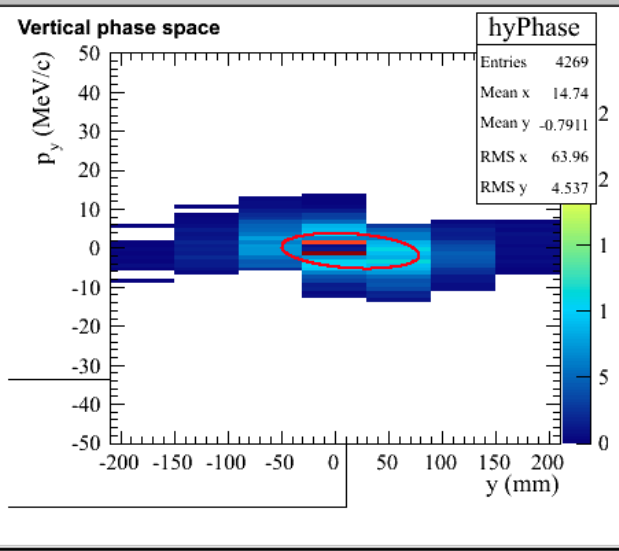
BeamLoss (mV)	Trig/spill	# of Triggers	Trig. Type	Spill gate (ms)	ISIS RepRate
1600	10	10070	TOF1	3.2	50 Hz

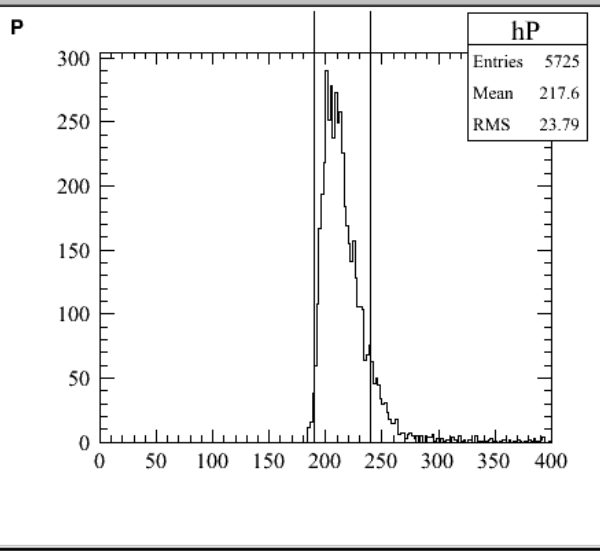
M0 3-200 R2266

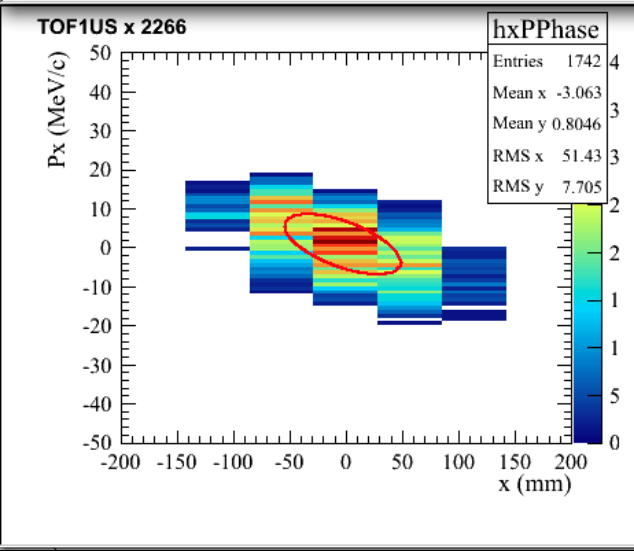
TOF1US 2266

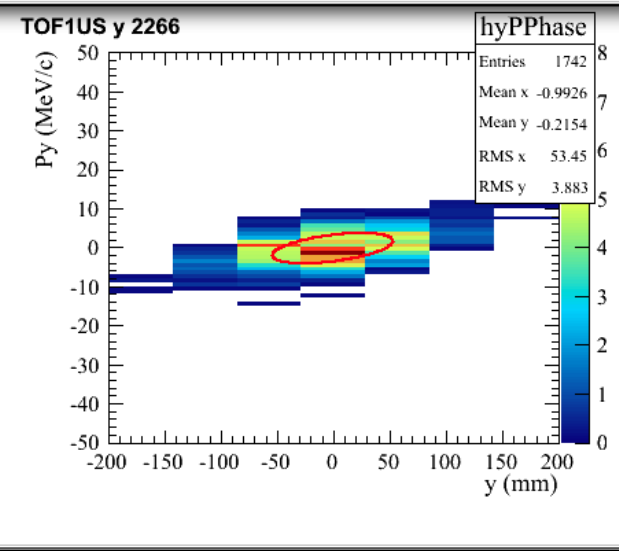
File Edit View Options Tools Help

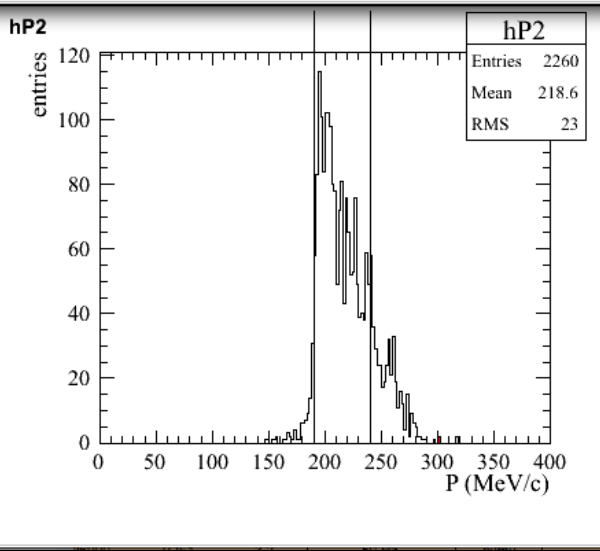












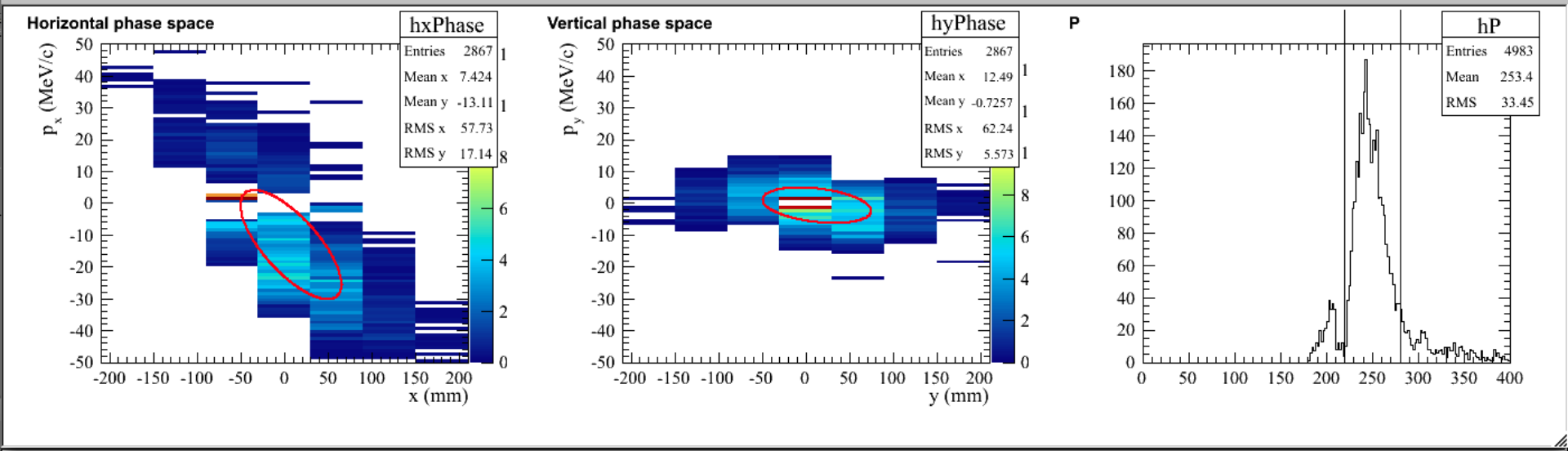
DATA

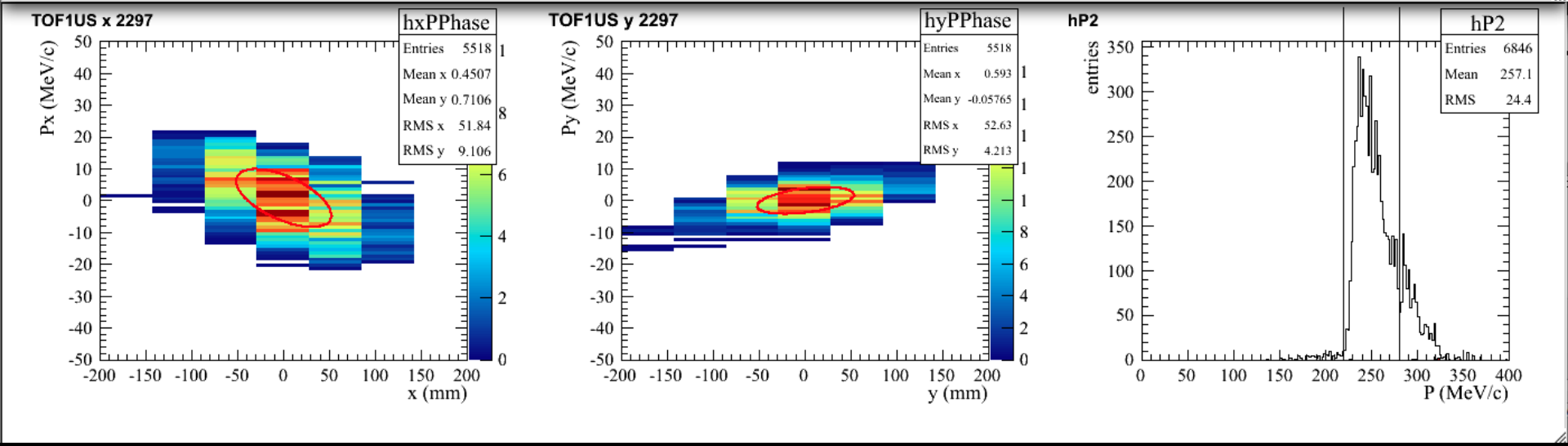
BeamLoss (mV)	Trig/spill	# of Triggers	Trig. Type	Spill gate (ms)	ISIS RepRate
1500	10	11130	TOF1	3.2	50 Hz

M0 3-240 R2297

TOF1US 2297

File Edit View Options Tools Help





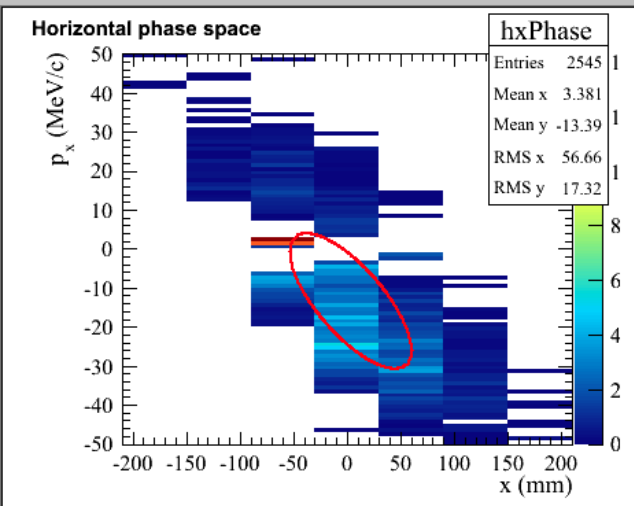
DATA

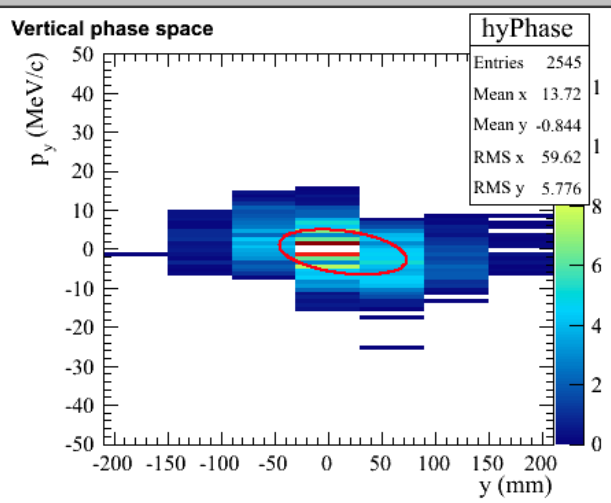
BeamLoss (mV)	Trig/spill	# of Triggers	Trig. Type	Spill gate (ms)	ISIS RepRate
1500	13	13000	TOF1	3.2	50 Hz

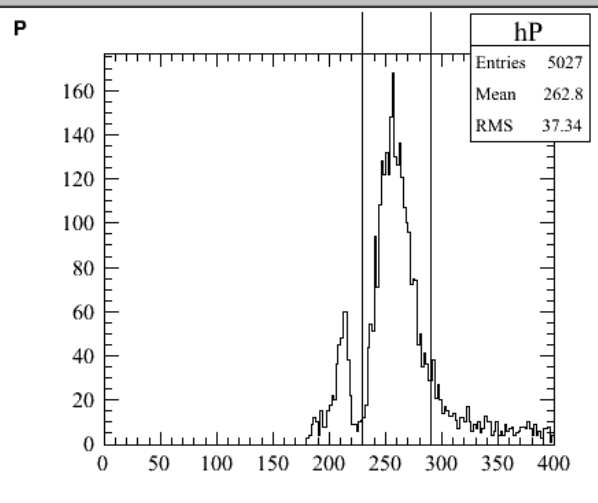
M0 6-240 R2269

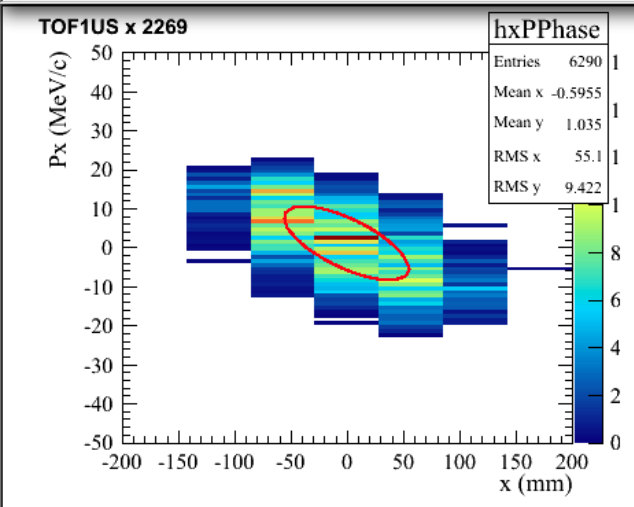
TOF1US 2269

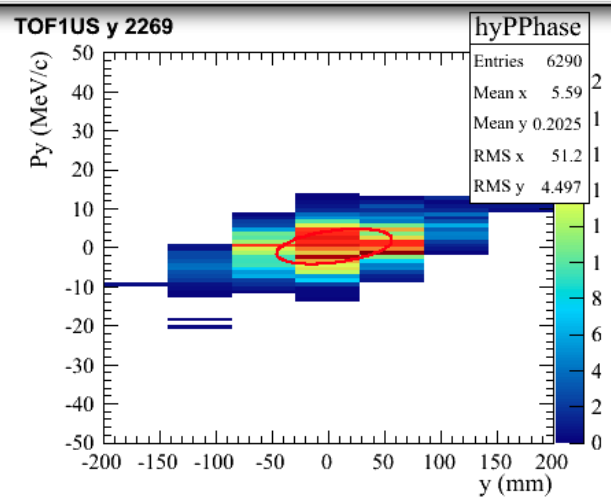
File Edit View Options Tools Help

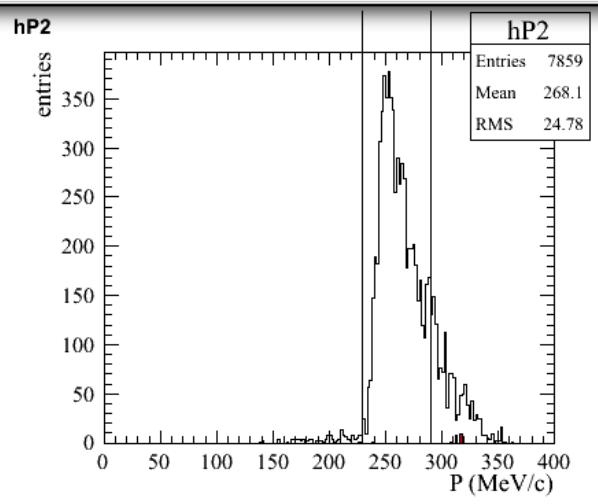












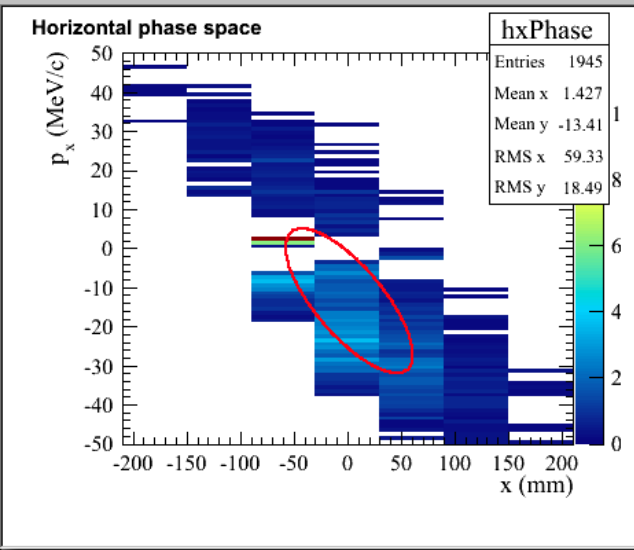
DATA

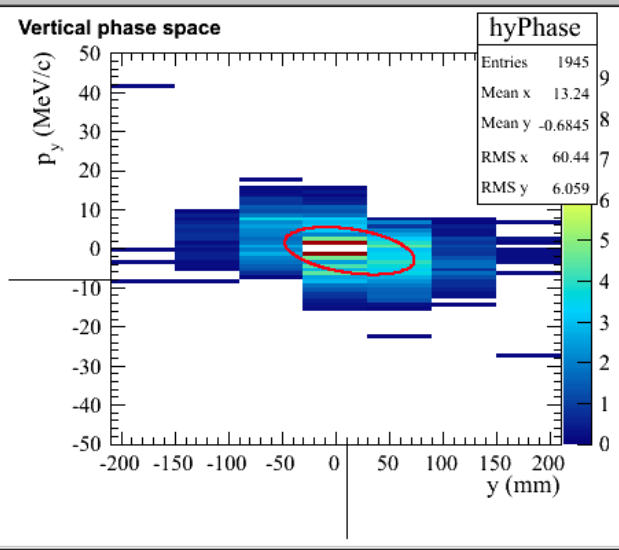
BeamLoss (mV)	Trig/spill	# of Triggers	Trig. Type	Spill gate (ms)	ISIS RepRate
1600	10	10070	TOF1	3.2	50 Hz

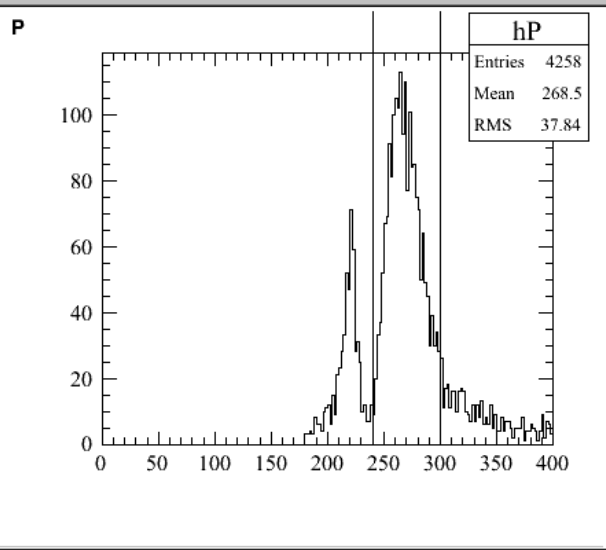
M0 10-240 R2280

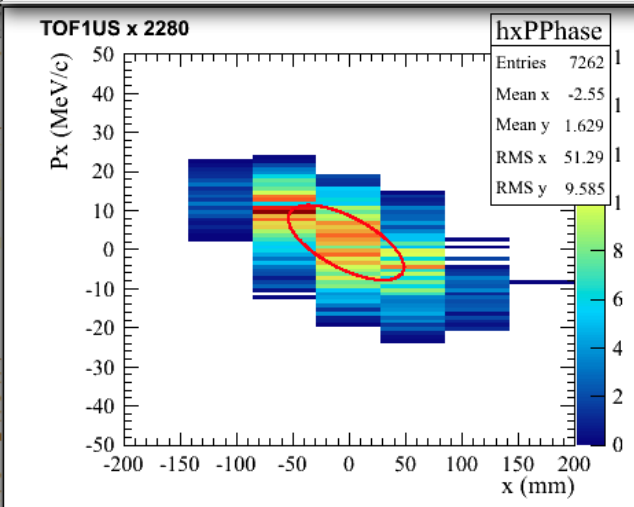
TOF1US 2280

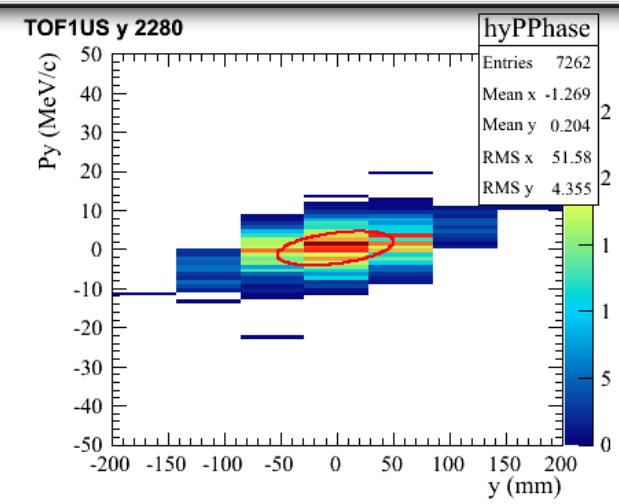
File Edit View Options Tools Help

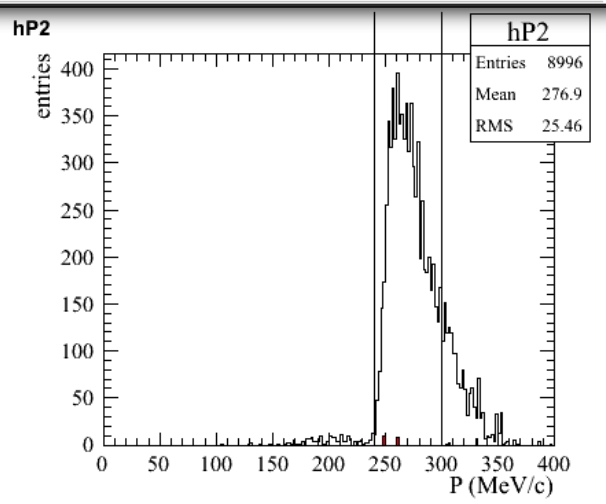












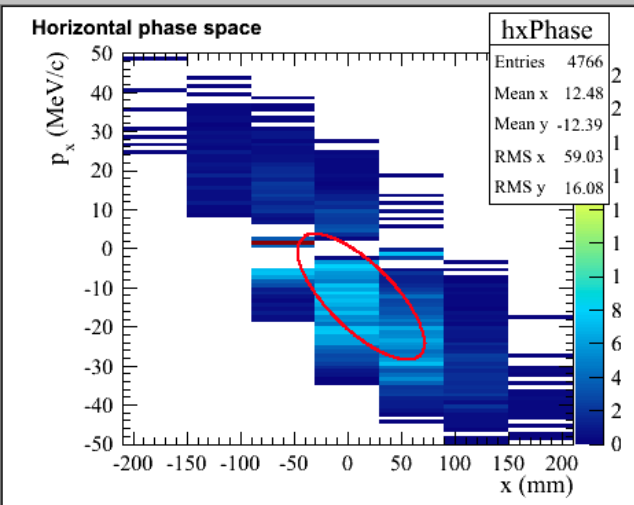
DATA

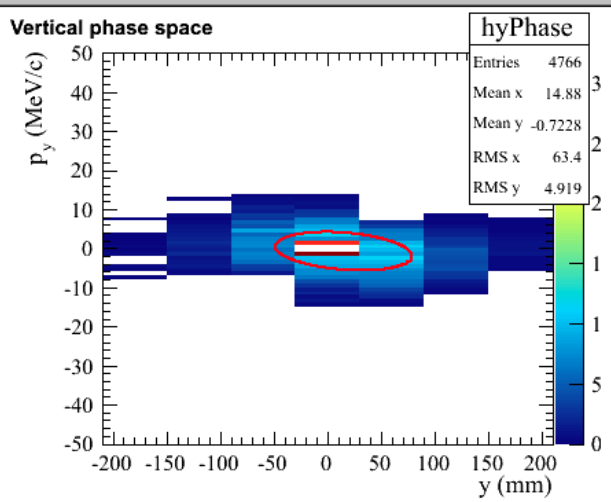
BeamLoss (mV)	Trig/spill	# of Triggers	Trig. Type	Spill gate (ms)	ISIS RepRate
1500	14	16520	TOF1	3.2	50 Hz

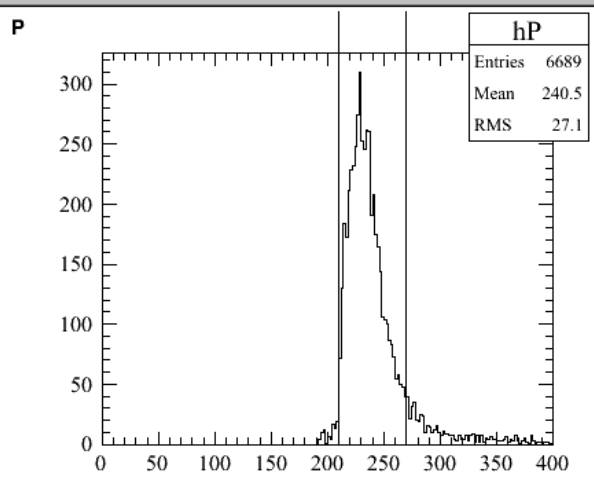
M0 10-200 R2284

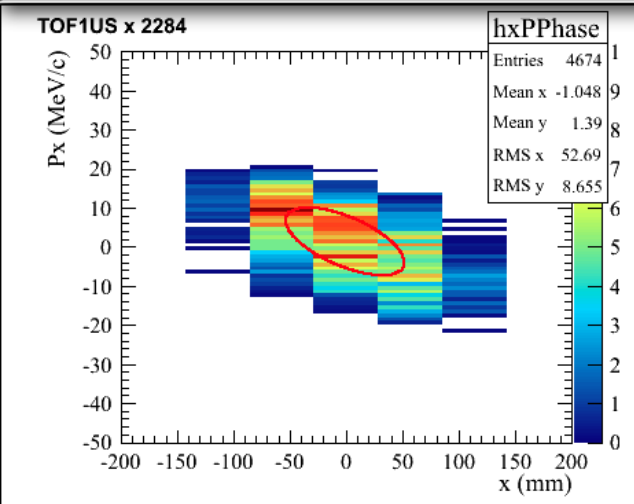
TOF1US 2284

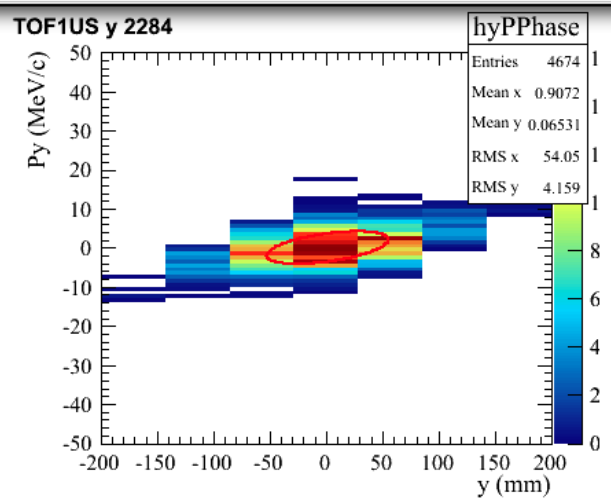
File Edit View Options Tools Help

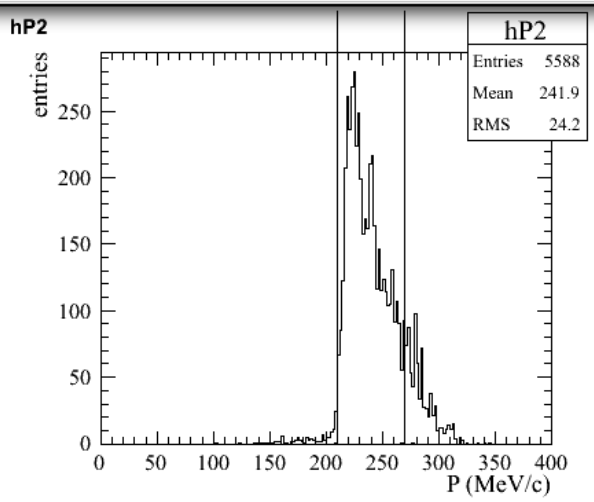












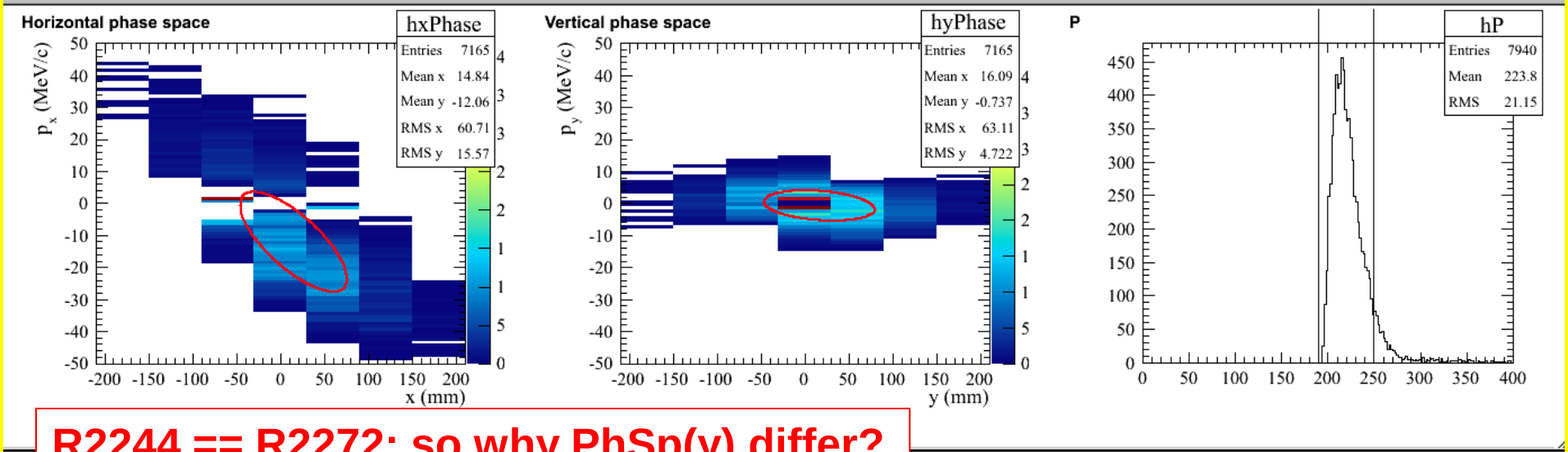
DATA

BeamLoss (mV)	Trig/spill	# of Triggers	Trig. Type	Spill gate (ms)	ISIS RepRate
1150	10.9	23871	TOF1	3.2	50 Hz

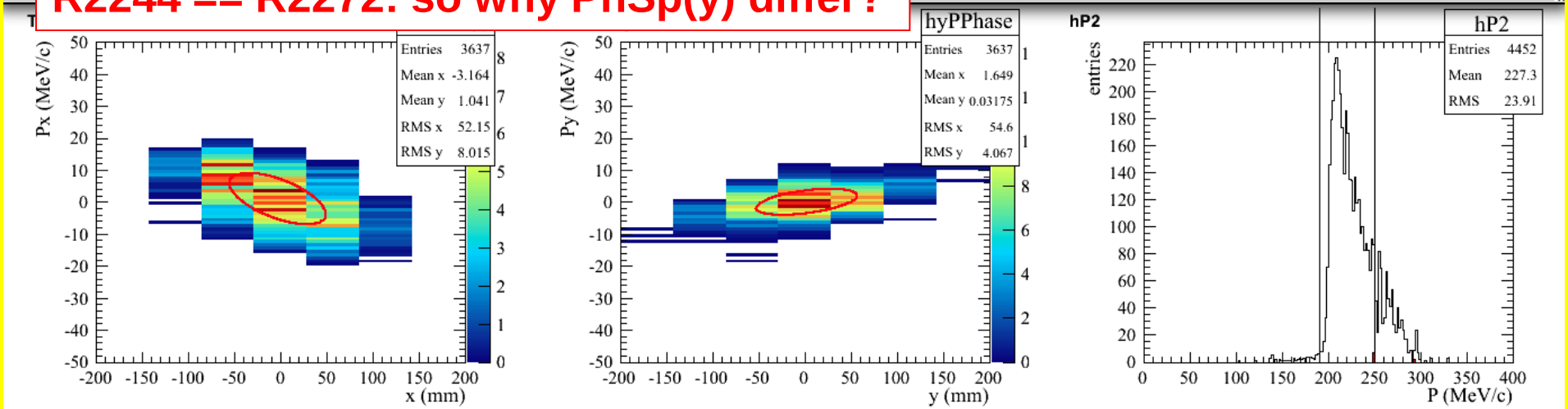
M0 6-200 R2244

TOF1US 2244

File Edit View Options Tools Help



R2244 == R2272: so why PhSp(y) differ?



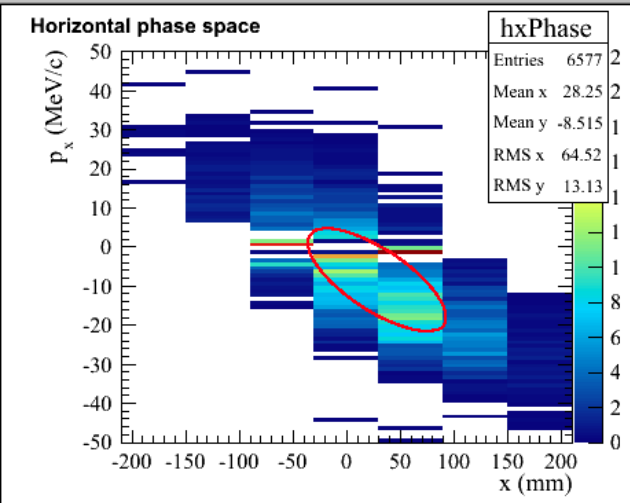
DATA

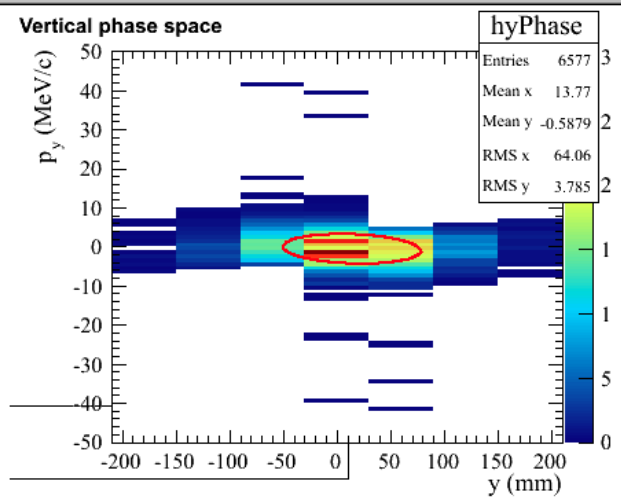
BeamLoss (mV)	Trig/spill	# of Triggers	Trig. Type	Spill gate (ms)	ISIS RepRate
1750	13	26000	TOF1	3.2	50 Hz

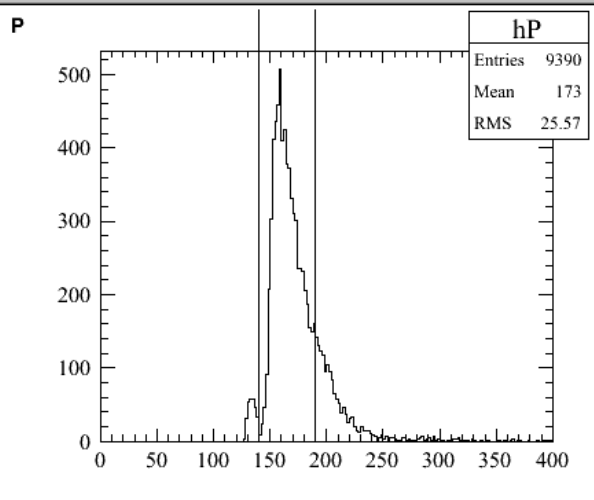
M0 6-140 R2271

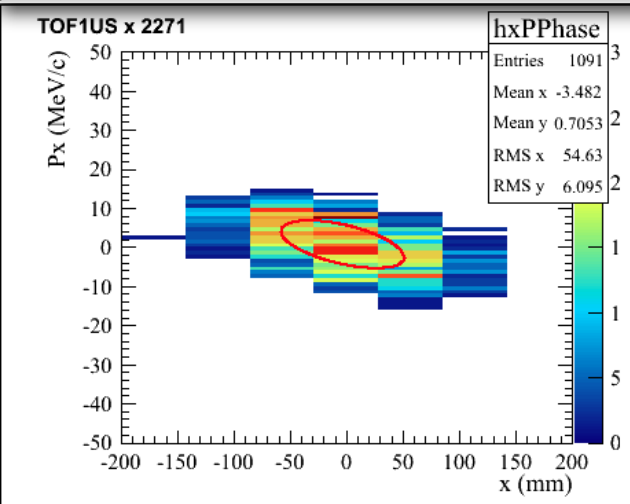
TOF1US 2271

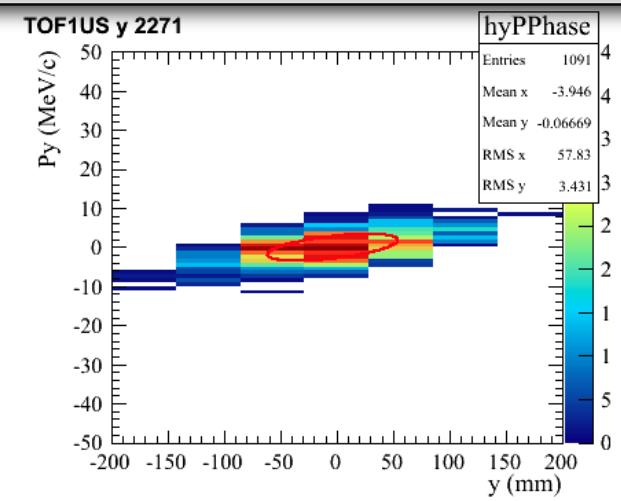
File Edit View Options Tools Help

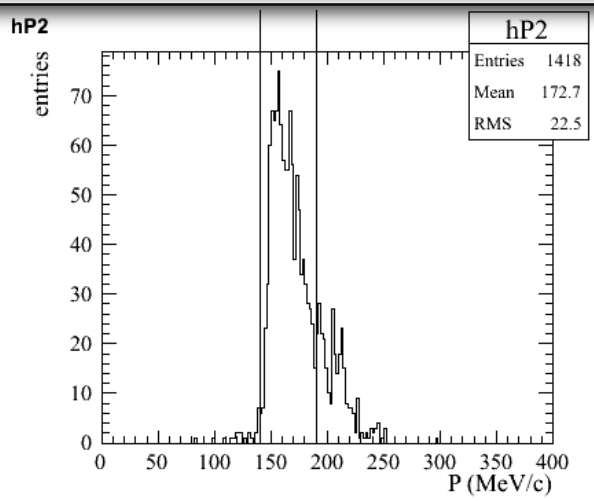








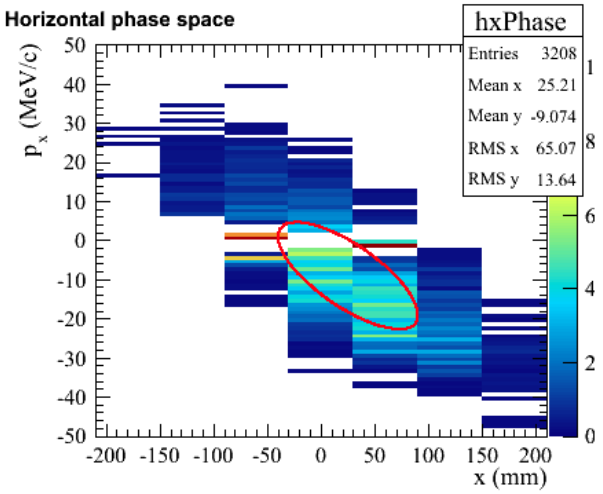


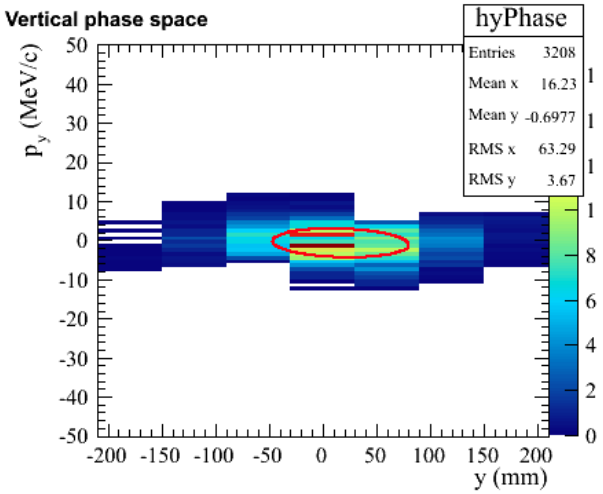


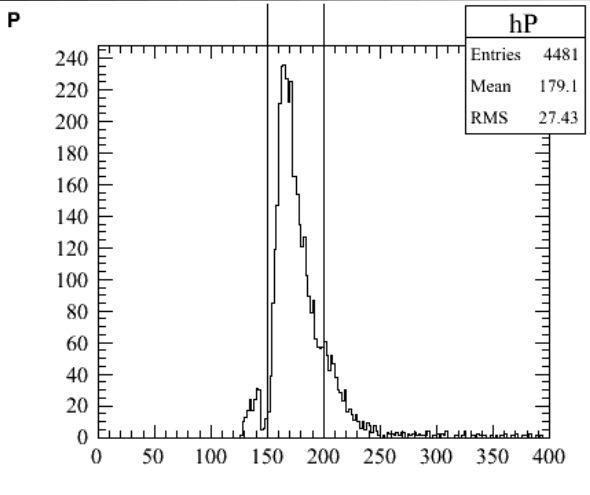
DATA

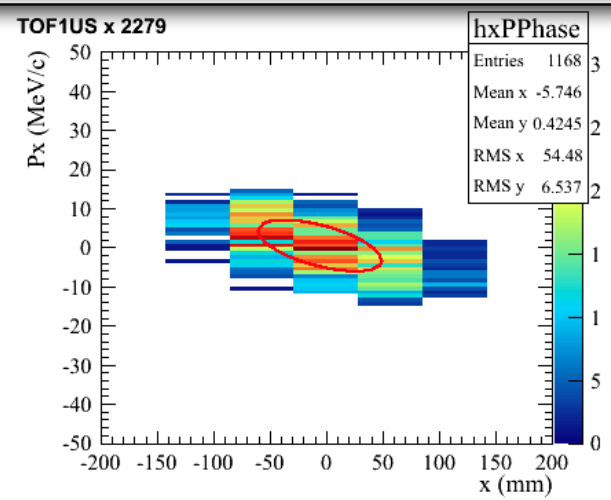
BeamLoss (mV)	Trig/spill	# of Triggers	Trig. Type	Spill gate (ms)	ISIS RepRate
1000	13	13000	TOF1	3.2	50 Hz

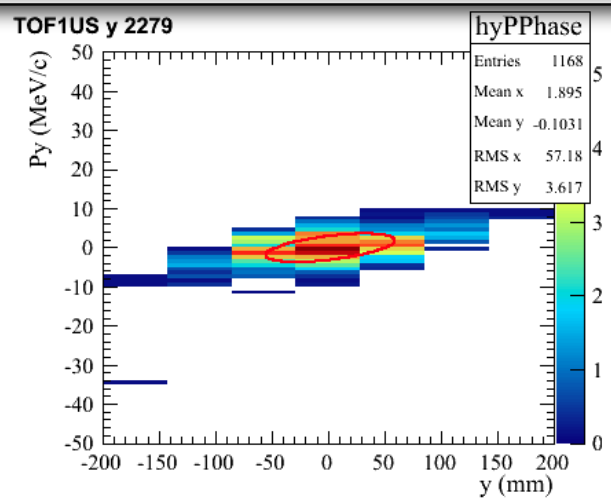
M0 10-140 R2279

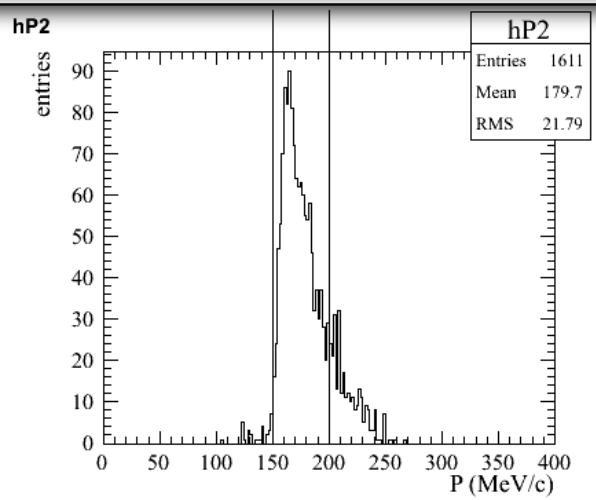






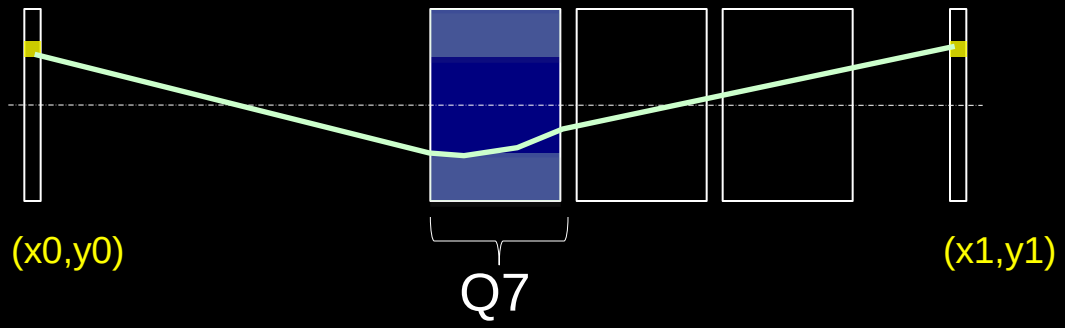




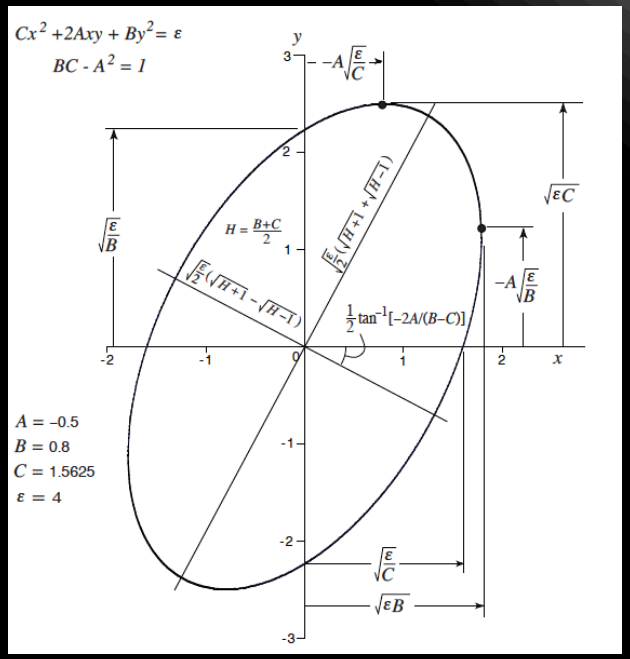


Phase Advance Studies in SINGLE Quadrupole Excitation
Isolate the behavior of a QUADRUPOLE ➔ assess MC reproducibility
Several PION runs
BUT: TofTrace not working properly, momentum scale completely wrong (but 20/30 MeV/c)

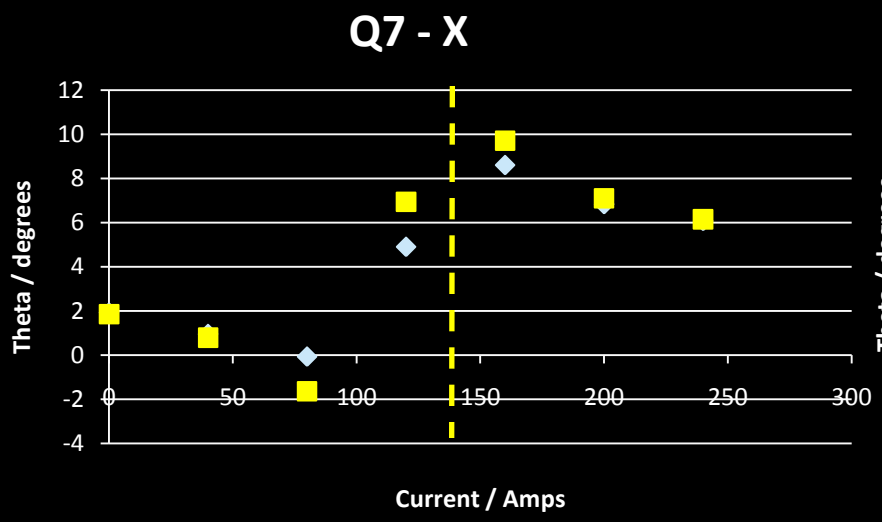
- use TOF0,1 to get space distributions
- hard edge model of Q7 (Q8) ➔ transport matrix calculated
- assume momentum from tables
- compare to phase advance from simulation

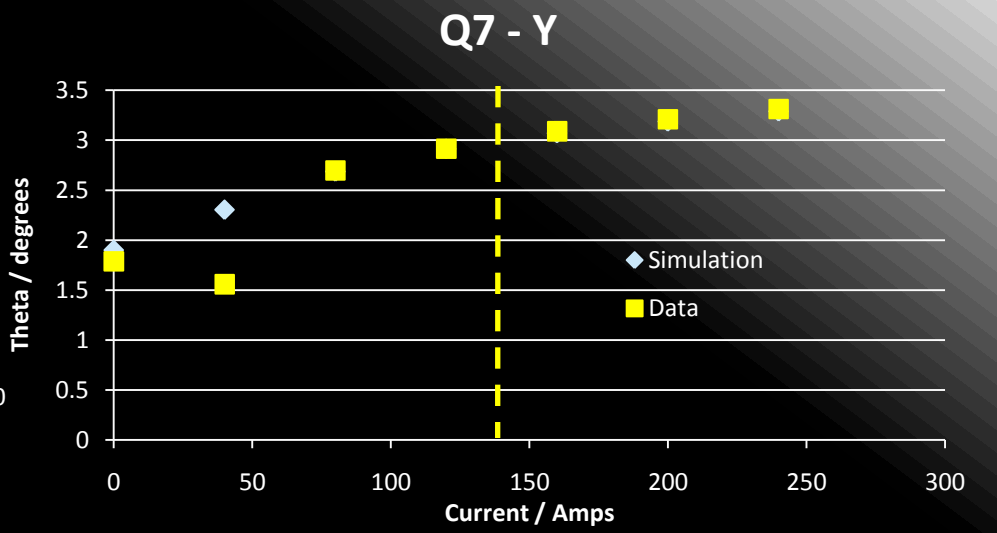


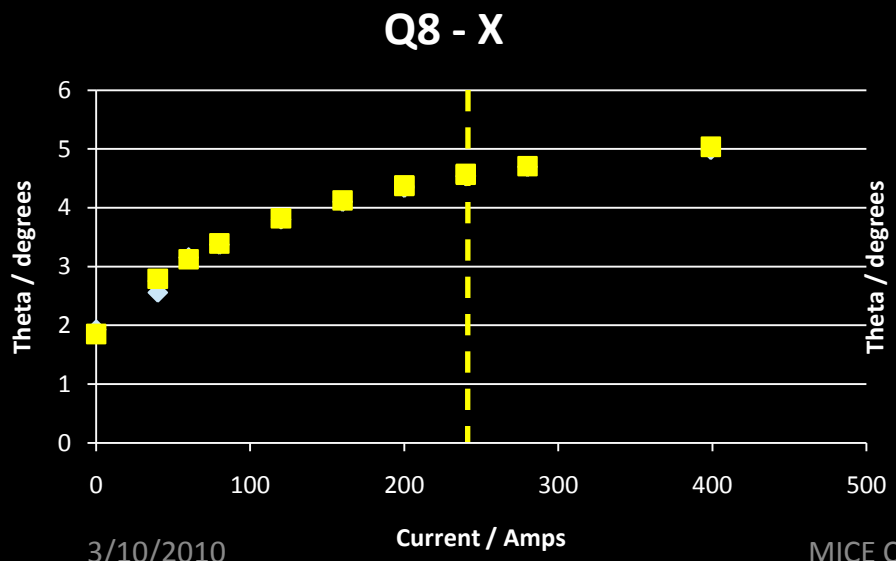
$$M = \begin{pmatrix} 1 & L_2 \\ 0 & 1 \end{pmatrix} \begin{pmatrix} C & S \\ C' & S' \end{pmatrix} \begin{pmatrix} 1 & L_1 \\ 0 & 1 \end{pmatrix}$$

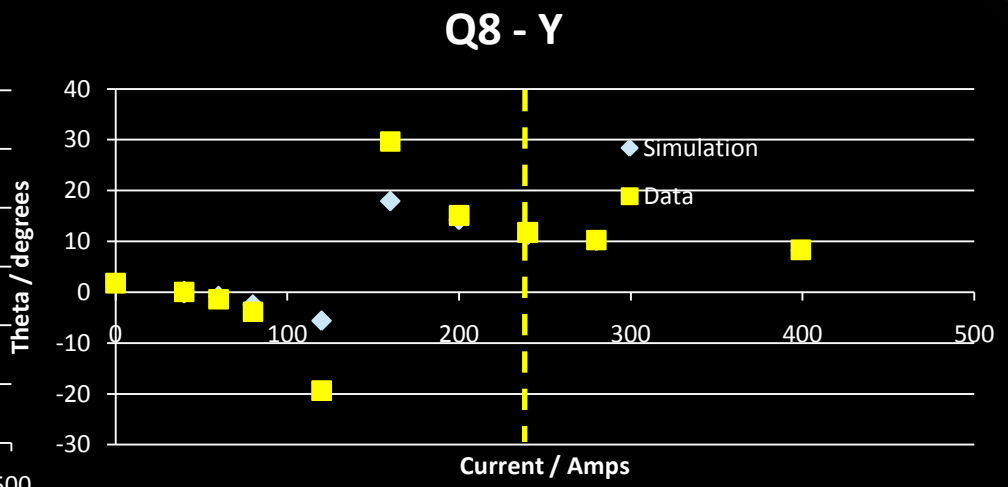


Θ phase angle = 1/2 atan[$-2\alpha/(\beta-\gamma)$]

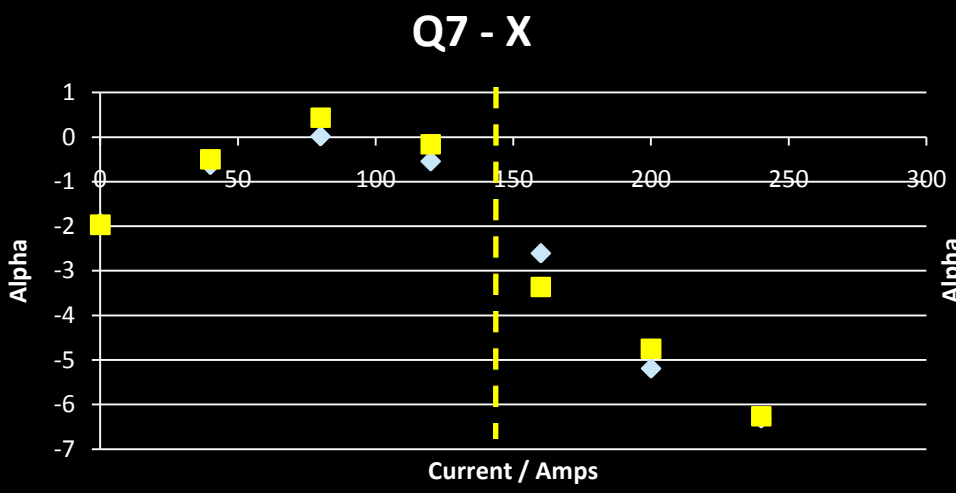


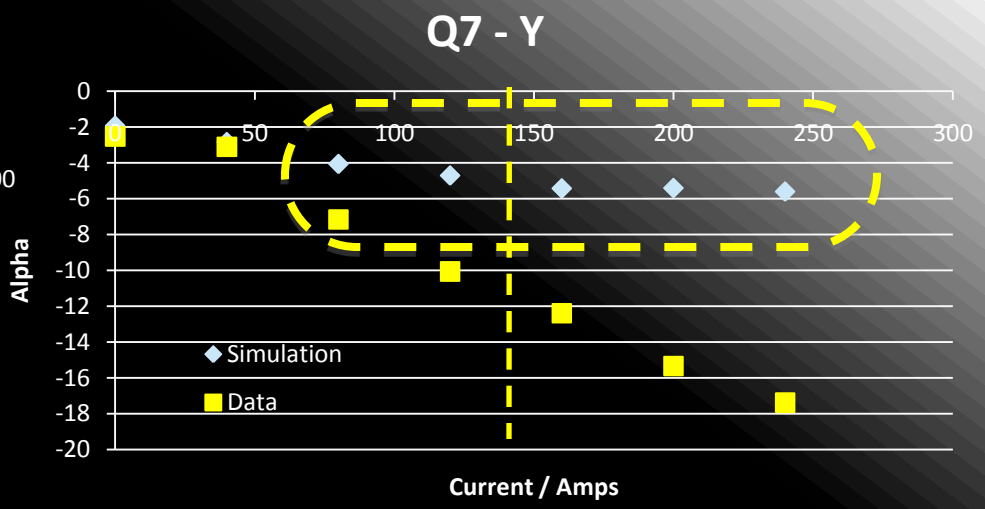


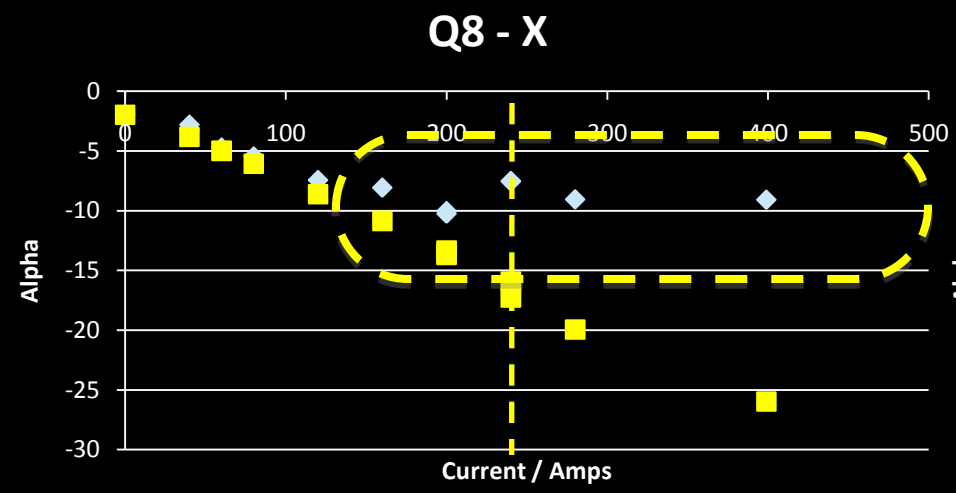


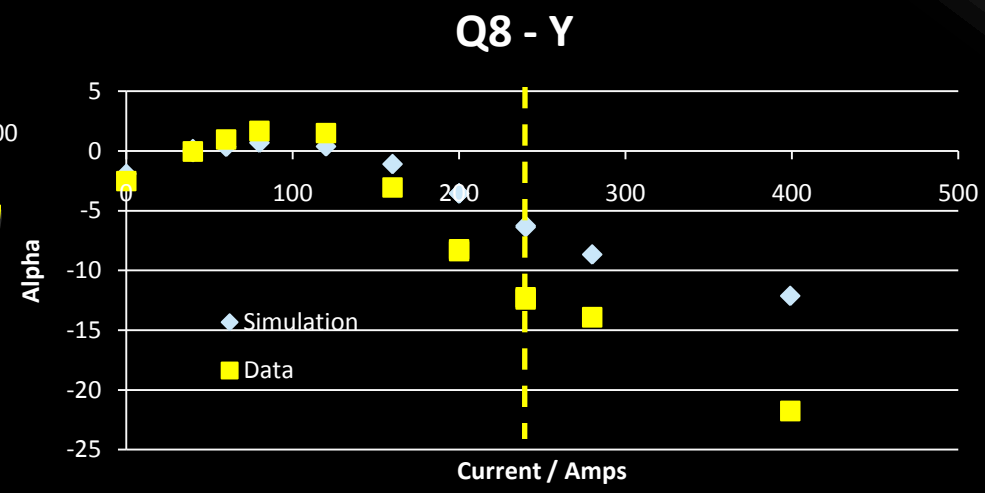


α Twiss Parameter









Post Partum Summary

Run Goals

- understand magnet impact on the beam
- beamline optics control (can we design our next beam?)
- optimization online

Method

- a full working and stable beamline
- DAQ / EPICS / Data Transfer
- Online Monitoring
- Online Reconstruction

- pros ☺
  - lot of data produced
  - HW/SW debugging
  - amazing participation (MOMs, BLOCs, experts, shifters …)
  - magnets OK
  - TOFs/Target/DAQ nearly flawless
  - remarkable progress in SW
  - very good similarity between MC and DATA
- cons ☹
  - TOF positions “unknown” (recently surveyed)(*)
  - missed a proper D2 study (few runs)
  - on-line optimisation too slow
  - some issues with data logging

(*) TOFs were NOT thought to do such a delicate job …

5 Months to GO
- We need to complete the analysis of these DATA
- finish the quality studies
    - identify bad runs (discard or cure where possible)
- go trough RunSummary and verify conistency (boring but necessary) via DB
- finish SCAN study
    - in particular Single Quad for phase advance
- improve MC (e.g. introduce survey prescriptions)
- produce MC-data
- in parallel: migrate to a more realistic simulation (G4MICE) and verify consistency
- assess ability to reproduce real beamline

DO WE NEED SOME EXTRA DATA?
- Probably yes, e.g. D1/D2 thorough scan (precise momentum)

STEP I Paper Plans

Q1: where do we aim at publishing?

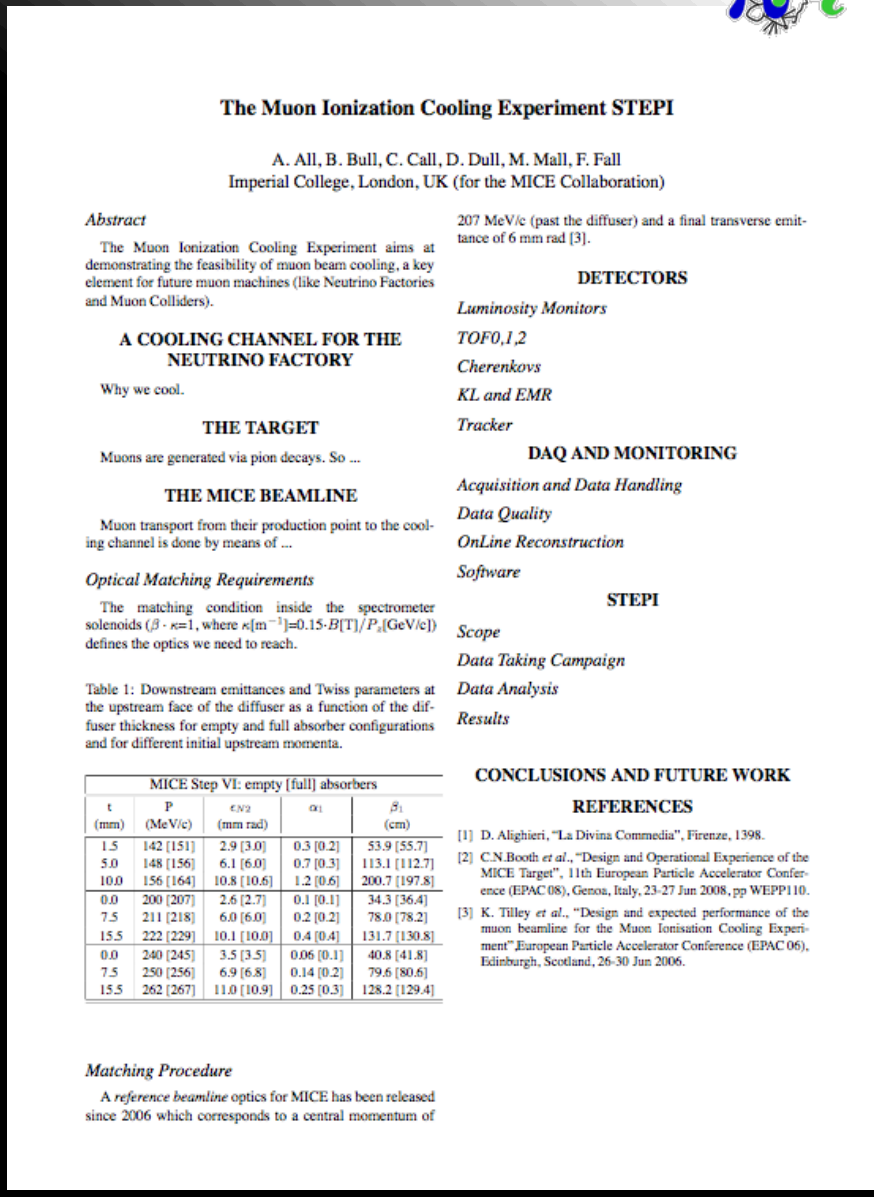
Q2: and by when?

Paper skeleton

- Introduction [MA]
- Beam Line [MA]
- Detectors […experts]
- DAQ [JSG]
- Online Monitoring [LC]
- DATA Taking [JSG+]
- Analysis [MA,CR,SB,EC,MR,RF,+]
  - TOF0,1 method to PhSpace determination [MR]
- Conclusion

Resume BL meetings or in the Analysis Meeting?

Fix a first date to release kick off draft?



The Muon Ionization Cooling Experiment STEPI

A. All, B. Bull, C. Call, D. Dull, M. Mall, F. Fall
Imperial College, London, UK (for the MICE Collaboration)

Abstract

The Muon Ionization Cooling Experiment aims at demonstrating the feasibility of muon beam cooling, a key element for future muon machines (like Neutrino Factories and Muon Colliders).

A COOLING CHANNEL FOR THE NEUTRINO FACTORY

Why we cool.

THE TARGET

Muons are generated via pion decays. So ...

THE MICE BEAMLINE

Muon transport from their production point to the cooling channel is done by means of ...

Optical Matching Requirements

The matching condition inside the spectrometer solenoids ($\beta \cdot \kappa = 1$, where $\kappa[m^{-1}] = 0.15 \cdot B[T]/P_s[GeV/c]$) defines the optics we need to reach.

Table 1: Downstream emittances and Twiss parameters at the upstream face of the diffuser as a function of the diffuser thickness for empty and full absorber configurations and for different initial upstream momenta.

MICE Step VI: empty [full] absorbers				
t (mm)	P (MeV/c)	ϵ_{N2} (mm rad)	α_1	β_1 (cm)
1.5	142 [151]	2.9 [3.0]	0.3 [0.2]	53.9 [55.7]
5.0	148 [156]	6.1 [6.0]	0.7 [0.3]	113.1 [112.7]
10.0	156 [164]	10.8 [10.6]	1.2 [0.6]	200.7 [197.8]
0.0	200 [207]	2.6 [2.7]	0.1 [0.1]	34.3 [36.4]
7.5	211 [218]	6.0 [6.0]	0.2 [0.2]	78.0 [78.2]
15.5	222 [229]	10.1 [10.0]	0.4 [0.4]	131.7 [130.8]
0.0	240 [245]	3.5 [3.5]	0.06 [0.1]	40.8 [41.8]
7.5	250 [256]	6.9 [6.8]	0.14 [0.2]	79.6 [80.6]
15.5	262 [267]	11.0 [10.9]	0.25 [0.3]	128.2 [129.4]

Matching Procedure

A *reference beamline* optics for MICE has been released since 2006 which corresponds to a central momentum of 207 MeV/c (past the diffuser) and a final transverse emittance of 6 mm rad [3].

DETECTORS

Luminosity Monitors

TOF0,1,2

Cherenkovs

KL and EMR

Tracker

DAQ AND MONITORING

Acquisition and Data Handling

Data Quality

OnLine Reconstruction

Software

STEPI

Scope

Data Taking Campaign

Data Analysis

Results

CONCLUSIONS AND FUTURE WORK

REFERENCES

[1] D. Alighieri, "La Divina Commedia", Firenze, 1398.

[2] C.N.Booth *et al.*, "Design and Operational Experience of the MICE Target", 11th European Particle Accelerator Conference (EPAC 08), Genoa, Italy, 23-27 Jun 2008, pp WEPP110.

[3] K. Tilley *et al.*, "Design and expected performance of the muon beamline for the Muon Ionisation Cooling Experiment",European Particle Accelerator Conference (EPAC 06), Edinburgh, Scotland, 26-30 Jun 2006.

Jun-Aug 2010 run campaign has been decisive to complete STEPI

Detectors have been commissioned

- TOF0, 1: NIM Nucl. Inst. Meth. A Volume 615, Issue 1, 21 March 2010, Pages 14-26
- Tracker: M. Ellis et al, http://arxiv.org/abs/1005.3491

Analysis of BL data is proceeding

- unify procedures (same run/TOFcalib/cuts …)
- interact & involve
- understand differences between results and MC
- TOF0,1 alignment
- estimate errors (x,y,P,Twiss Parameters …)
- migrate to a more complete MC, G4MICE (reproduce detector behavior)

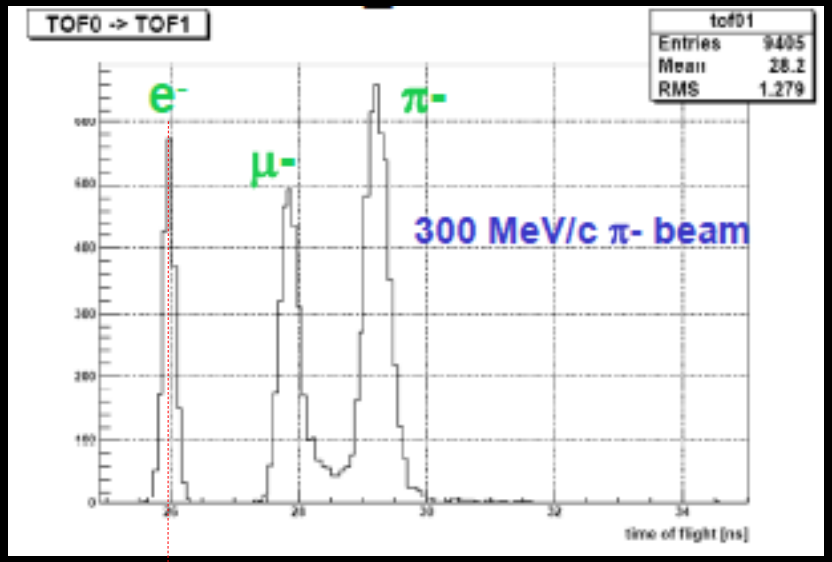
Completion of Data Analysis is key for a publication of MICE STEPI performance

- publication of STEPI results: in 5 months?
- run for 2011 to be discussed …today!

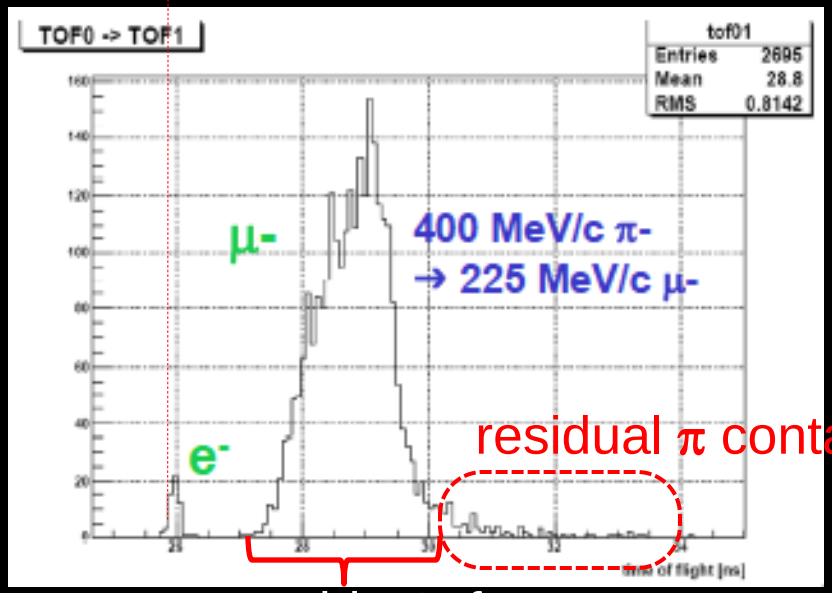
- we have a lot of data to analyze: enough mice ?

thanks for your attention

spares



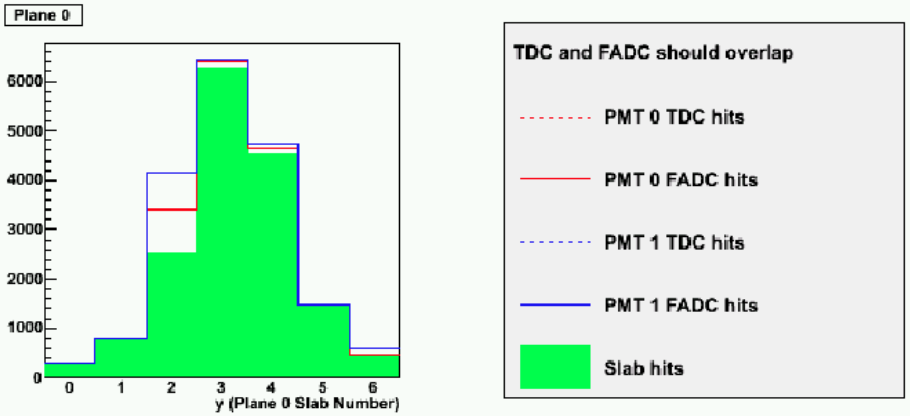
π optimized beamline for calibration studies

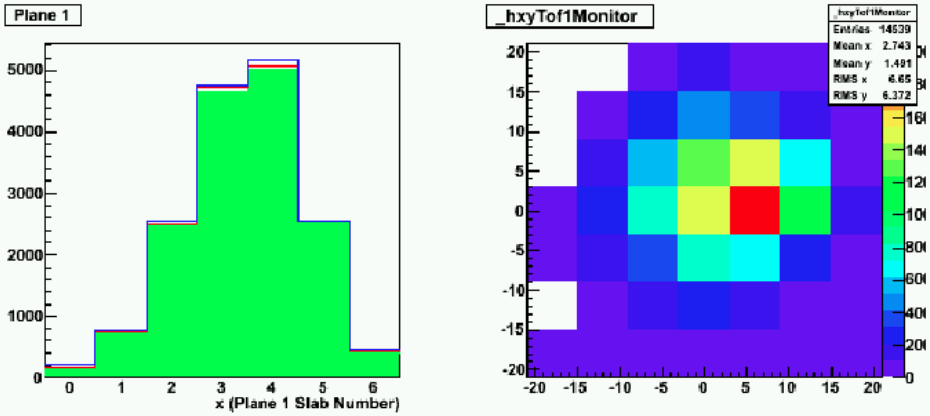


π → μ beamline

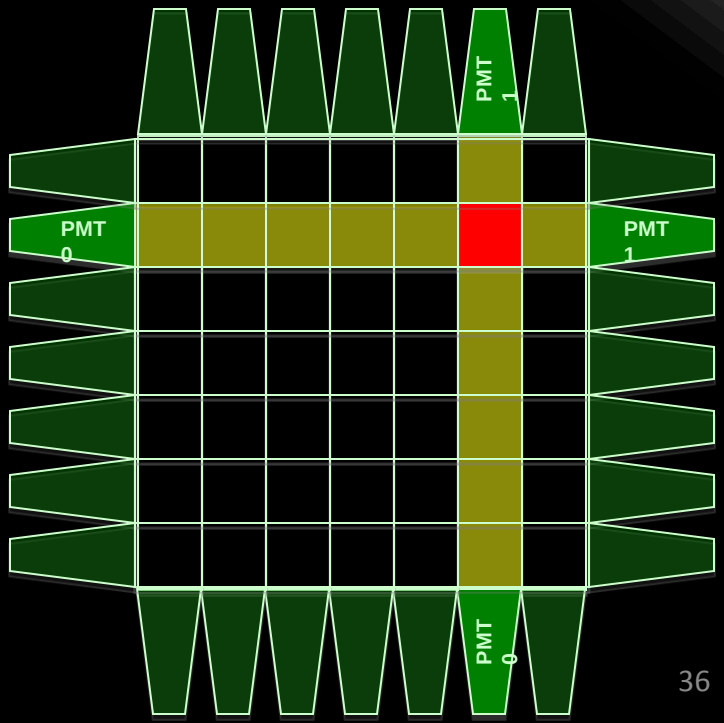
μ wide Δt from momentum acceptance at D2

Monitoring
- RUN 2873 (TOF1 h/v planes and x-y reconstruction)





0 && 1 = slab hit



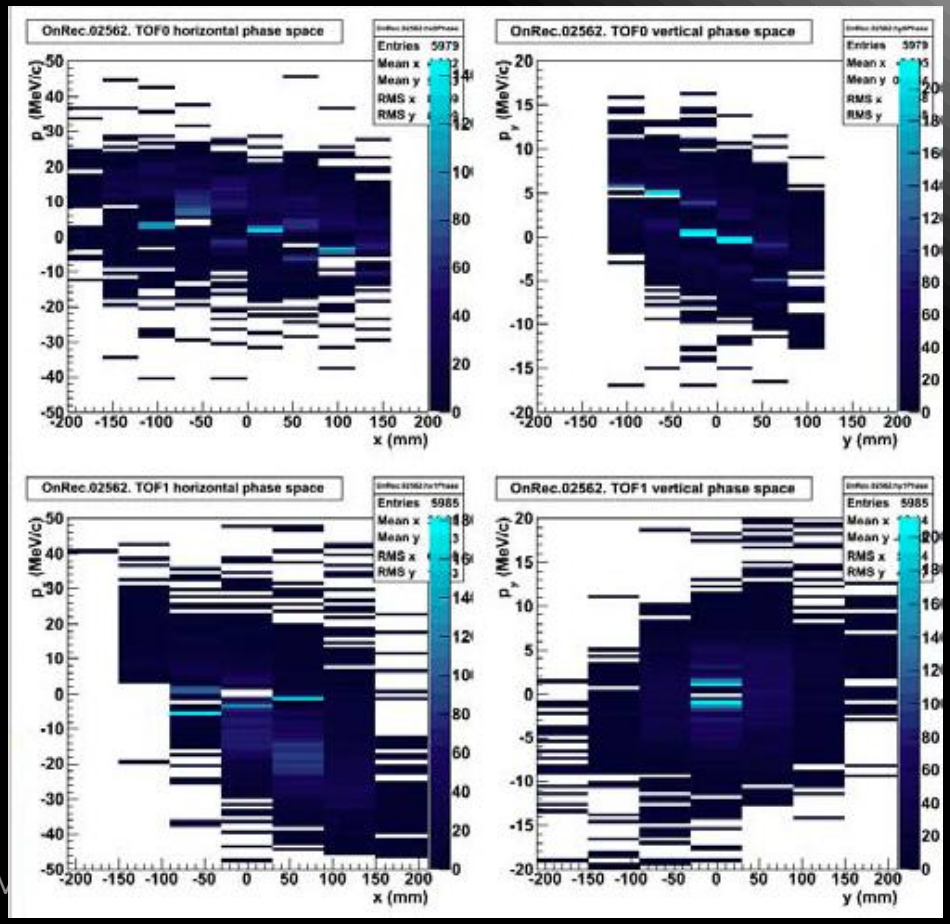
On Line Reconstruction

- Based on TOF0,1
- tracks reconstructed
- phase – space incrementally displayed on-line

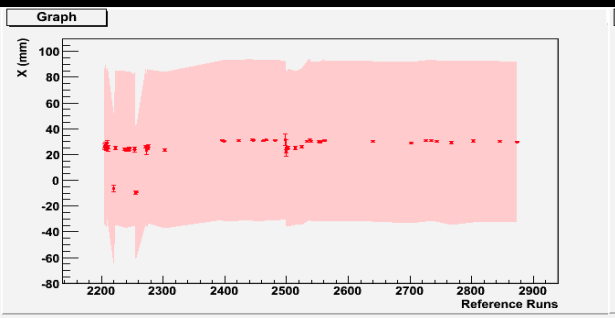
(x,Px) (y,Py)

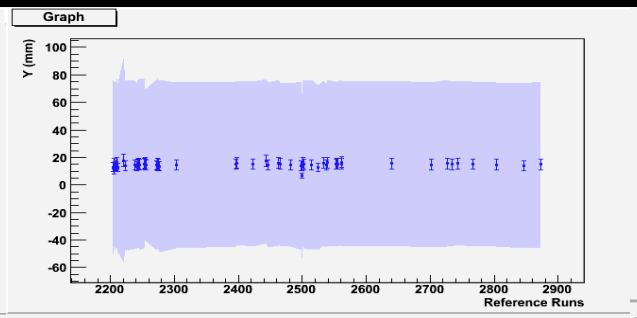
TOF0

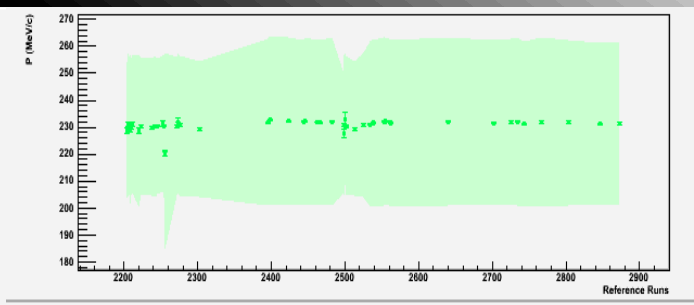
TOF1

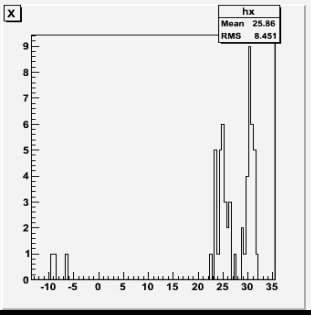


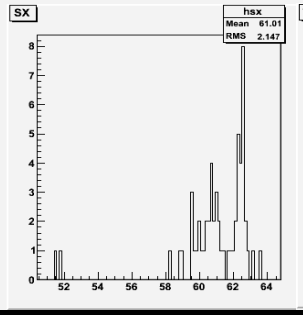
Data Quality
- stability of TOF1 in Reference Runs

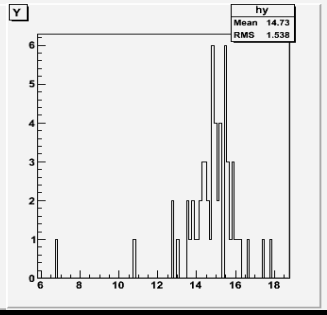


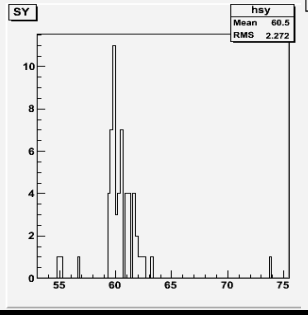


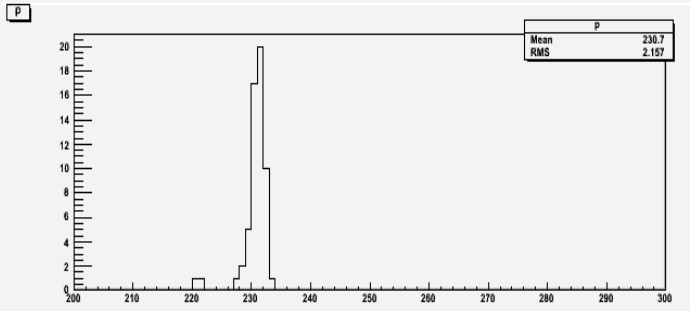


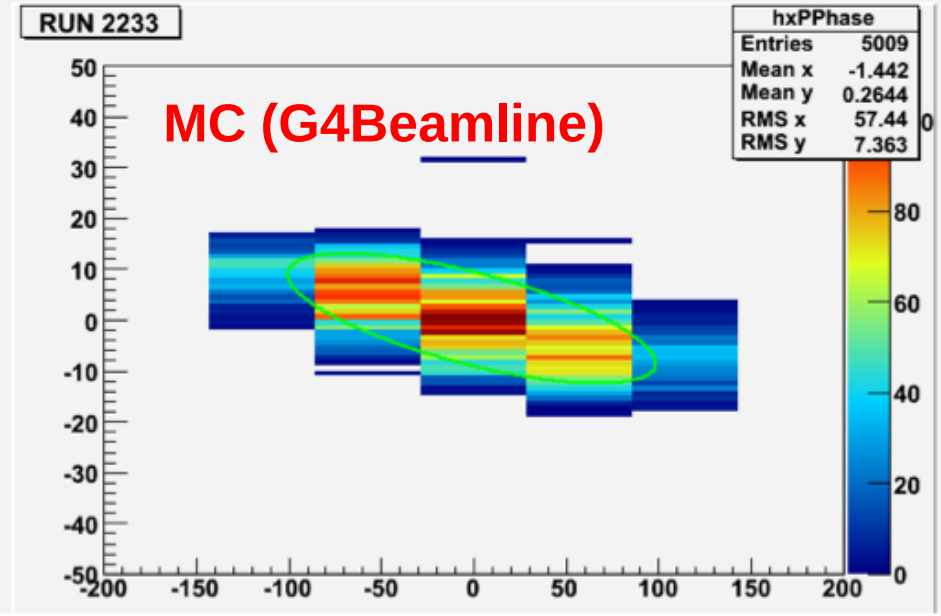


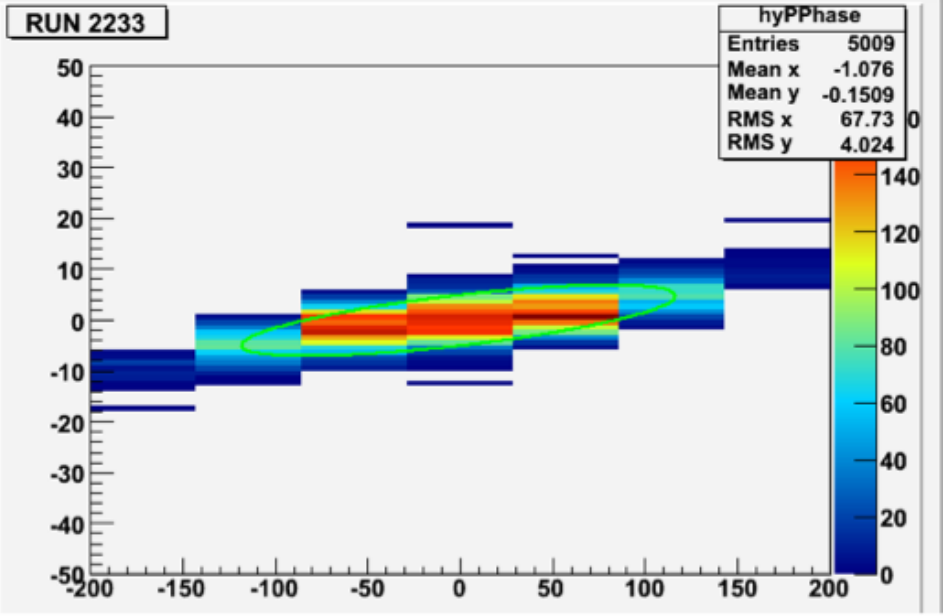


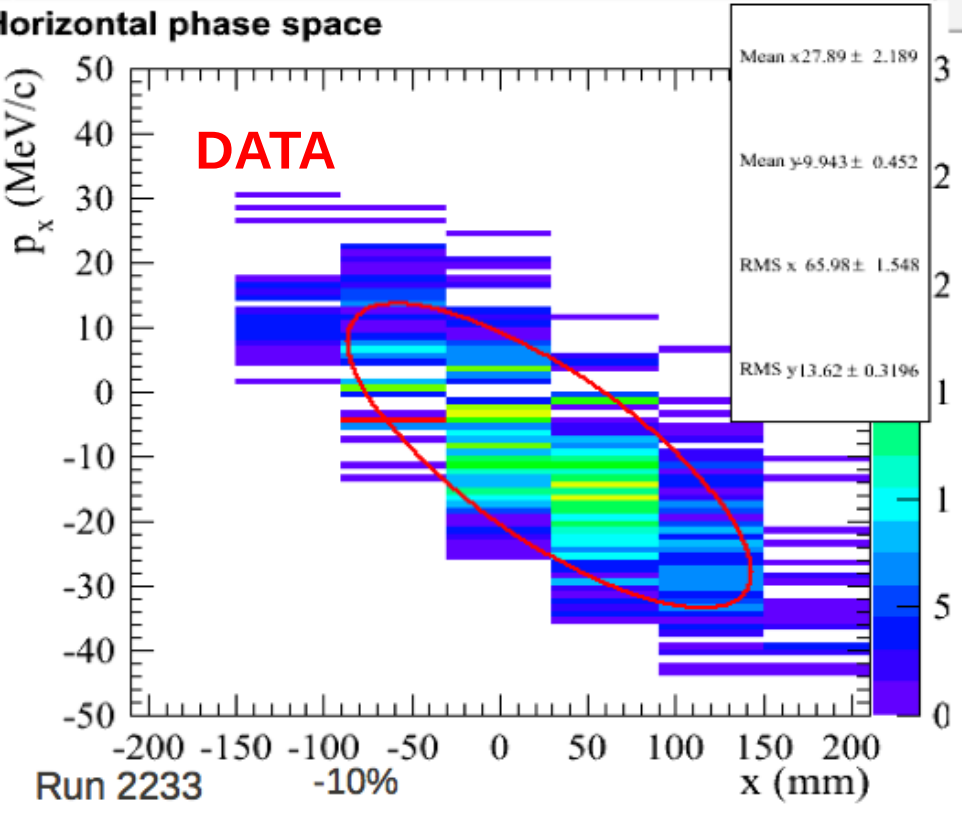


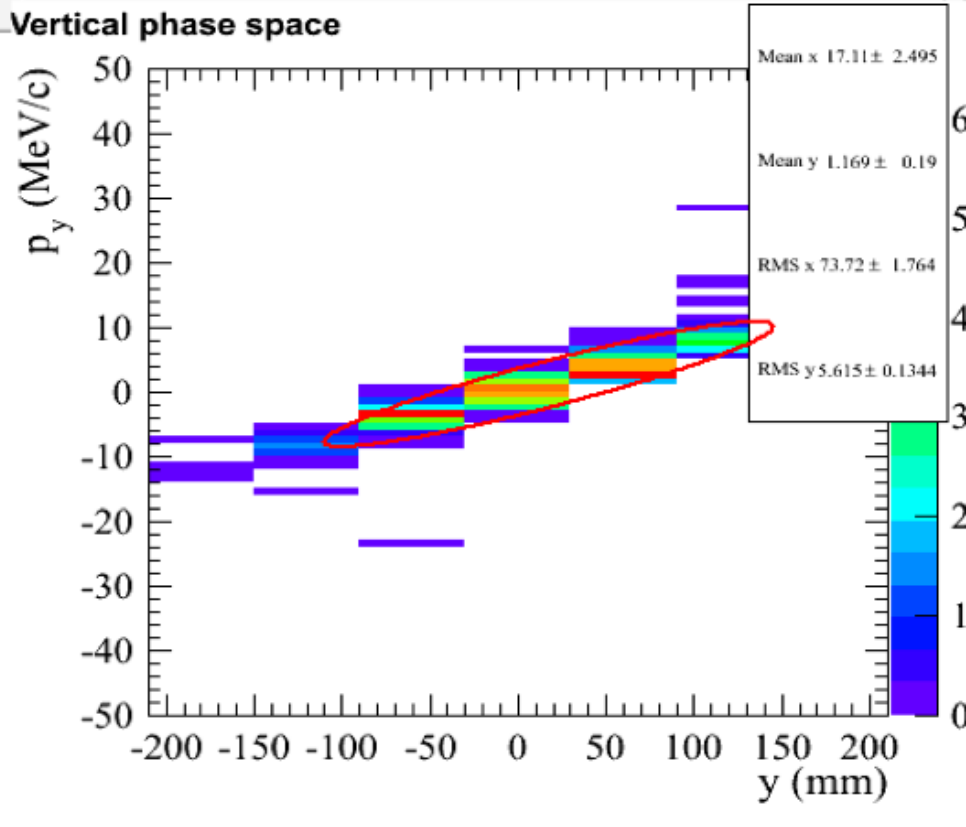




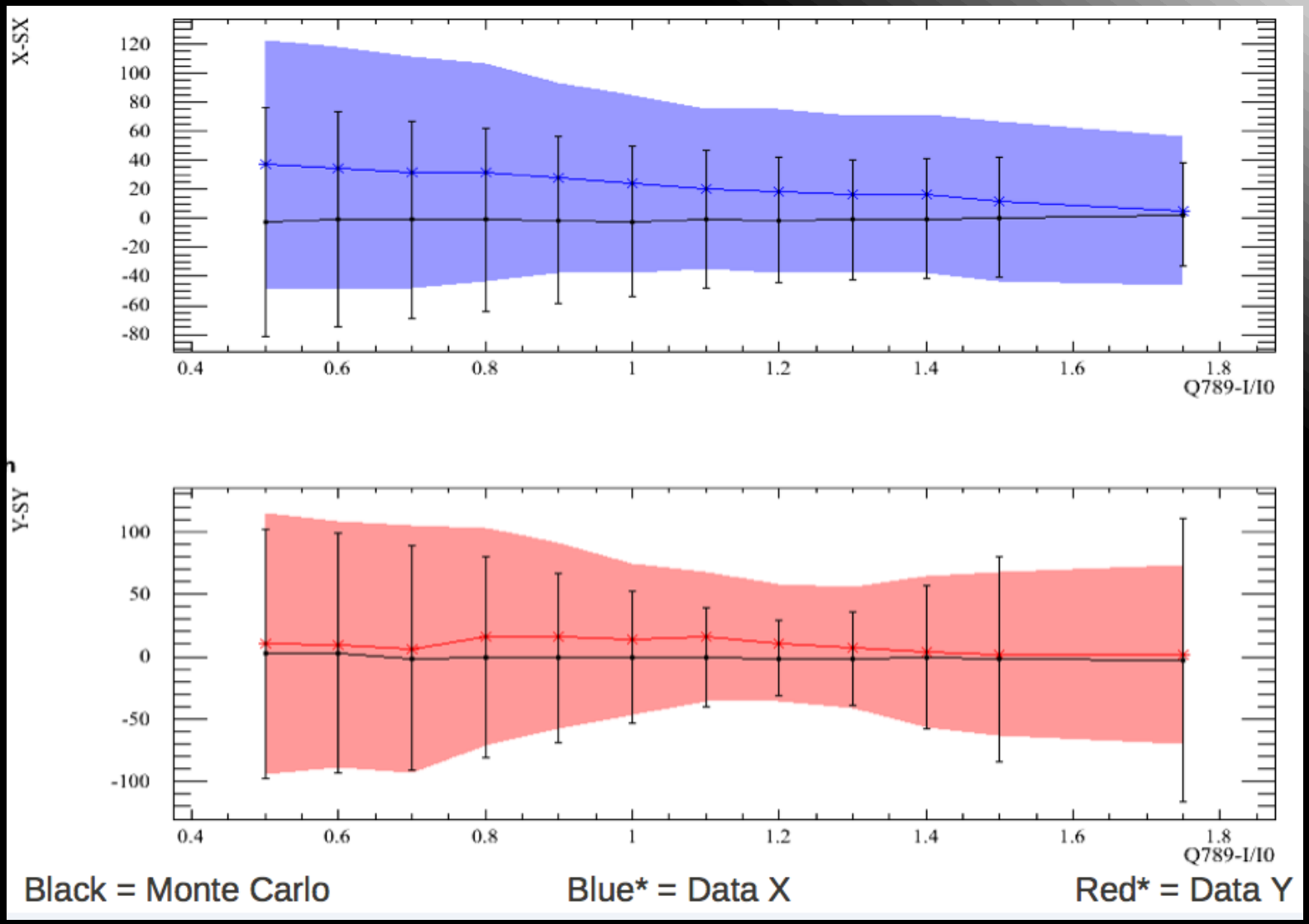

RUN 2233
hxPPhase
Entries 5009
Mean x -1.442
Mean y 0.2644
RMS x 57.44
RMS y 7.363
MC (G4Beamline)


RUN 2233
hyPPhase
Entries 5009
Mean x -1.076
Mean y -0.1509
RMS x 67.73
RMS y 4.024

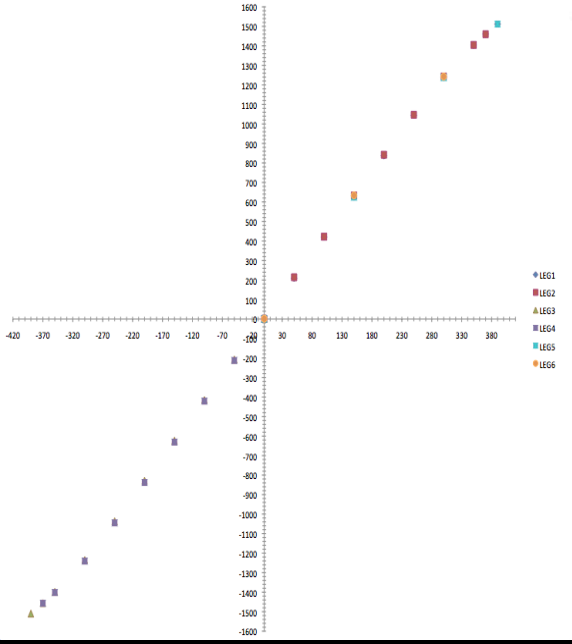

Horizontal phase space
Mean x 27.89 ± 2.189
Mean y -9.943 ± 0.452
RMS x 65.98 ± 1.548
RMS y 13.62 ± 0.3196
DATA
p_x (MeV/c)
x (mm)
Run 2233
-10%

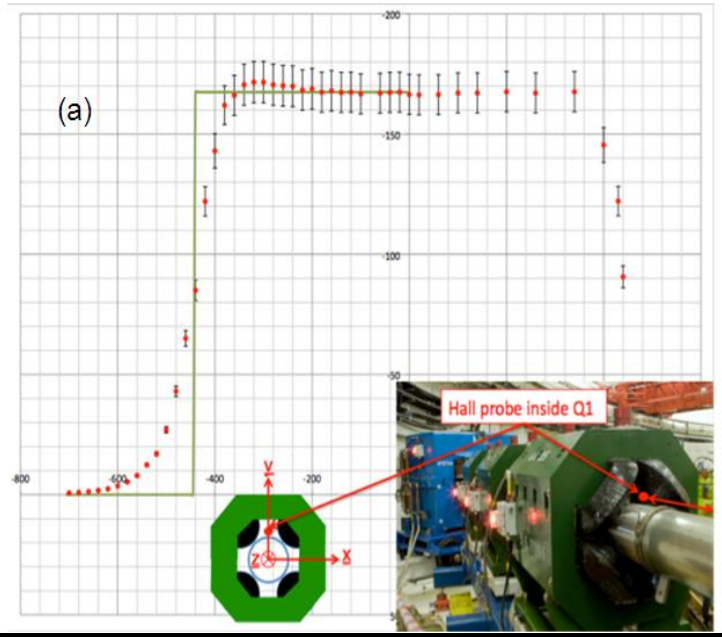

Vertical phase space
Mean x 17.11 ± 2.495
Mean y 1.169 ± 0.19
RMS x 73.72 ± 1.764
RMS y 5.615 ± 0.1344
p_y (MeV/c)
y (mm)

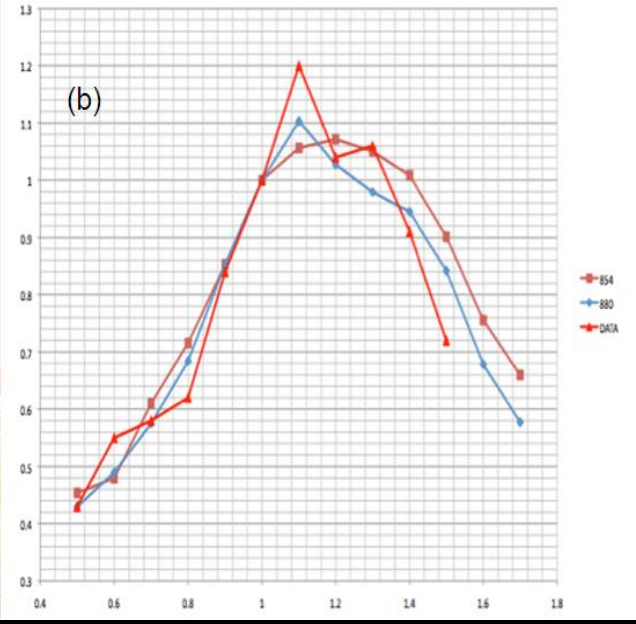
Q789 scan (-) polarity: X-σX / Y-σY .vs. triplet excitation



BL characterization – upstream magnets







Hysteresis check for D1

Leff measurement for Q1(2-3)

DATA/MC check: Q123 scan

DATA TAKING in numbers
- run characterized by target depth
- usually given in V (integral of the BLM-7)
- at 2-3 V (typical figure):
  - 20 μ^+ / spill [3 ms]
  - 5 μ^- / spill
- design goal: *500 μ / spill*

IMPLICATIONS
- operate BL in (+) mode [p contamination]
- production optimization (very marginal gain)
- target depth to be increased (within ISIS limits)

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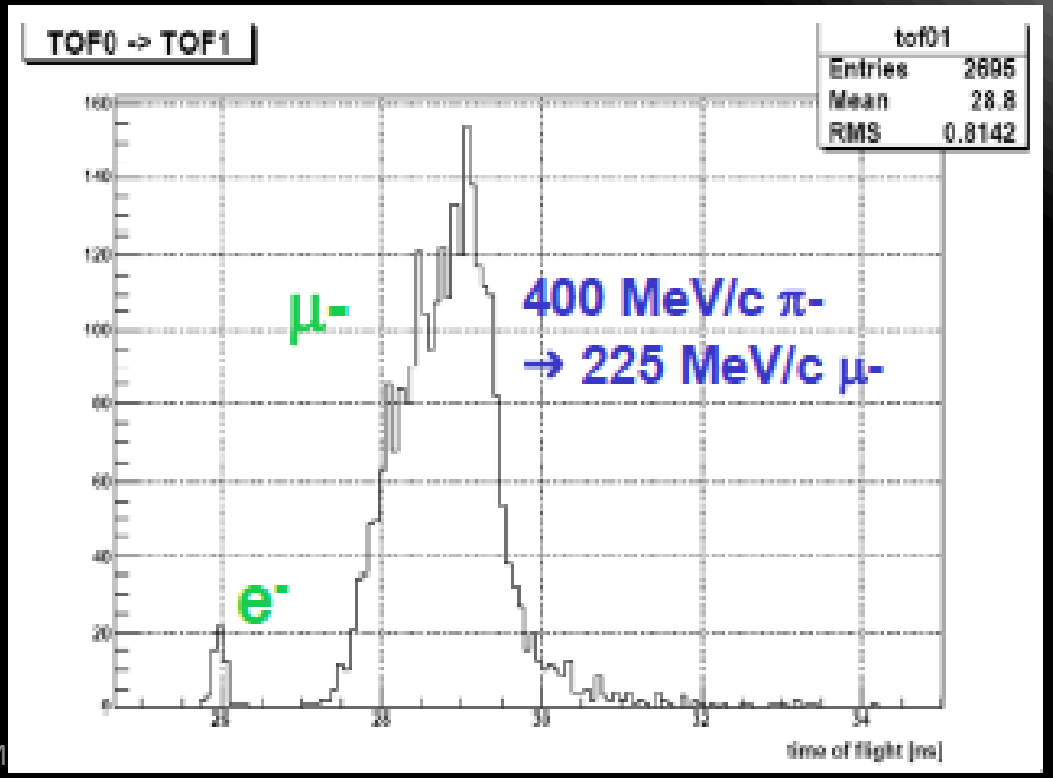
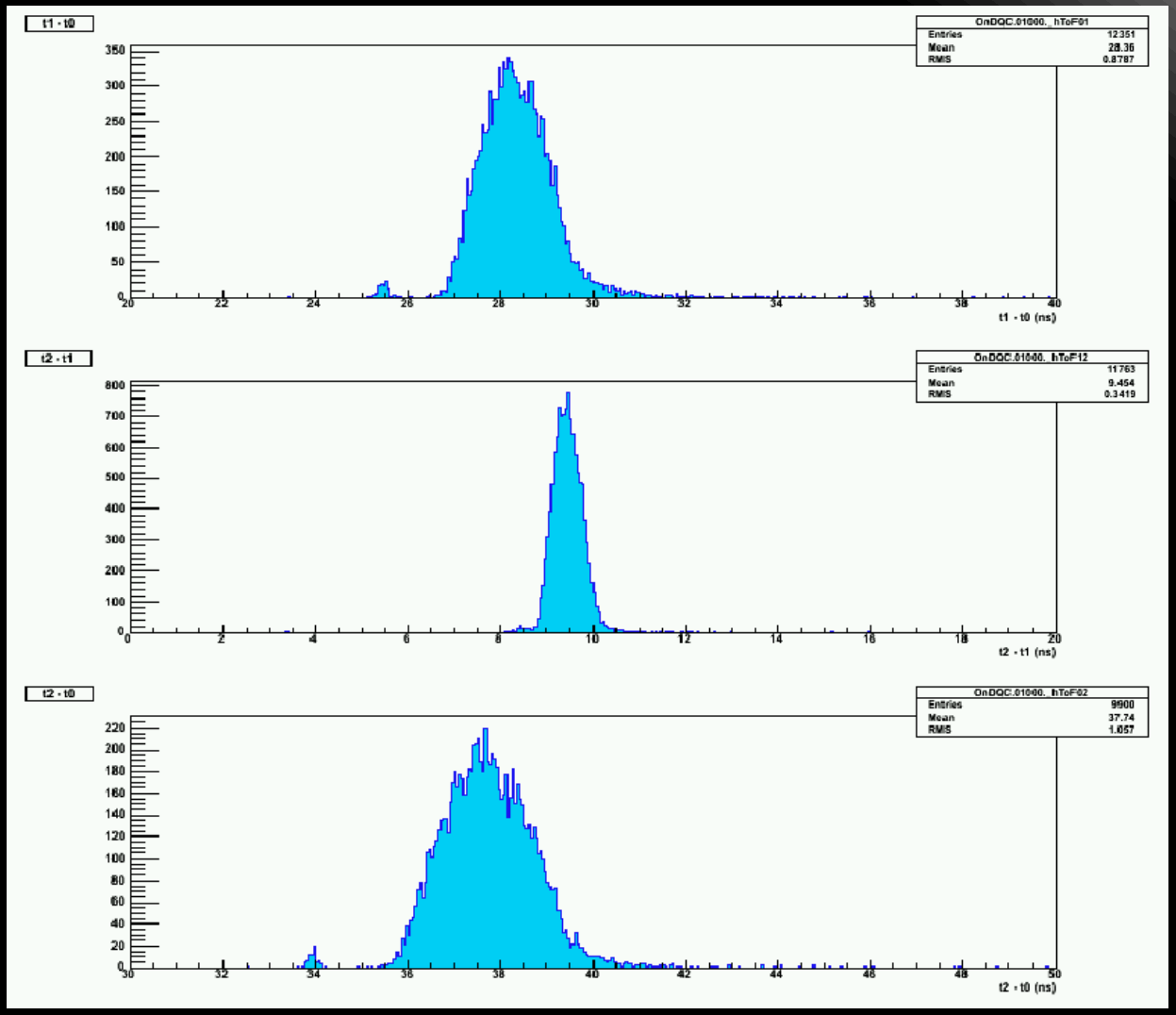
IMPLICATIONS
- operate BL in (+) mode [p contamination]
- production optimization (very marginal gain)
- target depth to be increased (within ISIS limits)

BEAM PURITY

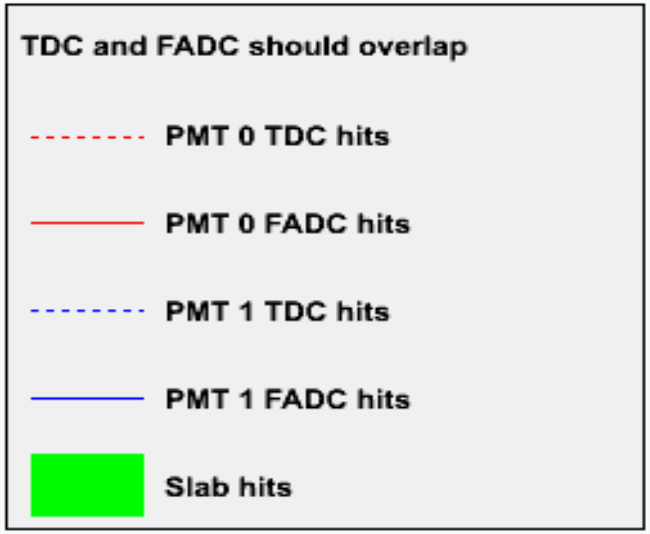
- $\pi \rightarrow \mu$ beam
- backward going μ selection should ensure a very high purity
- however we still need to measure it
- we need
  - reliable momentum determination
  - full MC reconstruction

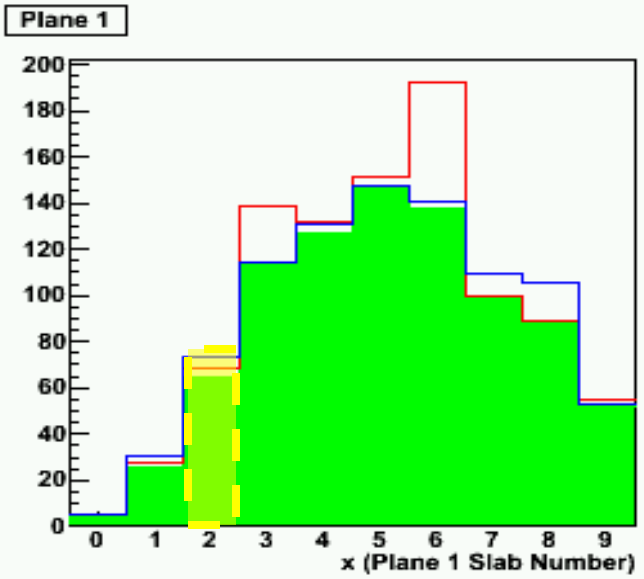


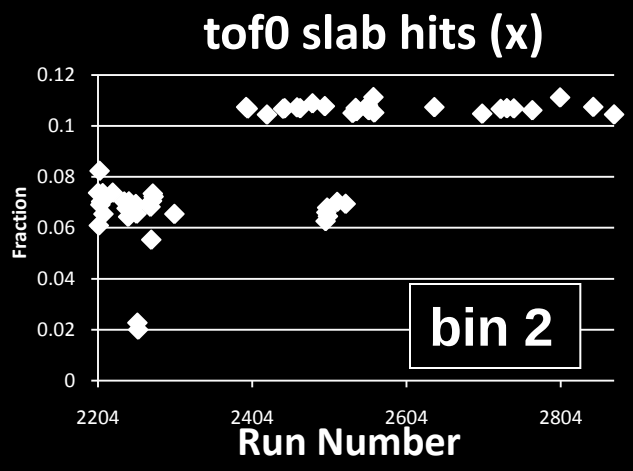
Monitoring
- RUN 2873 (time differences between TOF stations)

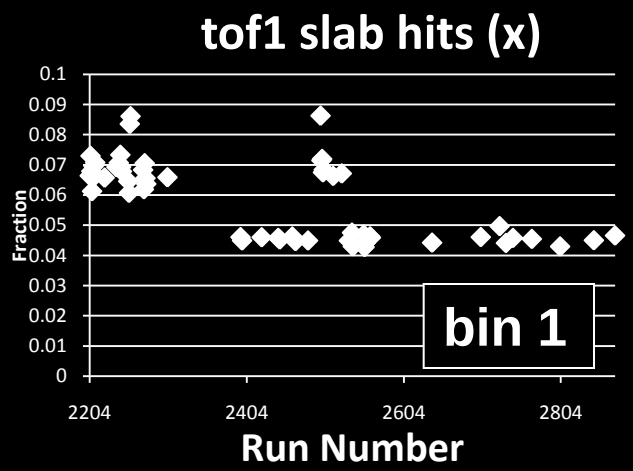


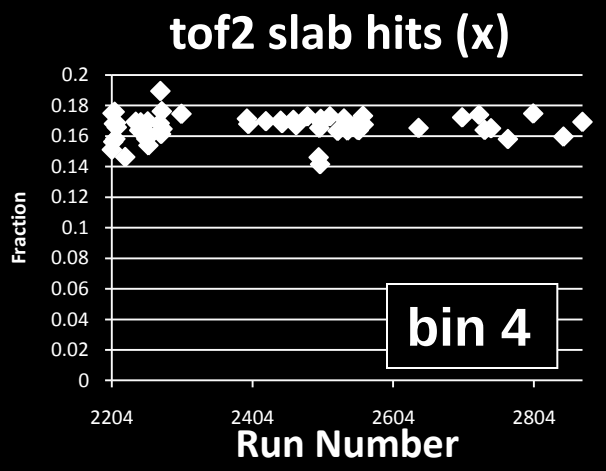
Data Quality
- stability of TOF0,1,2 slab hits in Reference Runs









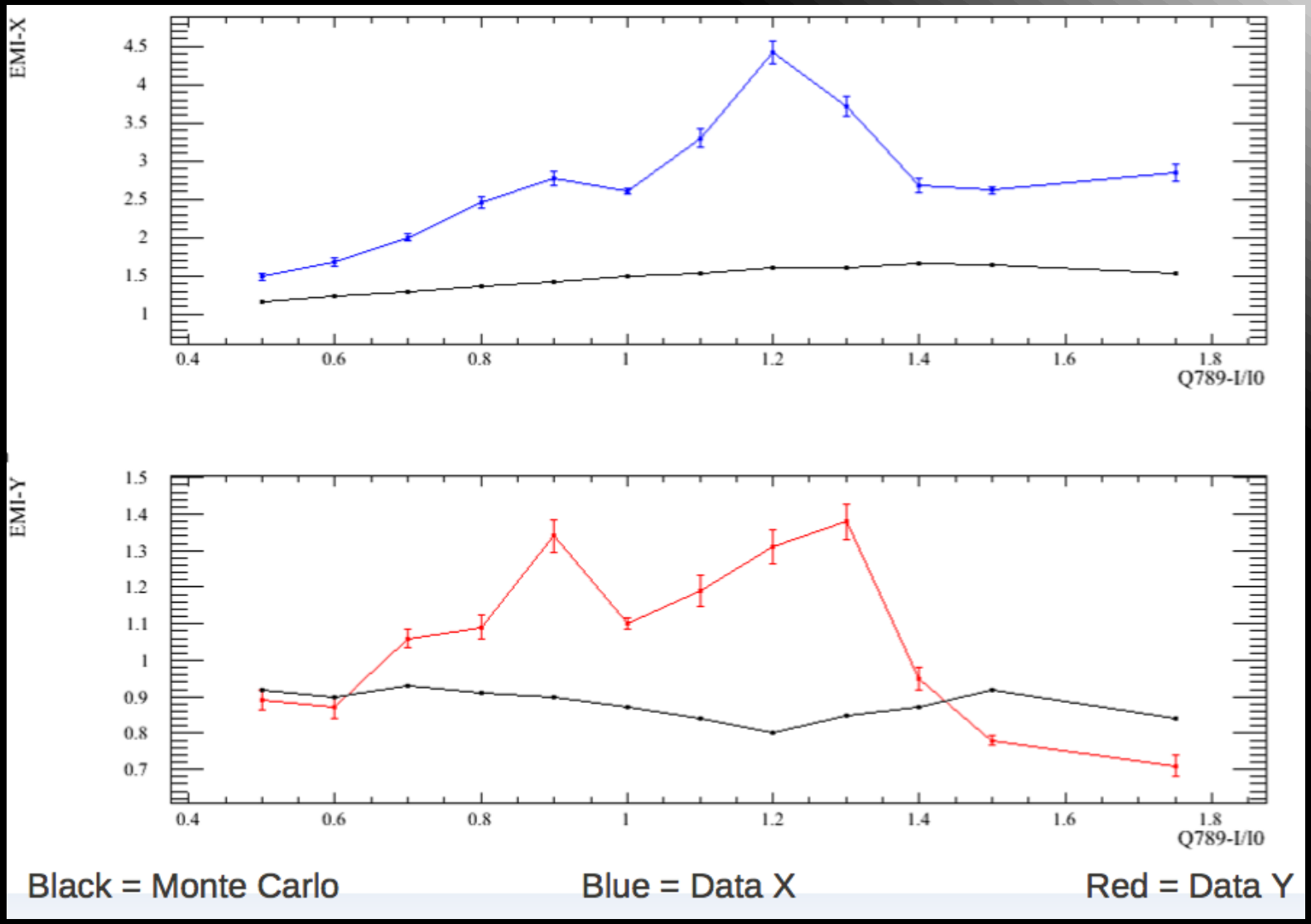


EMITTANCE

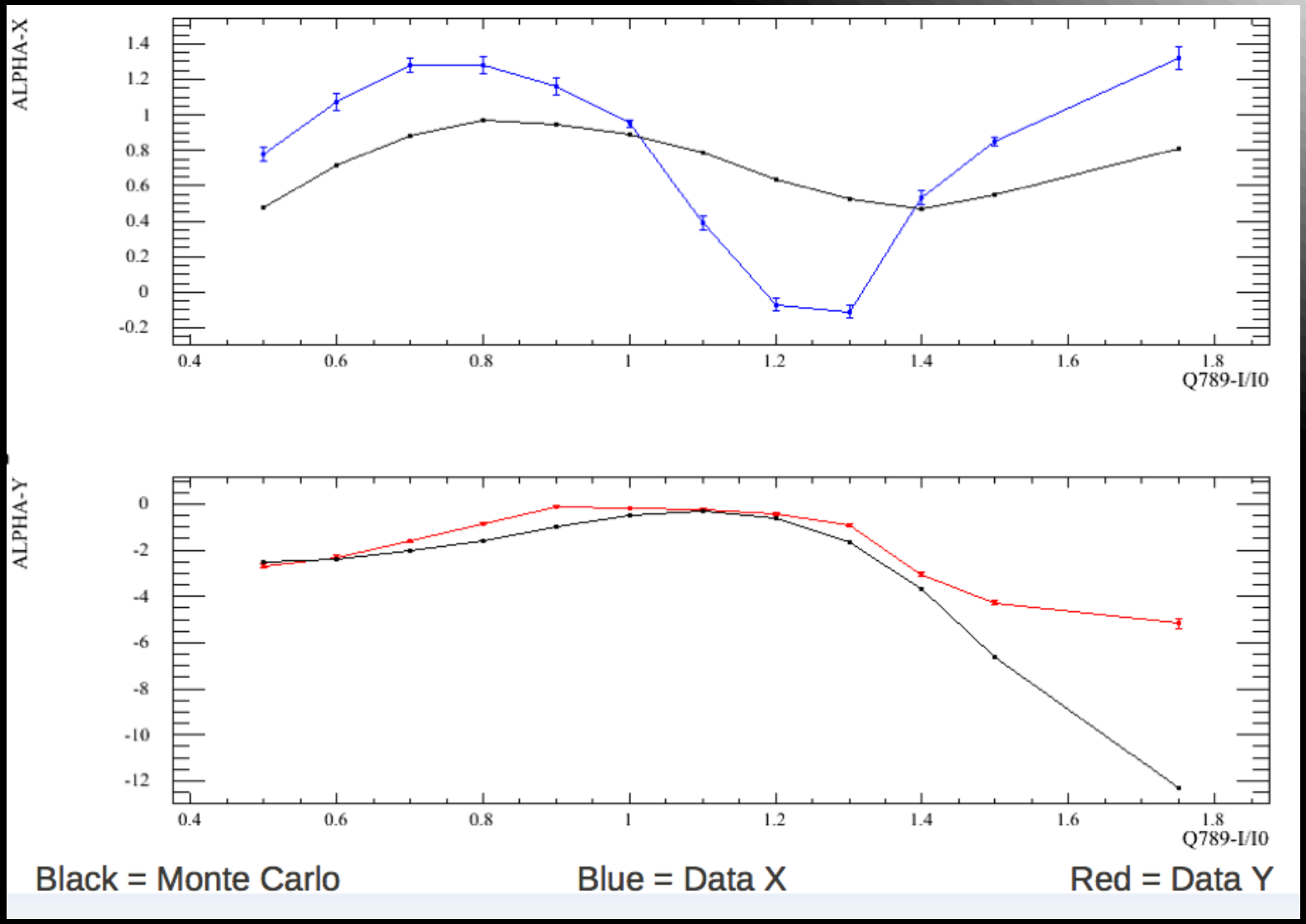
- emittance and Twiss parameter determination rely on a model for Q789 and a good knowledge of TOF0, 1 positions
- a derived quantity, whose *systematic error is still under investigation*
- measured values are in the ballpark of what was expected (~1-2 mm rad) but greater by a factor ~2

NOTE:
-TOF0,1 were NOT designed for such a measurement (σ_X~ 1.15/1.73 cm!)
- we are exploiting these detectors at the top of their possibilities
- a better knowledge of the system will certainly come with the installation of the tracker spectrometer(s)

Q789 scan (-) polarity: EMIx / EMIy [from beam covariance matrix]



Q789 scan (-) polarity: ALPHAx / ALPHAy



	140 MeV/c	200 MeV/c	240 MeV/c
3 mm rad	M0	M0	M0
6 mm rad	M0 & M1	M0 & M1 & M2 & M2+	M0 & M1
10 mm rad	M0 & M1	M0 & M1	M0 & M1

6 mm, 200 MeV/c Optics

P0=408.6 / PSol=238.0

	Momentum (MeV/c)	M0 Current (A)	M1 Current (A)	M2 Current (A)	M2+ Current (A)
Q1	405.93	102.38	102.38	102.38	
Q2	405.71	127.91	127.91	127.91	
Q3	405.49	89.00	89.00	89.00	
D1	405.27	323.15	323.15	323.15	
Decay Solenoid	405.04	668.63	668.63	668.63	
D2	237.87	94.15	94.15	94.15	
Q4	236.31	158.10	197.26	177.02	193.19
Q5	236.31	212.02	264.24	237.46	241.91
Q6	235.83	140.57	159.68	157.44	162.64
Q7	211.89	138.67	126.37	145.31	130.46
Q8	211.60	209.82	222.75	219.87	216.32
Q9	211.11	179.18	185.11	187.76	181.33

Negative polarity

	140		200		240	
	M0	M1	M0	M1	M0	M1
3	39,434		57,763		57,361	
6	52,440	45,284	61,652	50,522	39,417	45,942
10	42,490	53,006	50,446	27,814	43,870	45,212

Positive polarity

	140		200		240	
	M0	M1	M0	M1	M0	M1
3	80,160		171,600		236,630	
6	104,040	103,042	302,897	225,200	120,911	77,177
10	85,090	98,460	120,000	80,000	105,172	68,576

# of TOF1 triggers for the (e,P) matrix points during the July Users Run