What have we achieved with 2010 data taking campaign?

M. Apollonio
Imperial College, London

- 2010 data taking campaign
  - goals
  - highligths
- analysis
  - MC
  - Data
  - Comparison

Commissioning the Beam Line: goals

- calibrate detectors
- exercise DAQ
- *understand the beam*
  - composition
  - rates
  - momentum scale
  - 1st go at phase space reconstruction
  - (ε,p) runs
  - comparison with beam line model

Commissioning the Beam Line: data taking

- first trials end of 2009
  detector calibrations
- long stop due to DK Solenoid issues
- *successful* 2 months data taking during summer 2010 !

MICE STEPI

Machine Physics [15/6, 16/6] 2010

- Beam Rate vs Tgt depth studies
- max. beam loss: 4V

maximize μ production while operating in a parasitic mode

ISIS Users Run [19/6, 12/8] 2010

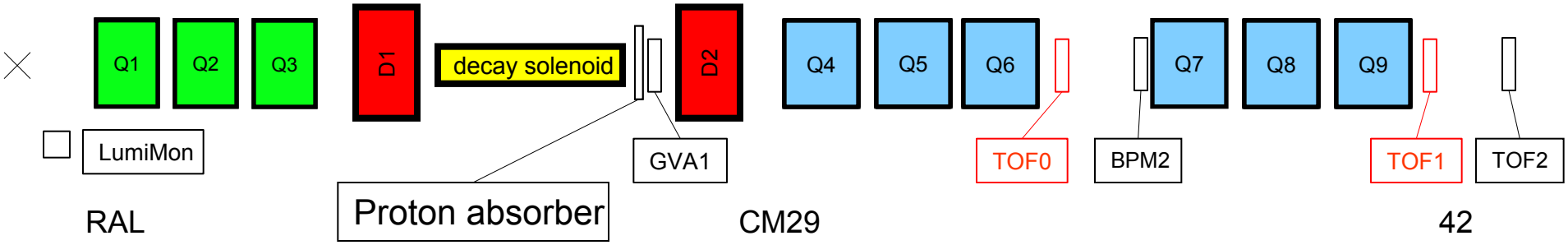
Over 340000 target actuations / 11M triggers / 917 runs

- upstream triplet scan
- dipoles scan
- downstream triplets scan
- downstream single quadrupole scan
- decay solenoid scan
- M0 data taking
- M1 data taking (also M2,M2+)
- DAQ tests
- On Line Monitoring

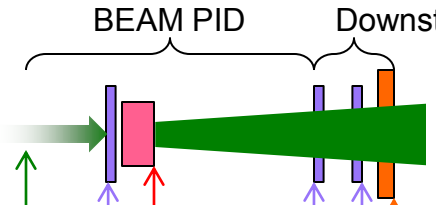
Machine Physics [13/8, 15/8] 2010

-Beam Rate vs Tgt depth studies
- max beam loss: 10V

Scheme of the BL with some of the detectors used for analysis and monitoring



RAL CM29



STEPI: characterize beam line and PID detectors (TOF0,1,2 / CKOVa,b / KL)

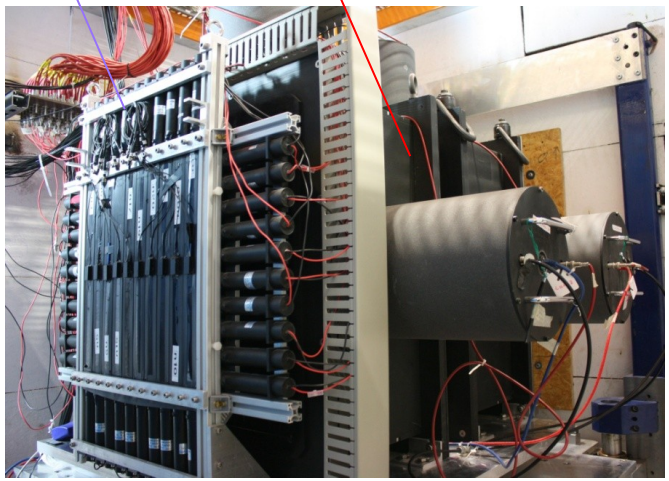
TOF0

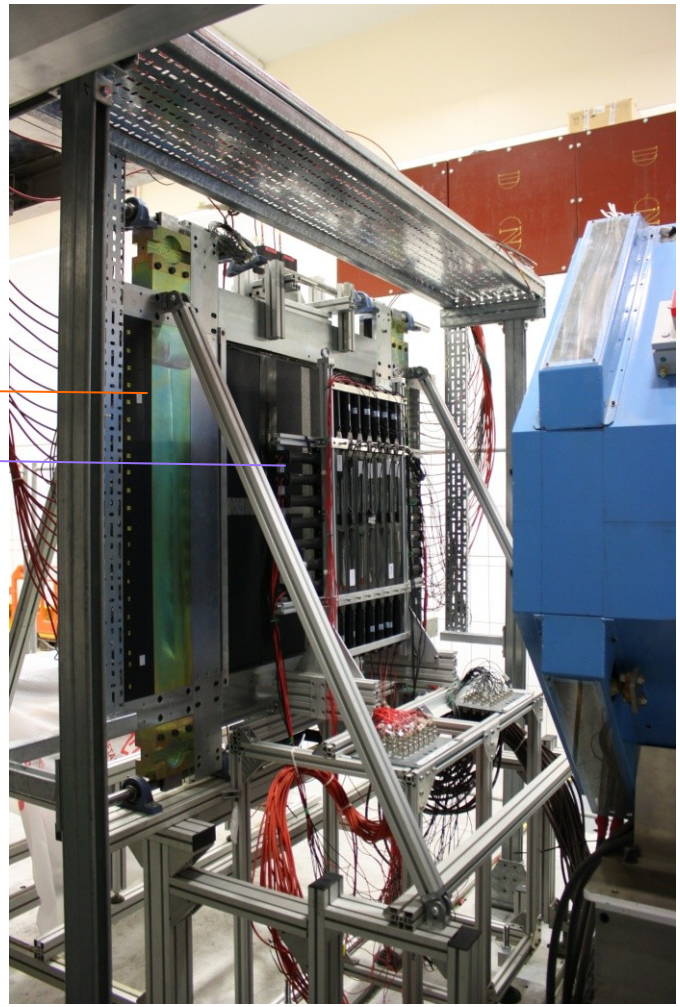
TOF1 TOF2

CKOVa,b

KL

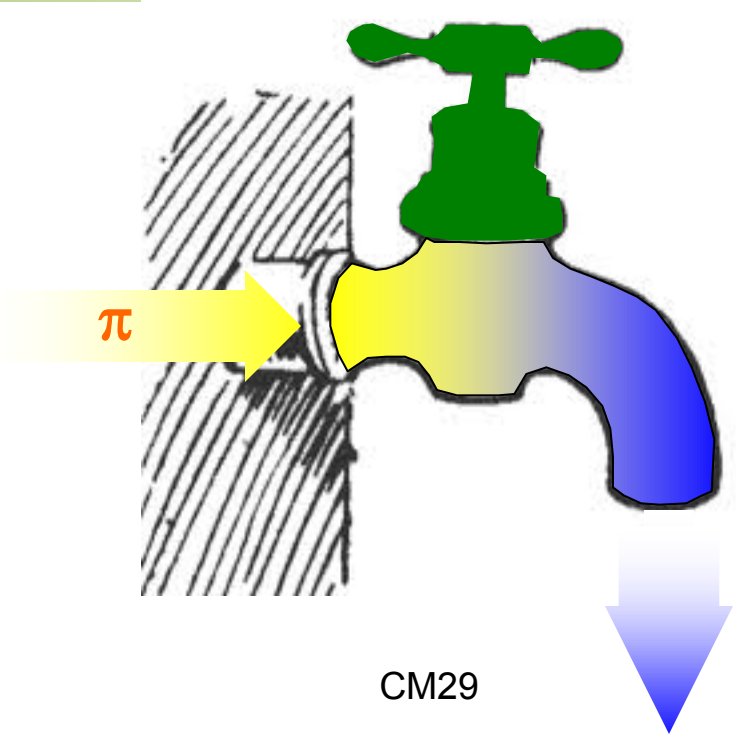
Beam Line:
provides μ for the
MICE cooling channel
with correct momentum
and optics
[details later]



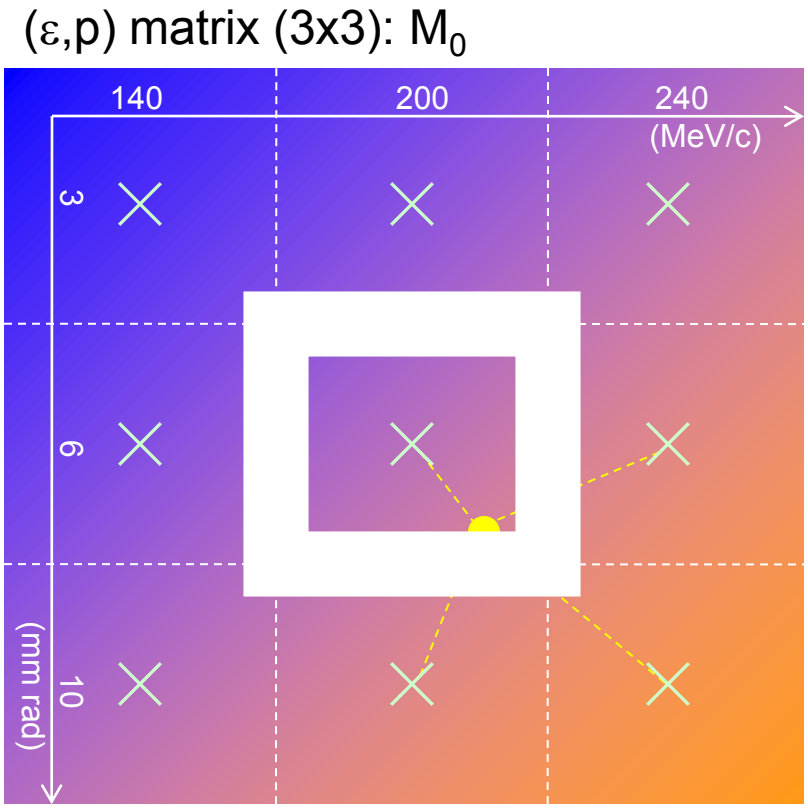


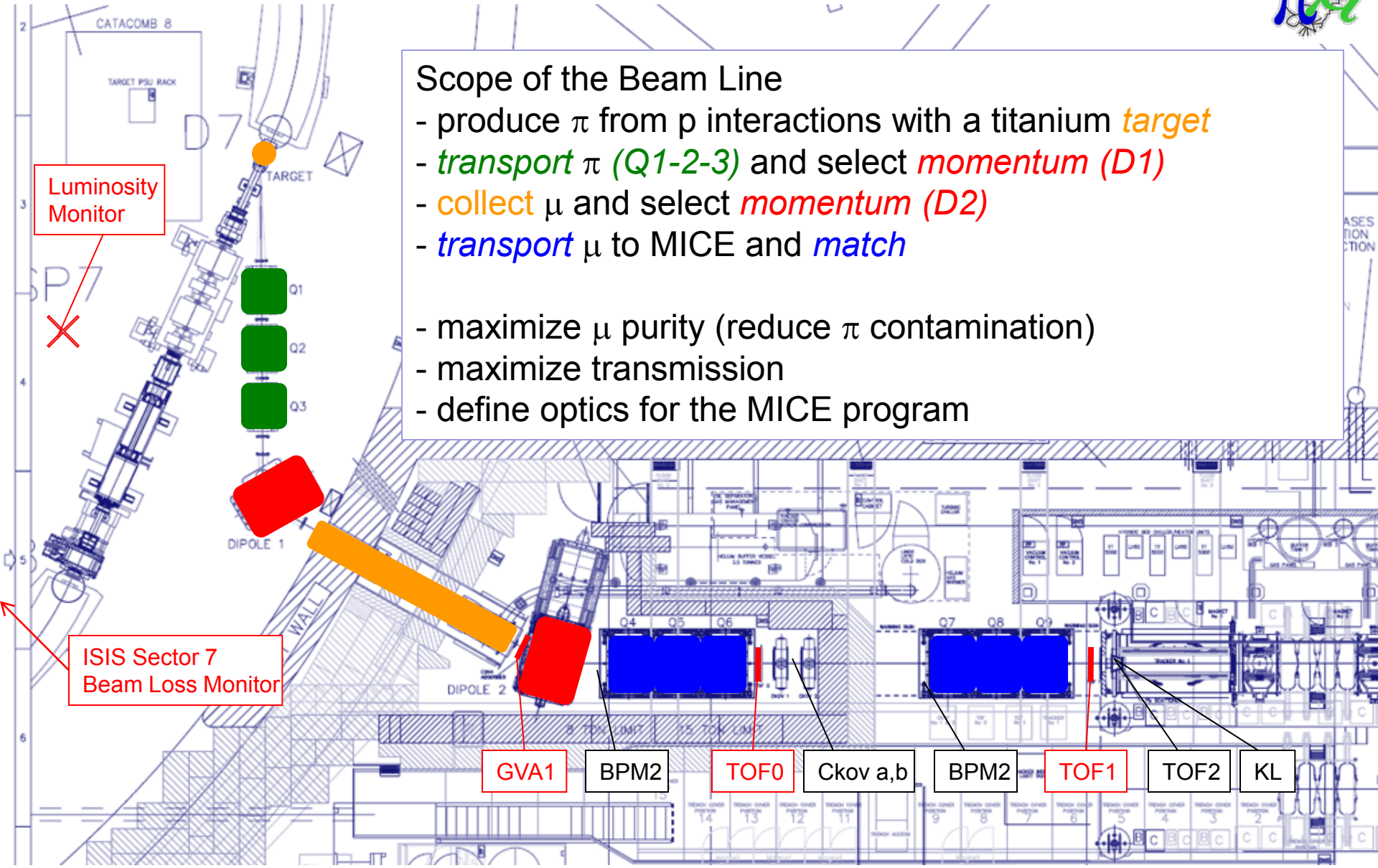
STEPI

- pion →muon beam (high purity)
- tunable in momentum [140, 240] MeV/c within MICE
- ε_N generation [3,10] mm rad within MICE
- match with MICE optics
- control transmission

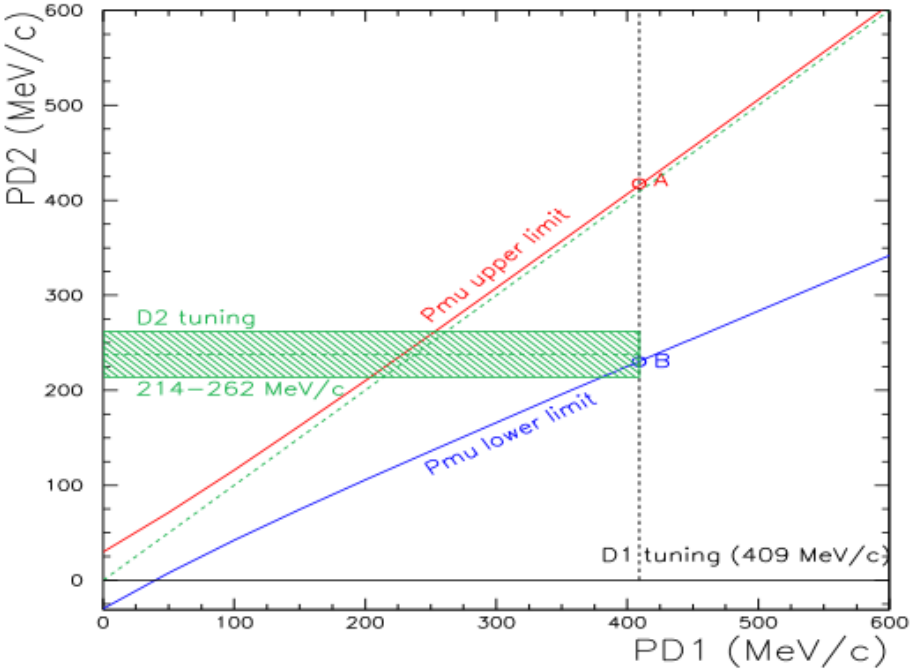


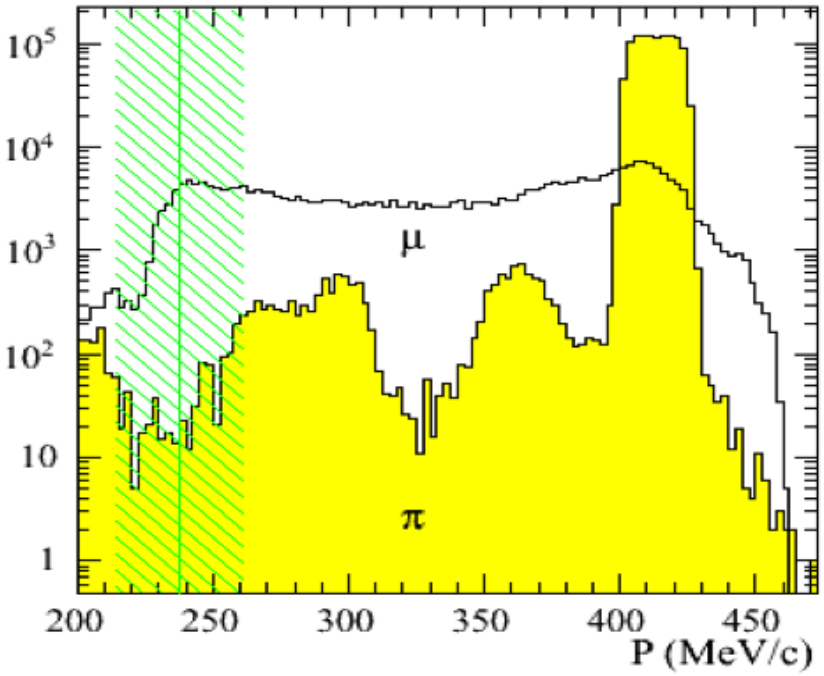
matrix of 9 elements in (e,P) space (any generic point can be interpolated)




Scope of the Beam Line
- produce π from p interactions with a titanium target
- transport π (Q1-2-3) and select momentum (D1)
- collect μ and select momentum (D2)
- transport μ to MICE and match
- maximize μ purity (reduce π contamination)
- maximize transmission
- define optics for the MICE program
Luminosity Monitor
ISIS Sector 7 Beam Loss Monitor
CATACOMB 8
TARGET PSU RACK
TARGET
Q1
Q2
Q3
DIPOLE 1
DIPOLE 2
WALL
Q4
Q5
Q6
Q7
Q8
Q9
GVA1
BPM2
TOF0
Ckov a,b
BPM2
TOF1
TOF2
KL

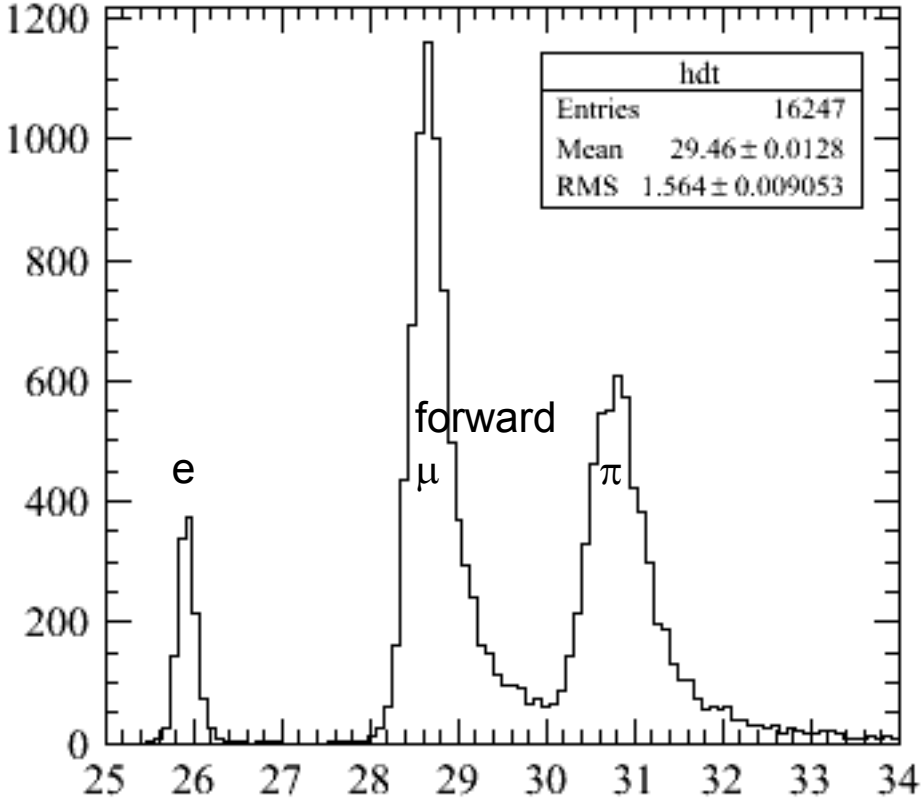
- μ purity (D1-D2 interplay)
- select *backward going μ (D2)*



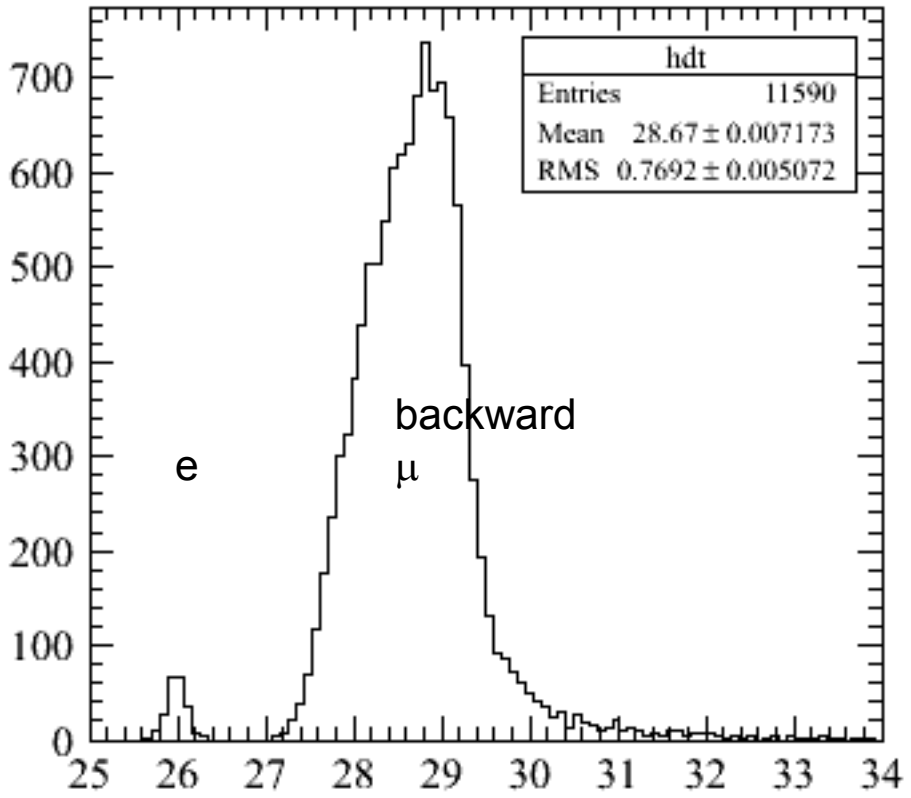


Beam Line operating modes: TOF0-1 time of flight distributions

PD1 ~ PD2 (single momentum – calibration)

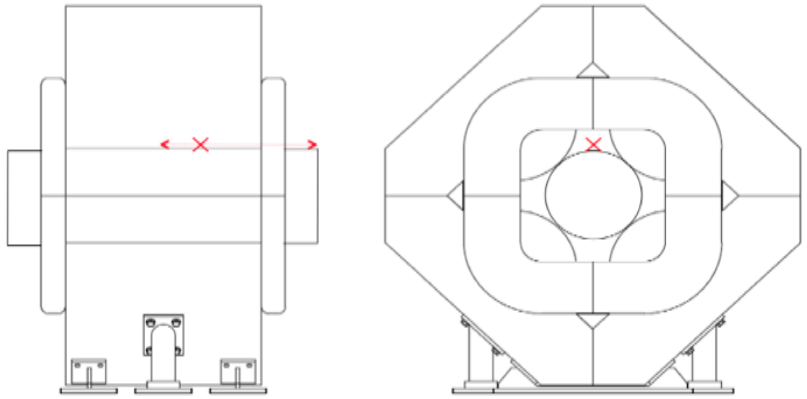


PD1 ~ 2xPD2 (π → μ)



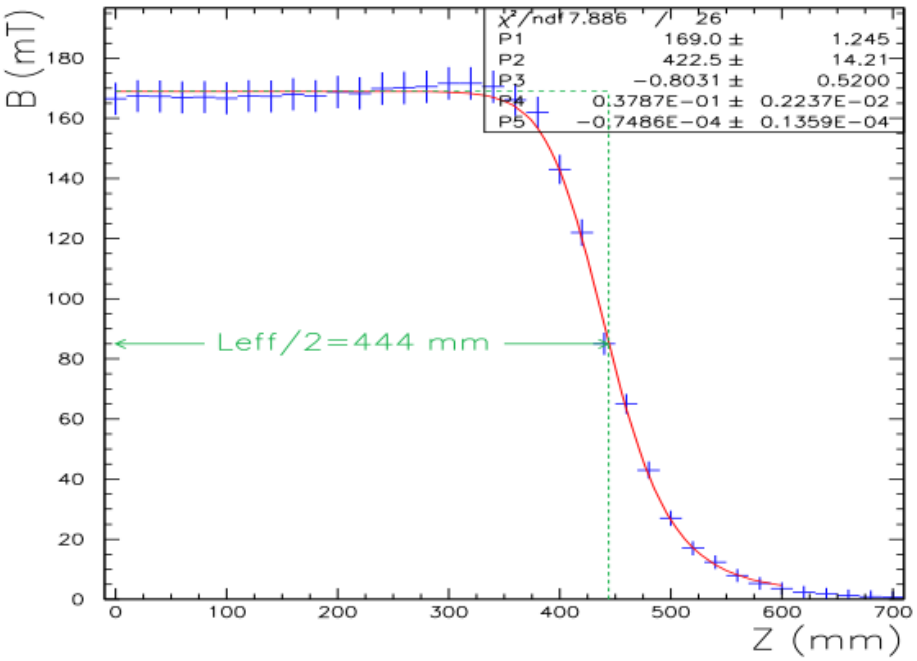
ϵ_N (mm·rad)		p_z (MeV/c)		
		140	200	240
	3	t=0.0 mm P_{dif}=151 α=0.2 β=56 cm	t=0.0 mm P_{dif}=207 α=0.1 β=36 cm	t=0.0 mm P_{dif}=245 α=0.1 β=42 cm
	6	t=5.0 mm P_{dif}=148 α=0.3 β=113 cm	t=7.5 mm P_{dif}=215 α=0.2 β=78 cm	t=7.5 mm P_{dif}=256 α=0.2 β=80 cm
	10	t=10.0 mm P_{dif}=164 α=0.6 β=198 cm	t=15.5 mm P_{dif}=229 α=0.4 β=131 cm	t=15.5 mm P_{dif}=267 α=0.3 β=129 cm

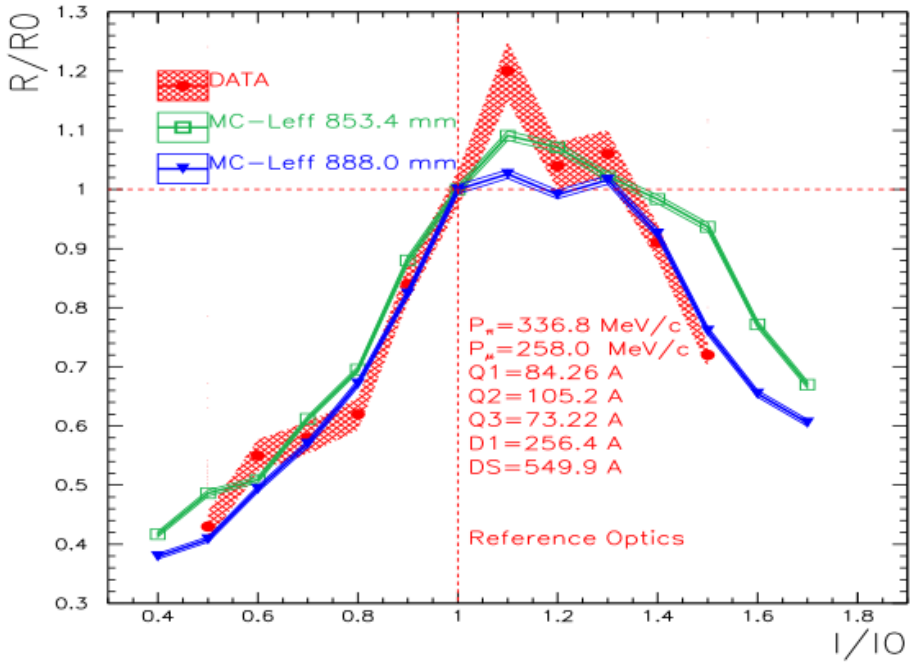
Up Stream Beam Line



GVA1 relative counts vs 1st triplet exitation

- Leff revisited in G4beamline after measurement
- better agreement on the right tail
- small impact on down-stream evolution





Down Stream Beam Line

This is the important part:
- we want muons at the right P and with the right Twiss Parameters
- we achieve this by tweaking Q4-5-6 / Q7-8-9

- all in all we need to MEASURE the Phase Space at some point along the BL
- compare it with our simulation
- understand how a variation in an element (say a quadrupole or a triplet) produces a change in the beam

- Exploration of MATRIX ELEMENTS → MARK?
- Study of Quadrupole SCANS → I have some old and newish stuff but difficult to reduce to good pictures, I was still working on it … maybe Mark has it too

Down Stream Beam Line (Simulation)

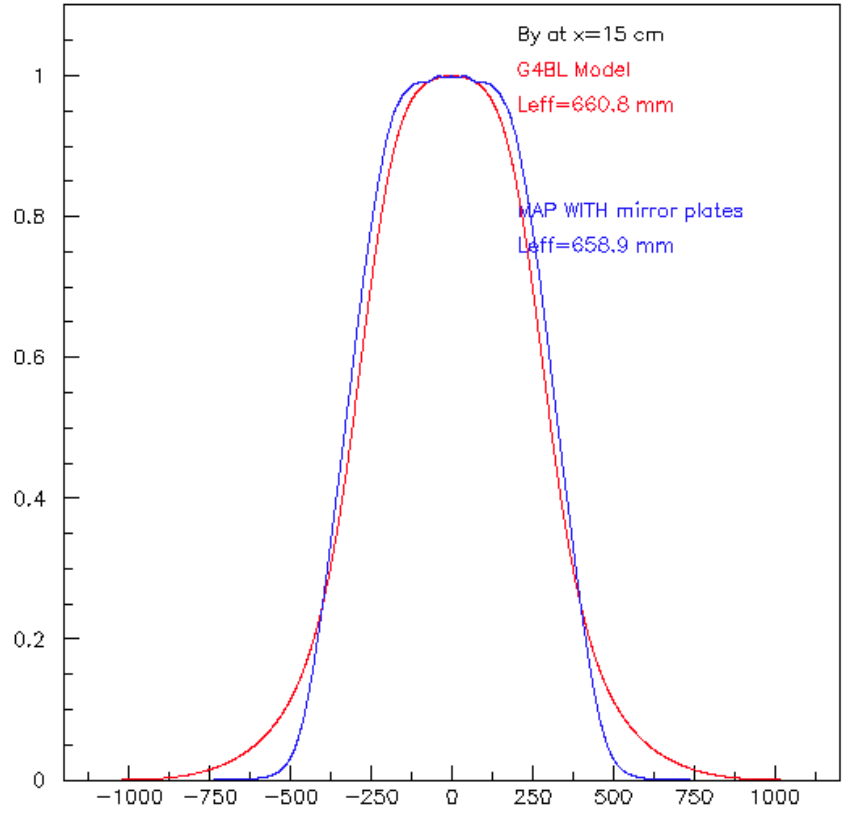
We had quite some discussion on the use of maps / Enge Functions / Tanh functions to provide a more realistic field / gradient for the qaudrupoles

In fact in the original G4beamline version the gradients were not right

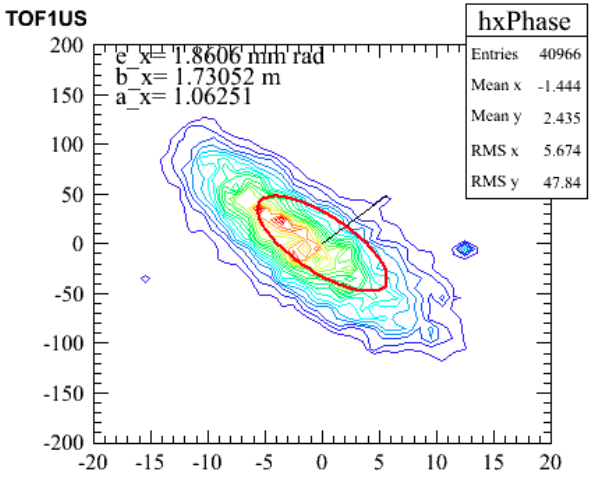
I am using OPERA maps now

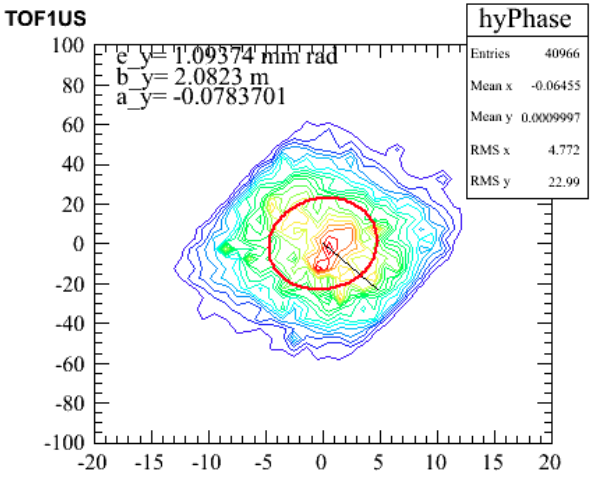
Mark/Chris could comment on G4MICE

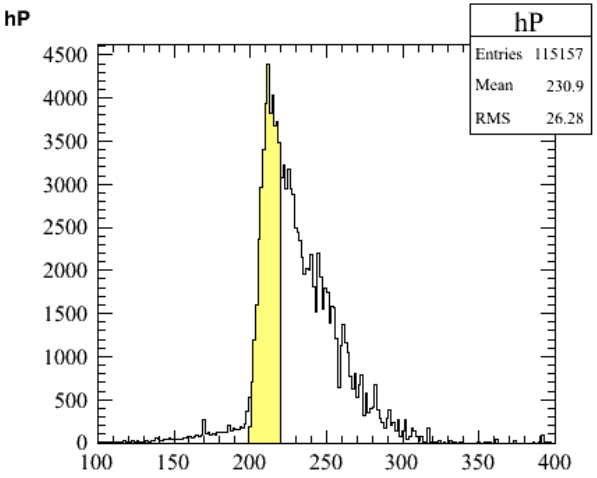
G4MICE/G4beamline have the SAME maps available



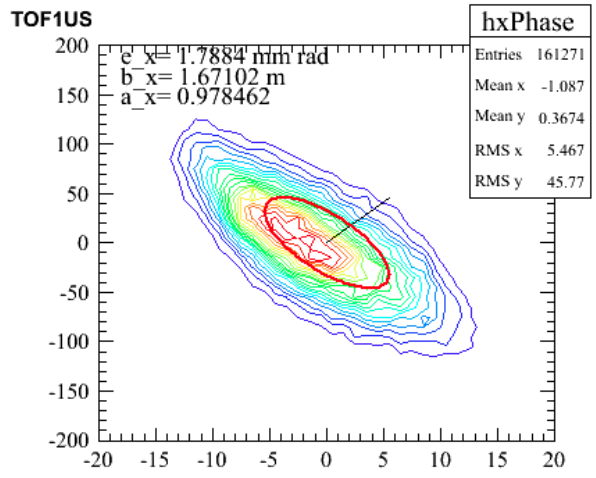
G4Beamline @ TOF1US (muons) (x-x') (y,y') (P)

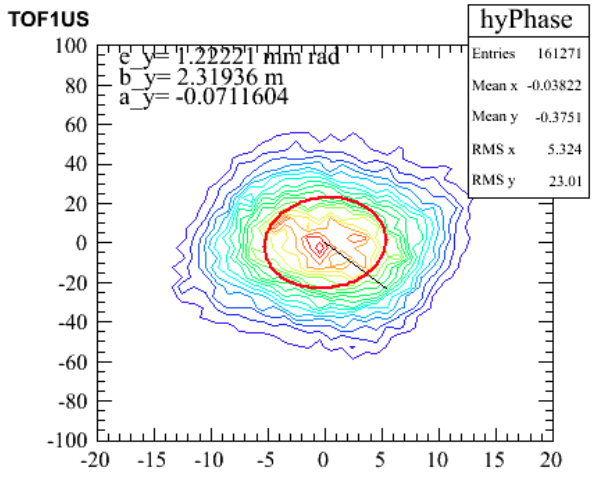


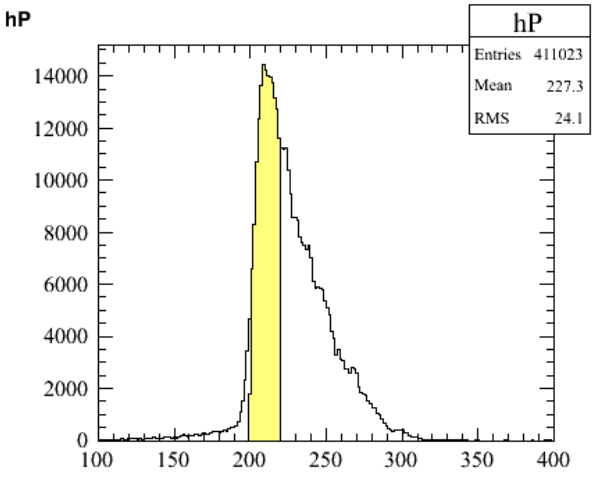




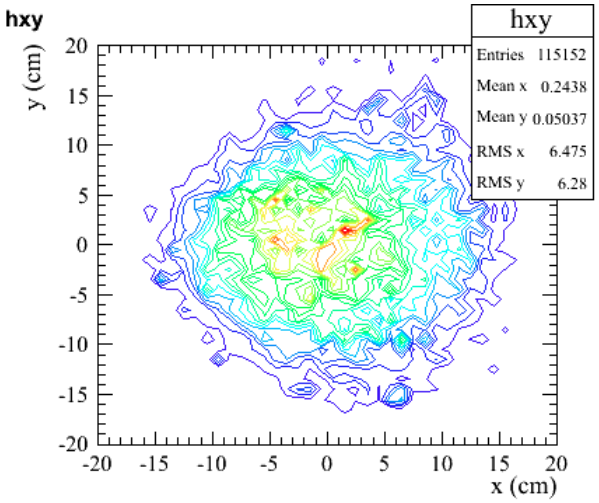
G4MICE @ TOF1US (muons) [MONTECARLO TRUTH] (x-x') (y,y') (P)

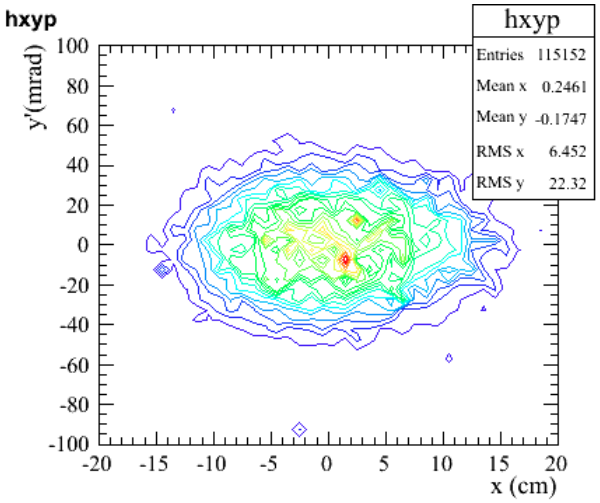


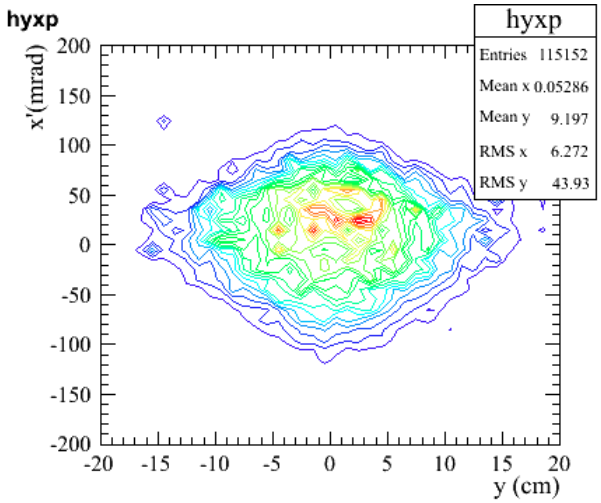




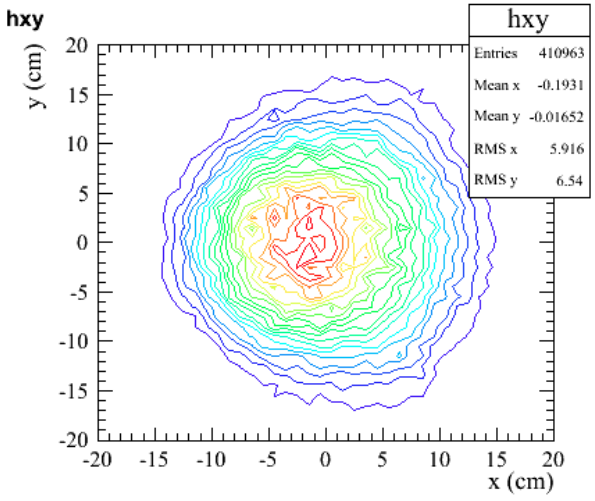
G4Beamline @ TOF1US (muons) (x,y) (x,y') (y,x')

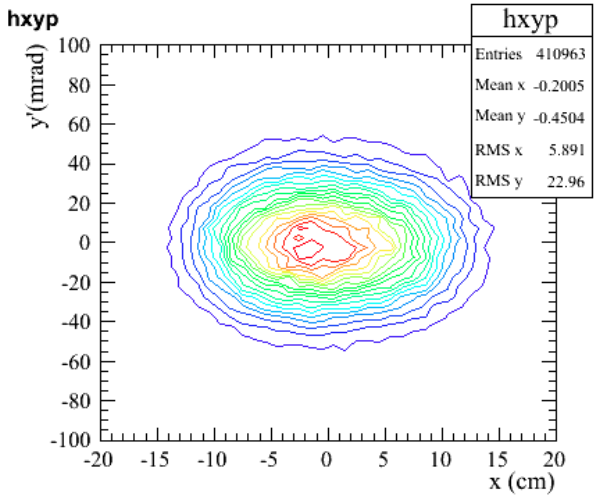


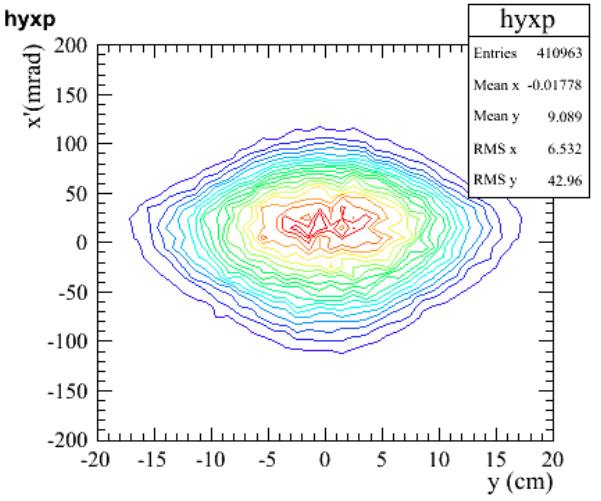




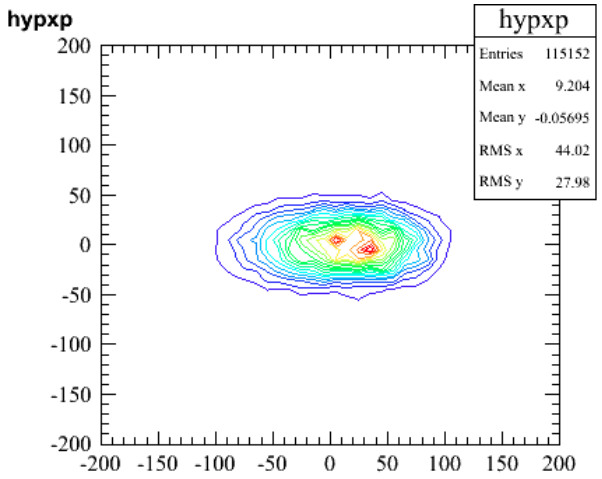
G4MICE @ TOF1US (muons) [MONTECARLO TRUTH] (x,y) (x,y') (y,x')

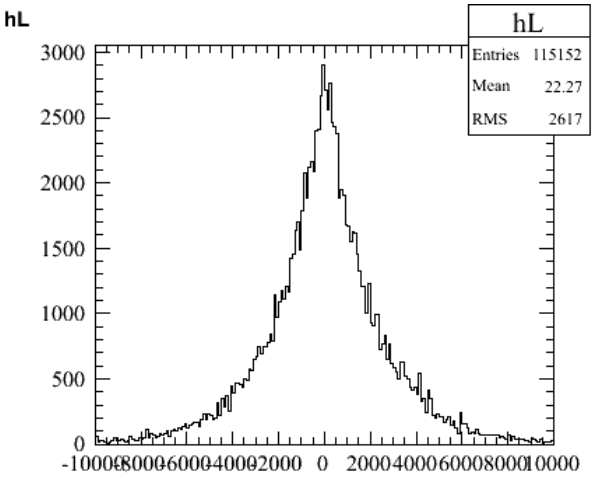


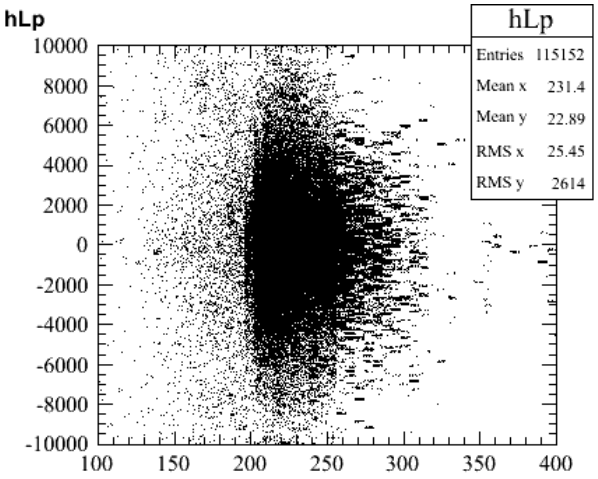




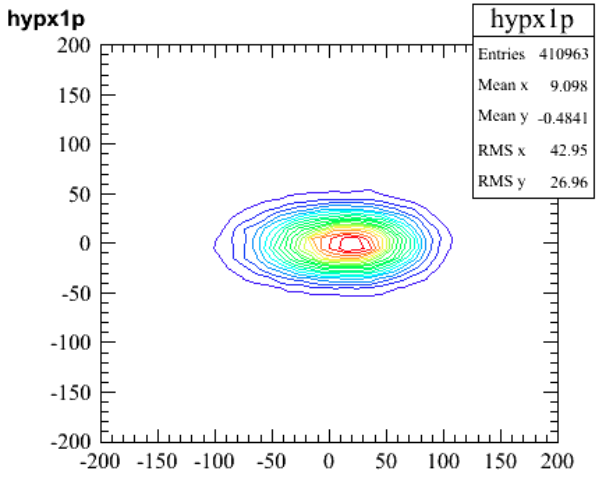
G4Beamline @ TOF1US (muons) (x',y') (L=xy'-yx') (L,p)

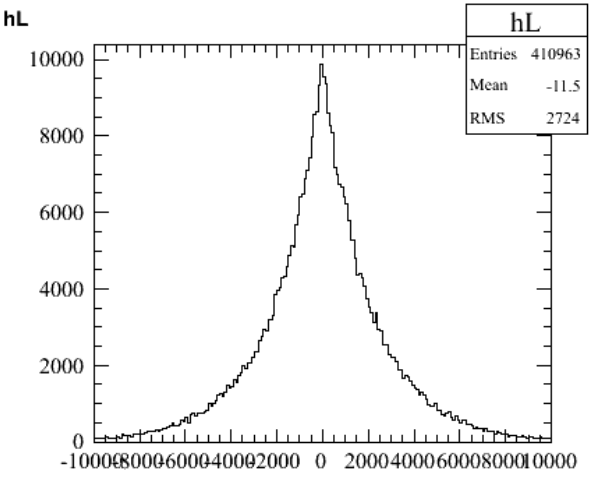


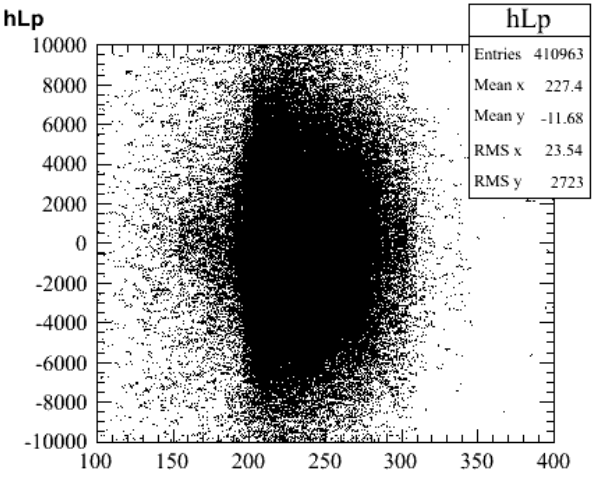




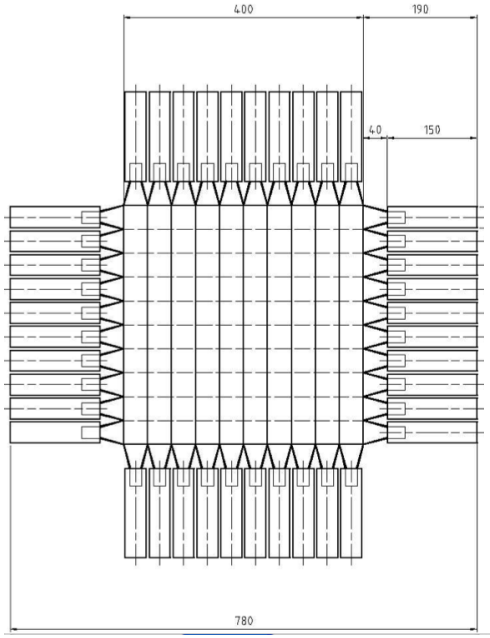
G4MICE @ TOF1US (muons) [MONTECARLO TRUTH] (x',y') (L=xy'-yx') (L,p)

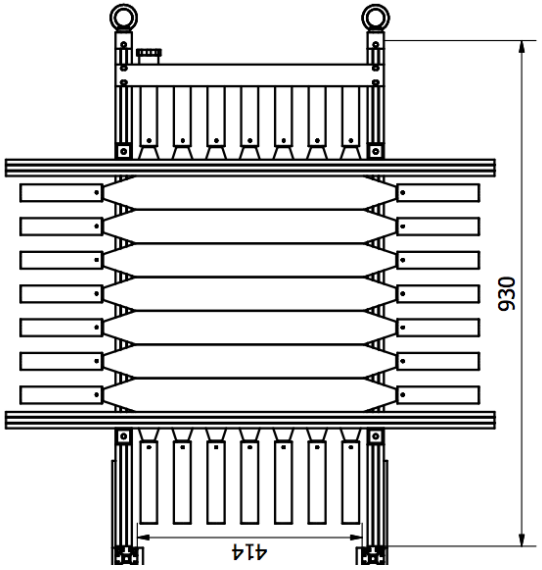






DATA Taking Campaign 2009-2010: TOF0, 1





TOF0

10 x 4 cm scintillating bars

σx = 1.15 cm

σt = 50 ps

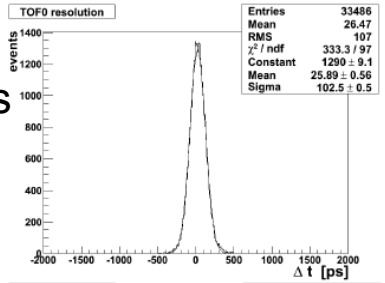
TOF1

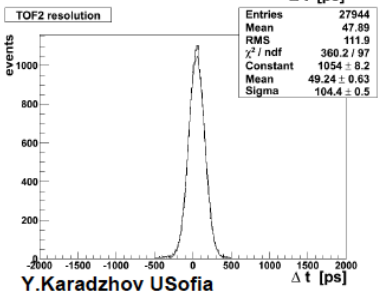
7 x 6 cm scintillating bars

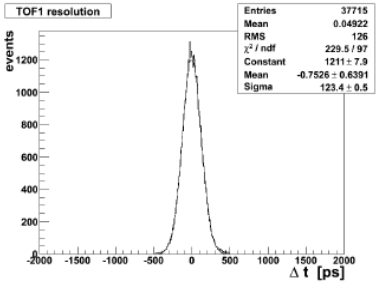
σx = 1.73 cm

σt = 50 ps

[The design and commissioning of the MICE upstream time-of-flight system,
R. Bertoni et al. , NIM-A 615 (2010) 14-26]



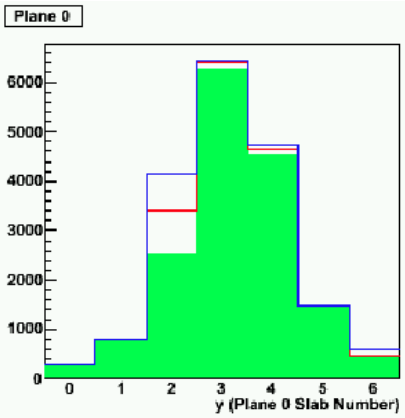


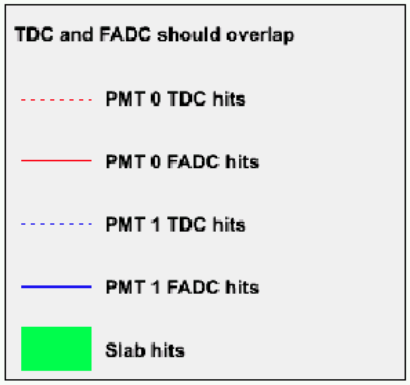


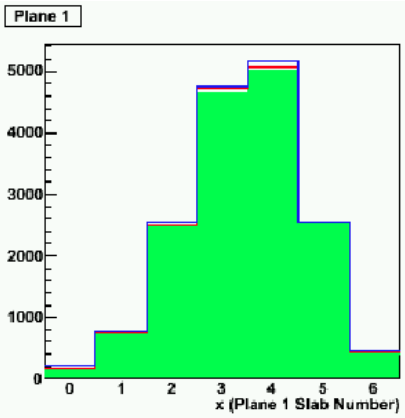
- ***Time resolution after calibration:***
- ***TOF0 – 51ps***
- ***TOF1 – 62ps***
- ***TOF2 – 52ps***
- ***Resolution meets design goals for TOFs***

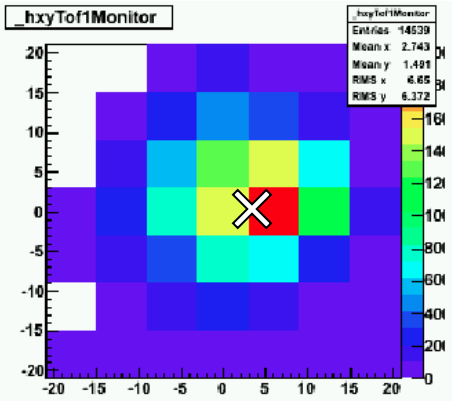
Y.Karadzhov USofia

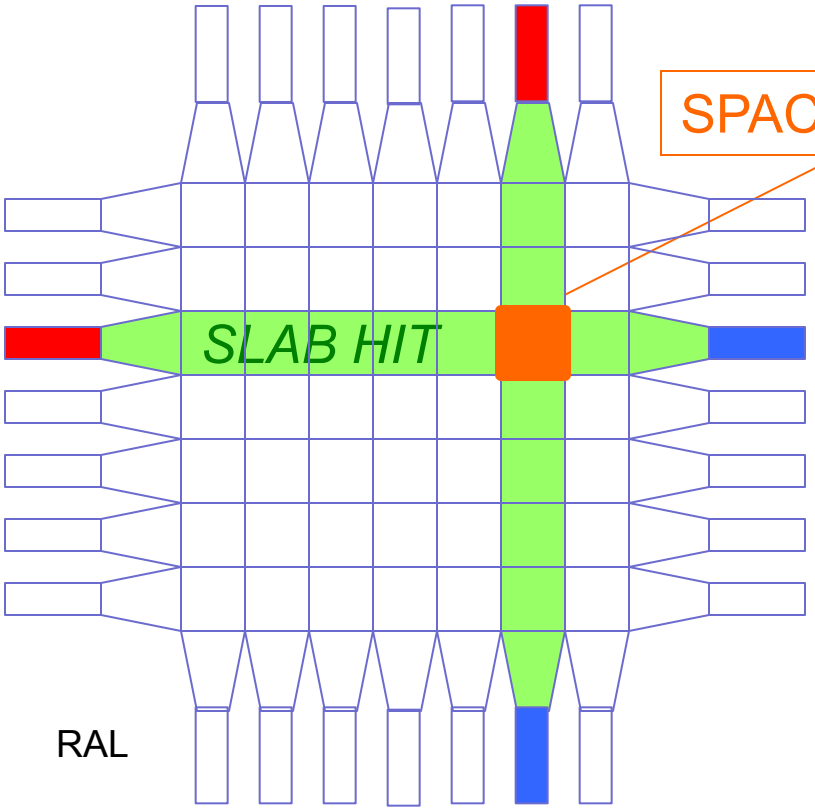
Beam Monitoring







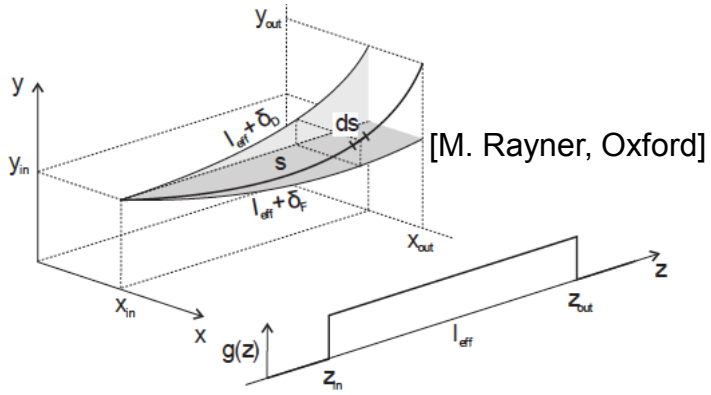




(X,Y) displacement confirmed by post DATA taking survey

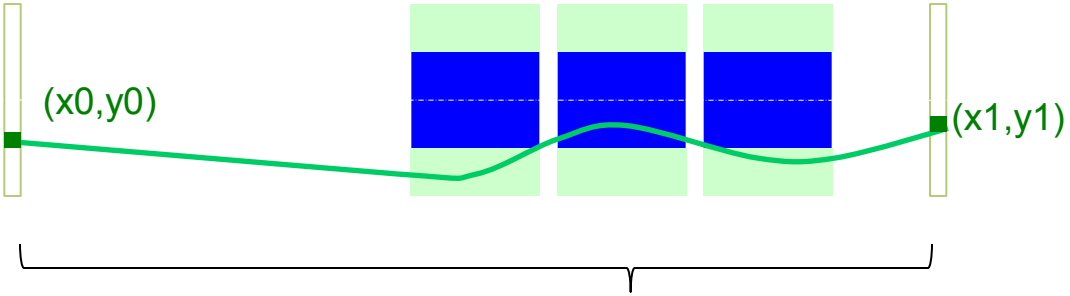
X = 2.74±0.05 cm (ΔX=+3.02 cm)

Y = 1.49±0.05 cm (ΔY=-1.76 cm)



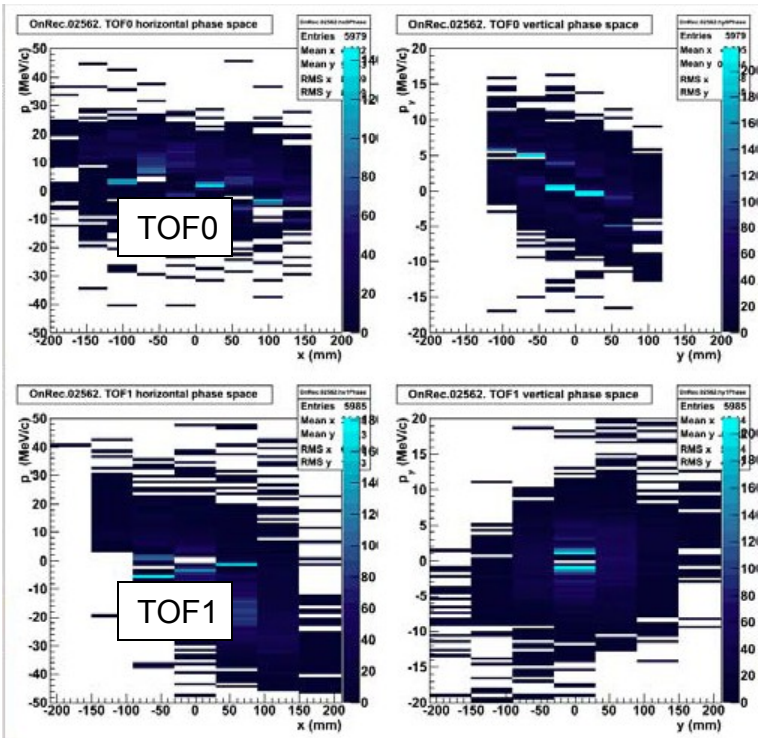
[M. Rayner, Oxford]

TOF0,1 used in tandem



On Line beam monitoring and Analysis

(x,px) (y,py)



M: transfer matrix

Infer x0' and x1' from x0,x1

$$\begin{pmatrix} x \\ x' \end{pmatrix}_1 = \begin{pmatrix} M_{11} & M_{12} \\ M_{21} & M_{22} \end{pmatrix} \begin{pmatrix} x \\ x' \end{pmatrix}_0$$

reconstruct:
- momentum
- phase space
- Twiss Parameters
- emittance

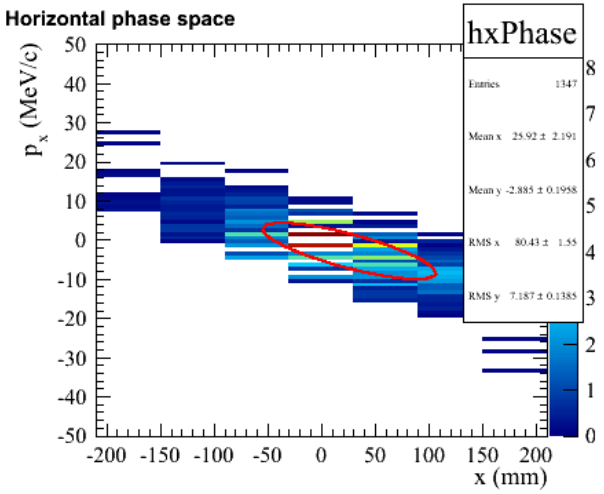
$$\begin{pmatrix} x'_0 \\ x'_1 \end{pmatrix} = \frac{1}{M_{12}} \begin{pmatrix} -M_{11} & 1 \\ -1 & M_{22} \end{pmatrix} \begin{pmatrix} x_0 \\ x_1 \end{pmatrix}$$

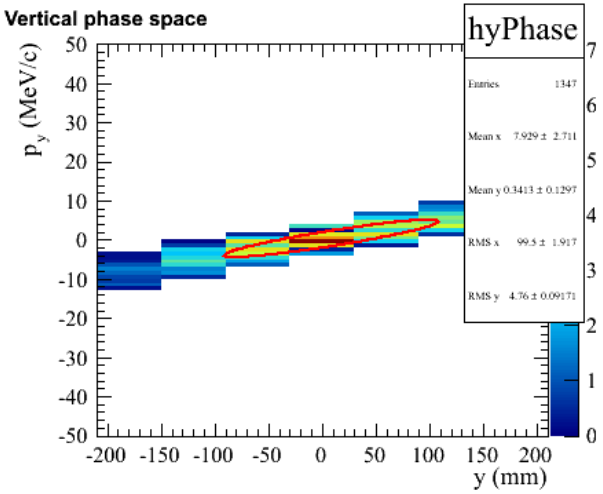
Phase Space and Momentum Reconstruction: Q789 scan runs

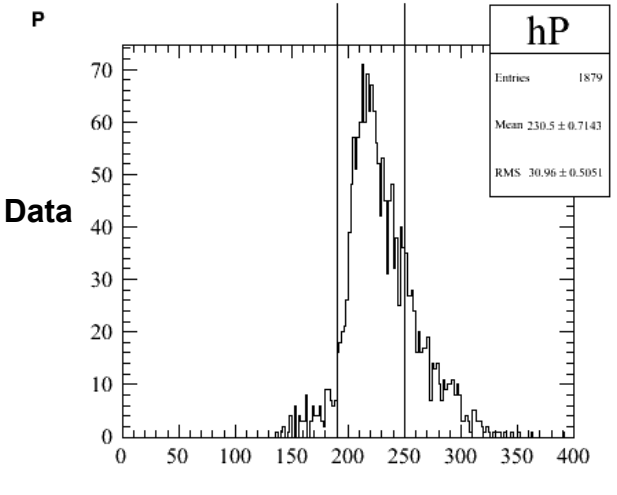
- triplet Q789 is scaled in current
- phase space rotation is reconstructed using TOF0,1 stations
- comparison with G4Beamline simulation
- results are VERY PRELIMINARY
- still need to introduce the survey corrections

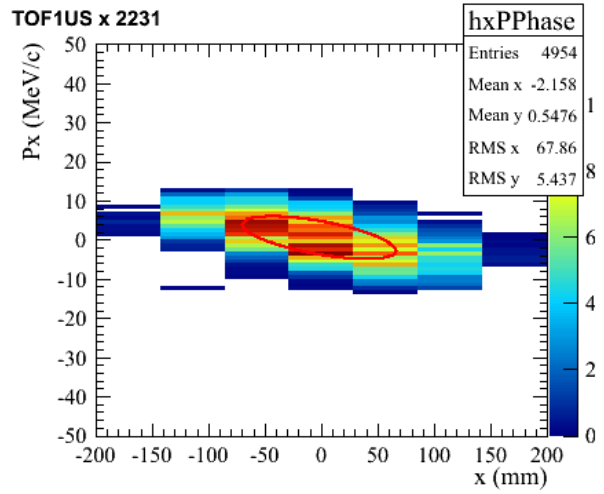
NOTE:
- TOFs are not simply used as PID detectors
- They give direct information about beam properties and momentum

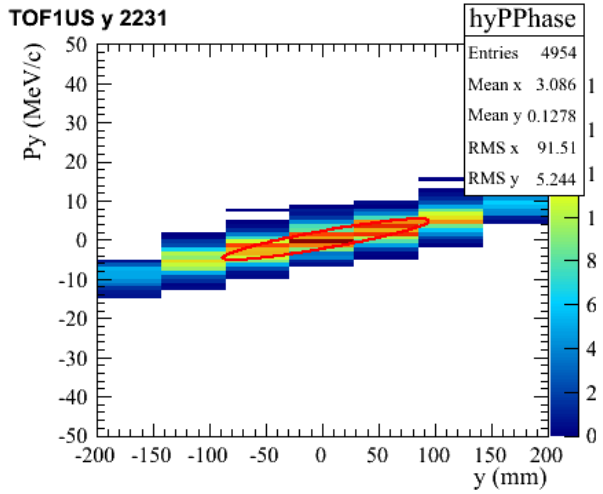
Phase Space and Momentum Reconstruction: Q789 scan runs

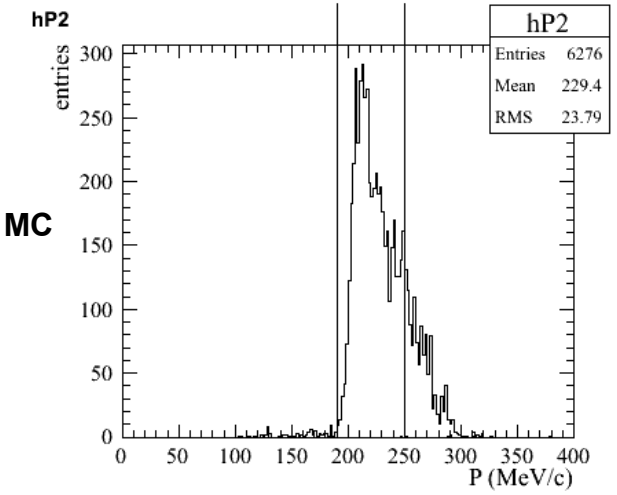






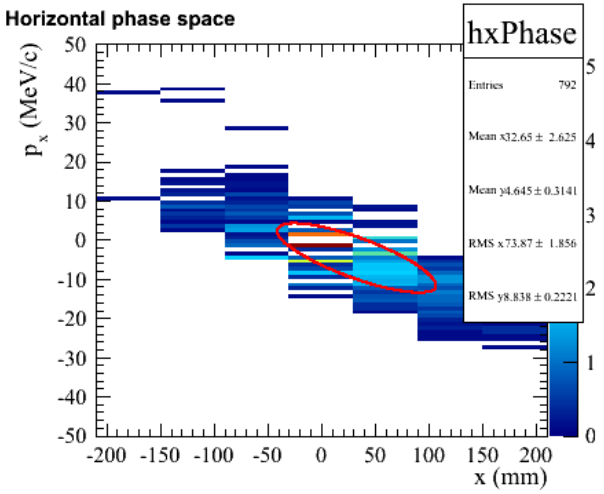


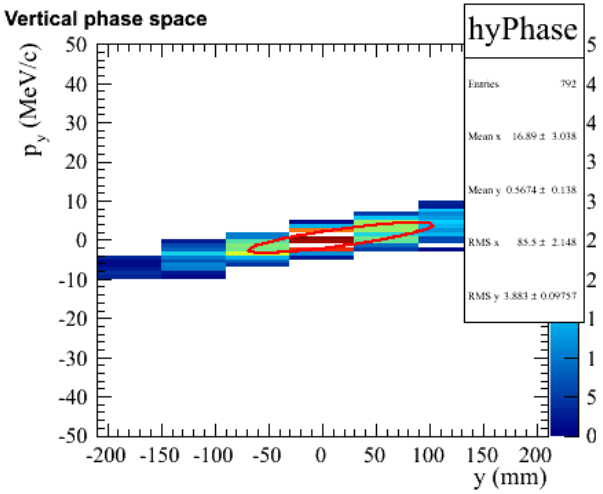




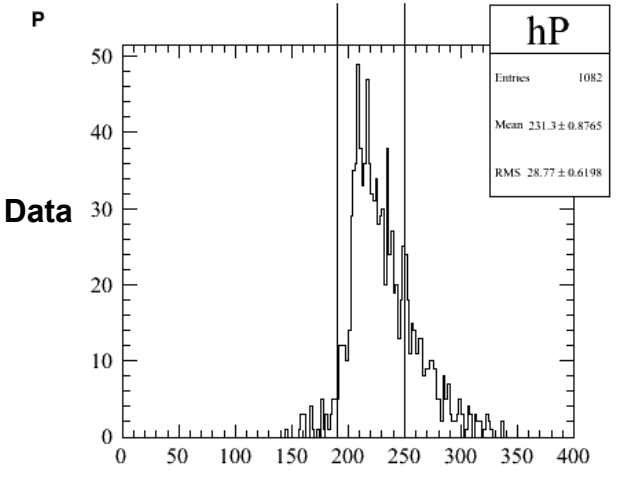
Q789 = -30%

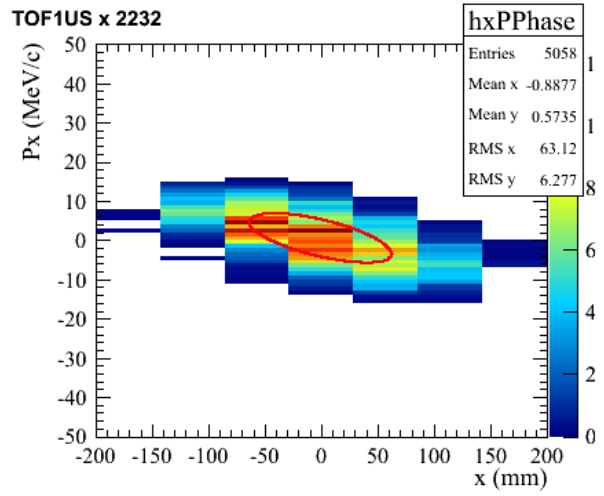
Phase Space and Momentum Reconstruction: Q789 scan runs

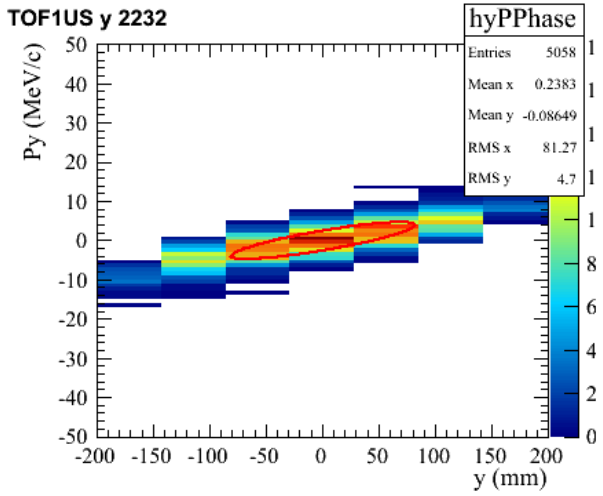




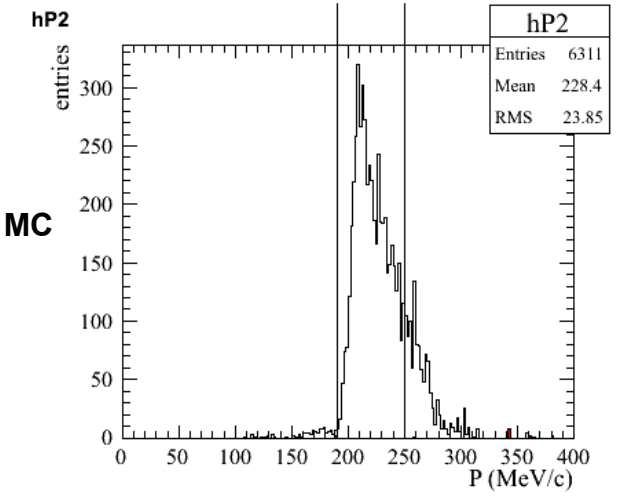
Data





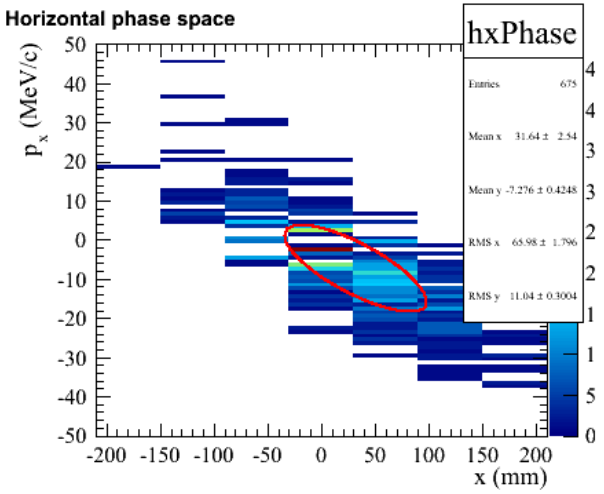


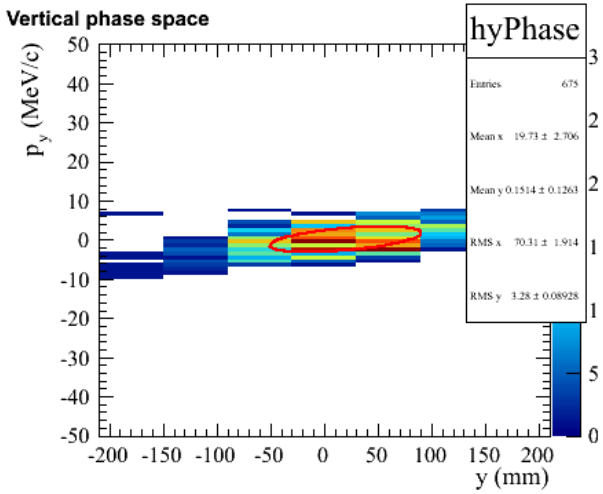
MC

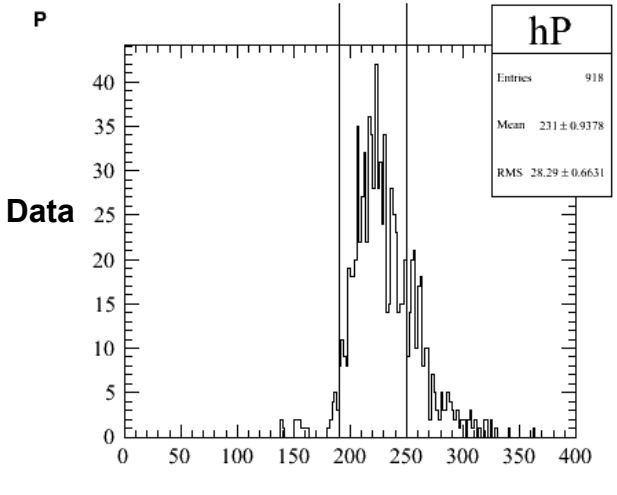


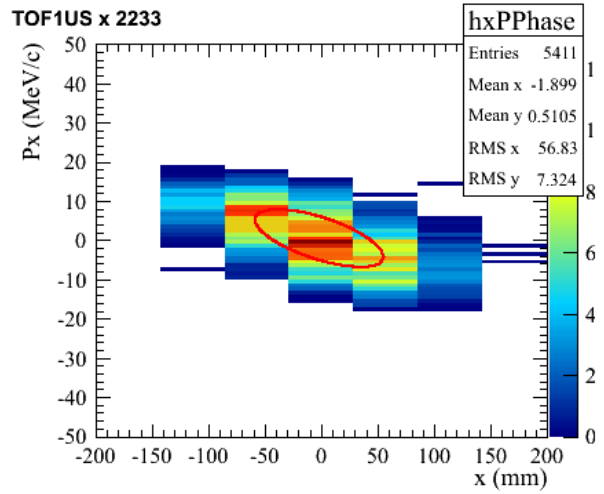
Q789 = -20%

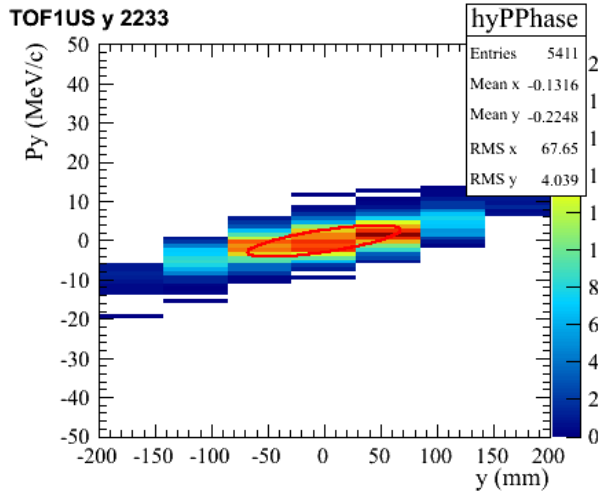
Phase Space and Momentum Reconstruction: Q789 scan runs

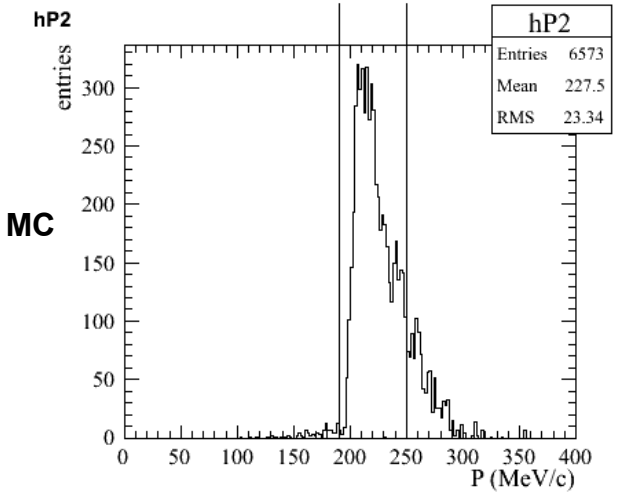






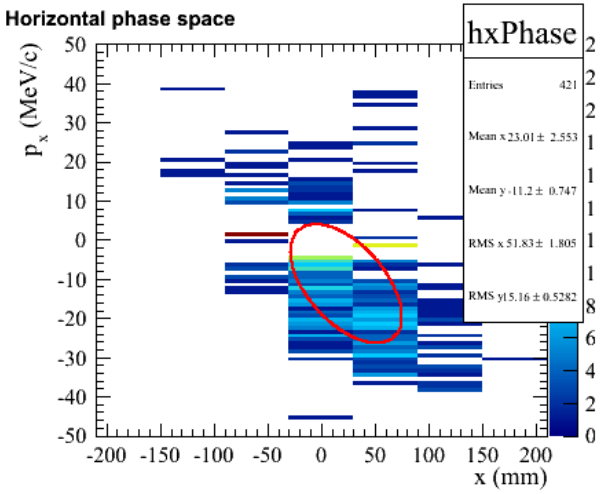


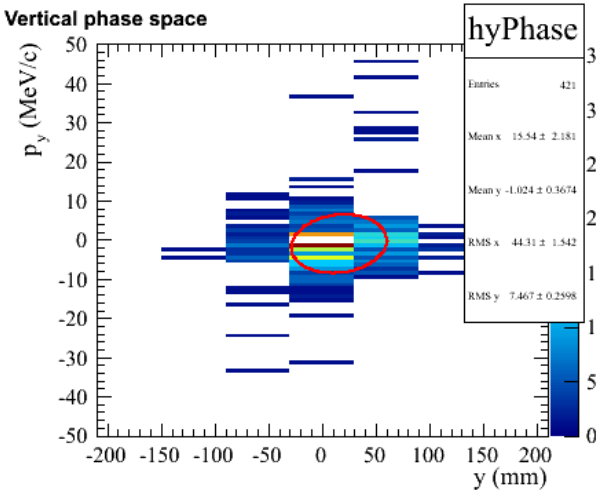


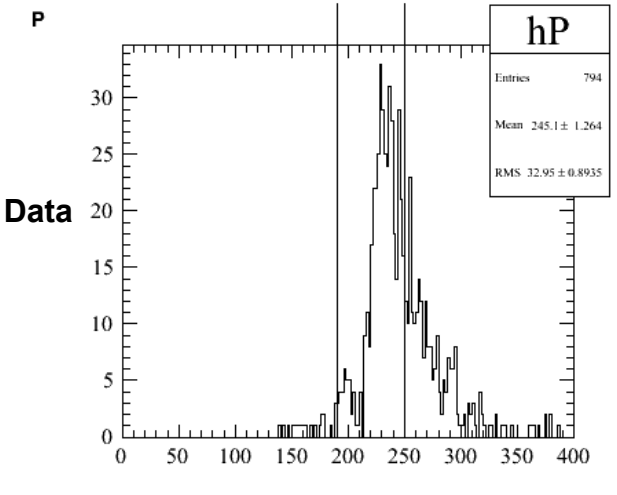


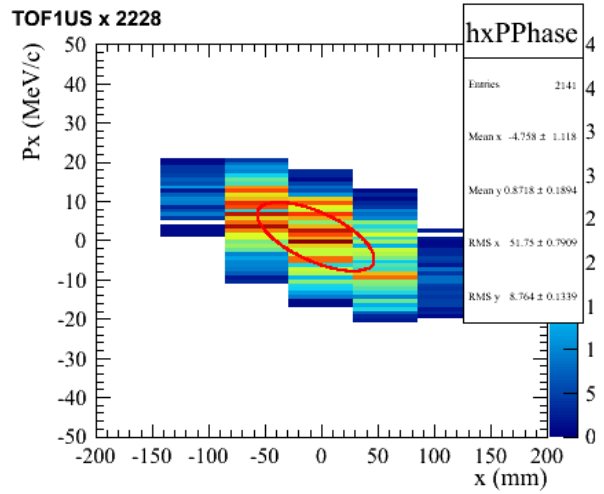
Q789 = -10%

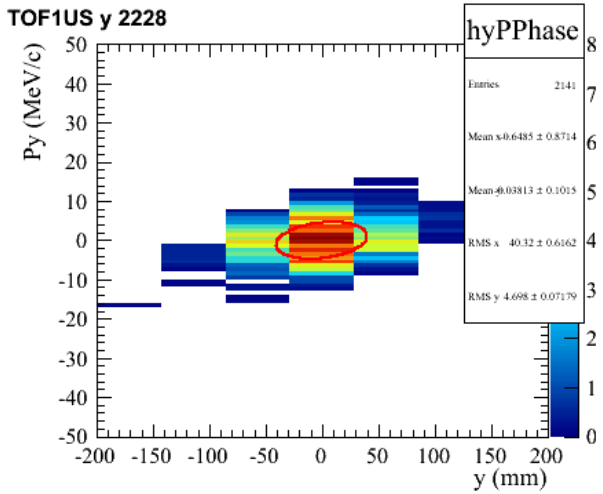
Phase Space and Momentum Reconstruction: Q789 scan runs

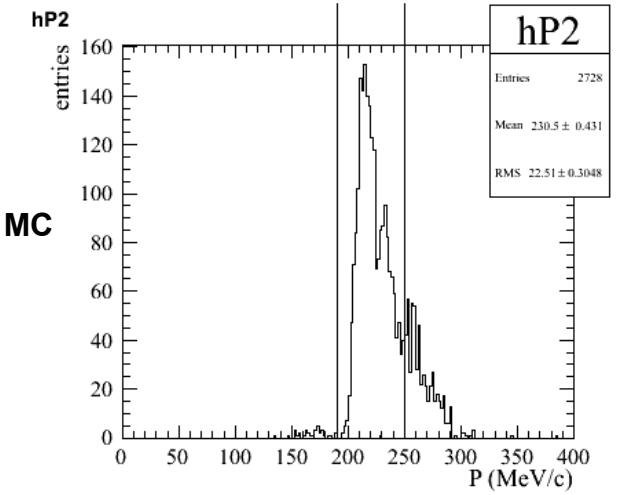






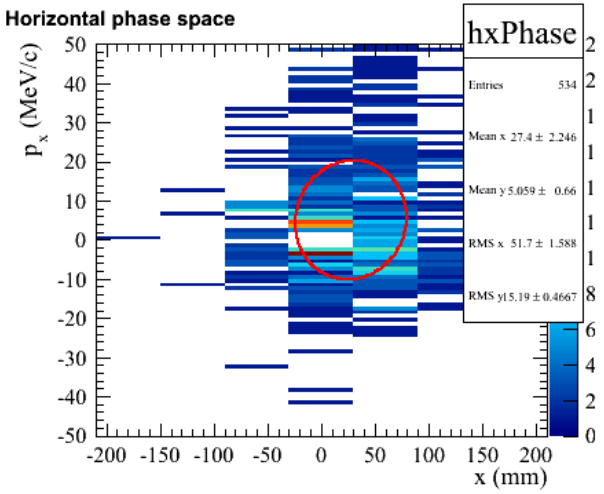


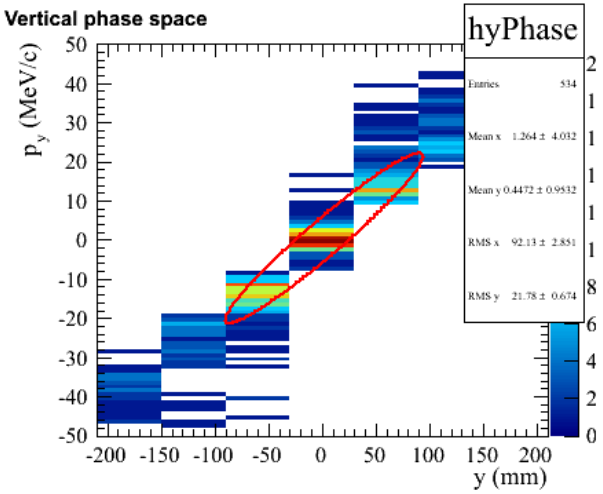


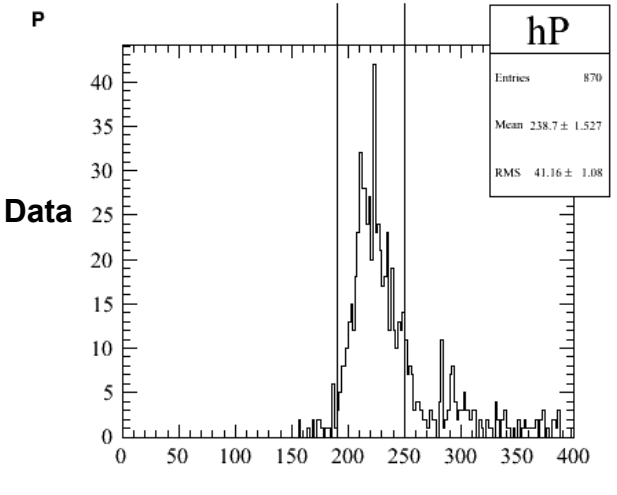


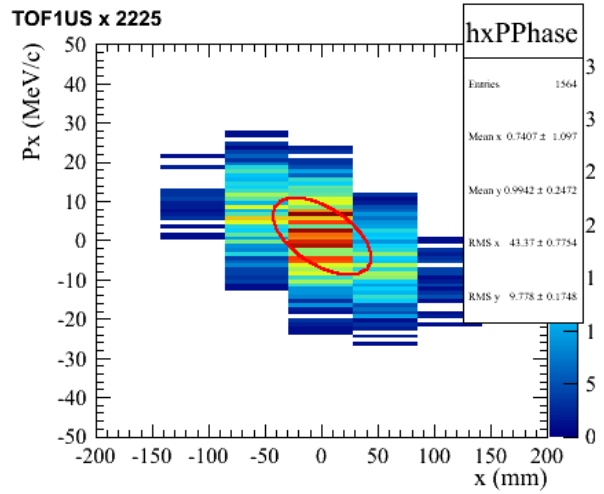
Q789 = +10%

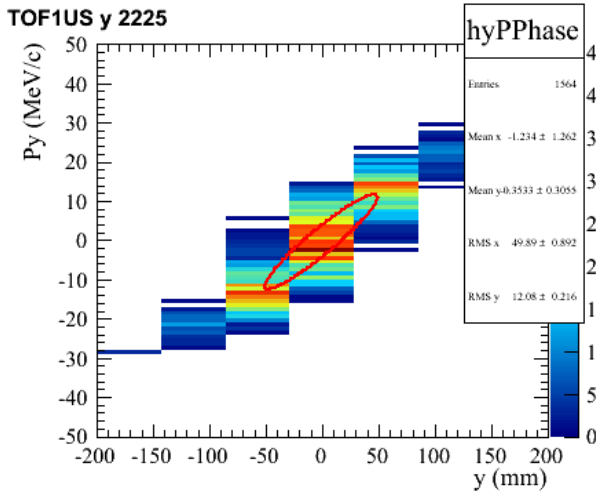
Phase Space and Momentum Reconstruction: Q789 scan runs

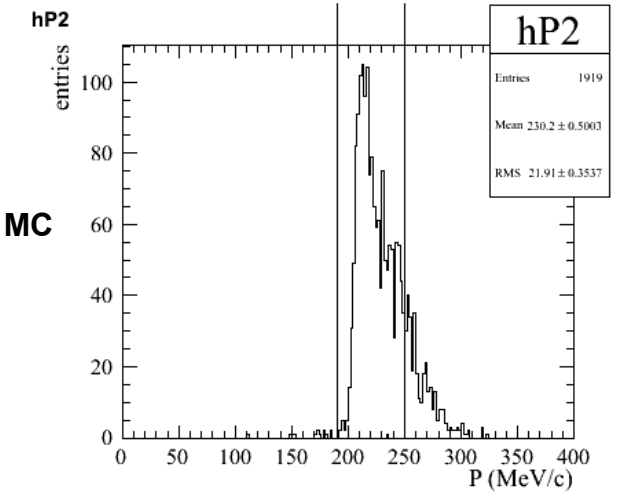






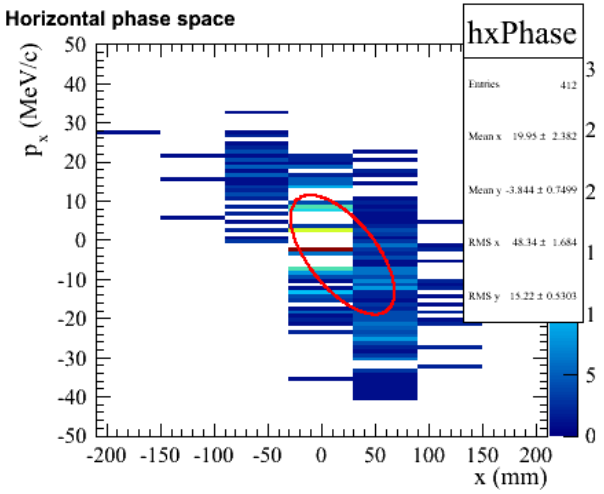


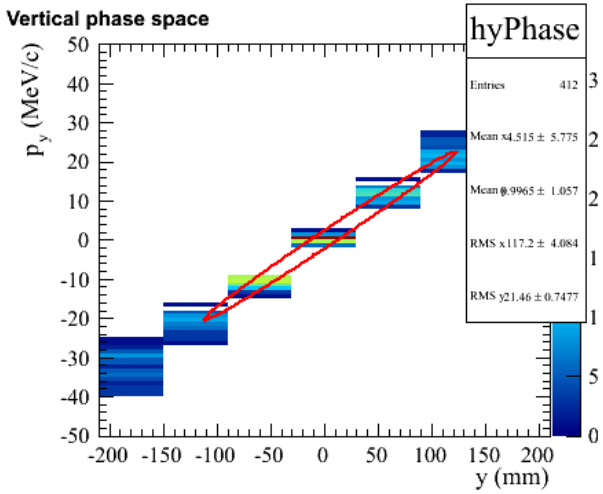




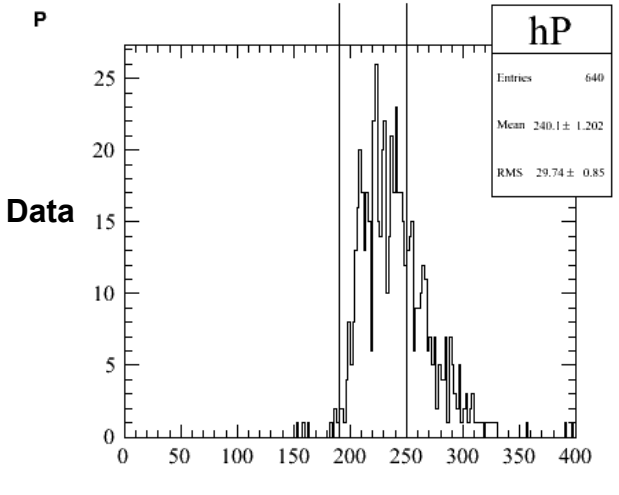
Q789 = +40%

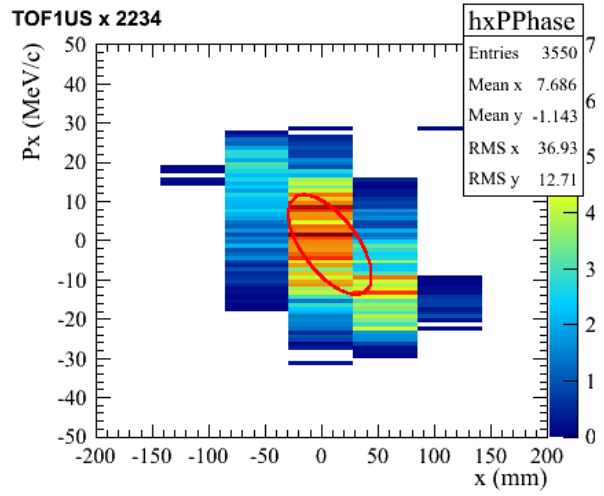
Phase Space and Momentum Reconstruction: Q789 scan runs

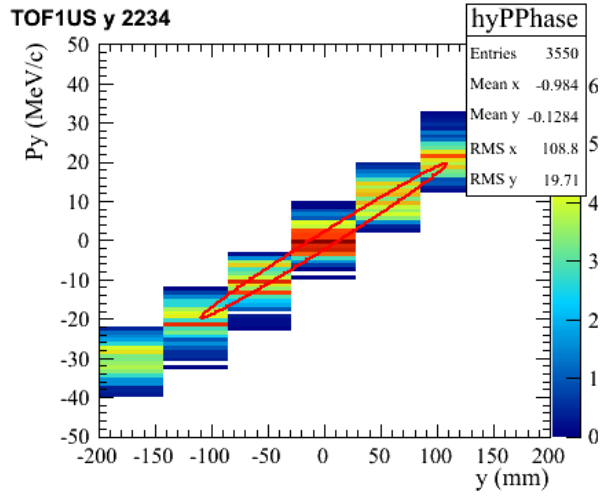




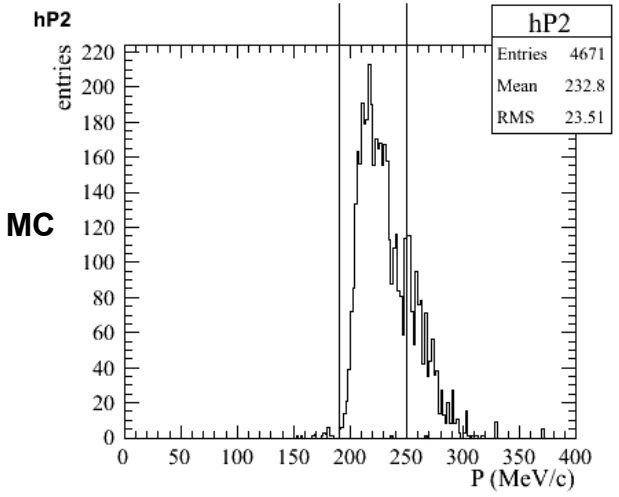
Data







MC



Q789 = +75%

Reconstructed TOF Track Rate

Rates are normalized with respect to the Beam Loss from Sector 7

TOF tracks/3.2 ms spill/V.ms

~ 4.8 tracks / spill / V.ms

~ 27.2 tracks / spill / V.ms

M0		μ^- rate			μ^+ rate		
		P_z (MeV/c)			P_z (MeV/c)		
		140	200	240	140	200	240
ϵ_N (mm·rad)	3	4.1 ±0.2	6.3 ±0.2	4.9 ±0.2	16.8 ±1.8	33.1 ±3.2	33.0 ±2.6
	6	4.1 ±0.4	4.8 ±0.2	4.5 ±0.2	17.8 ±1.8	31.0 ±2.0	31.7 ±2.0
	10	4.6 ±0.2	5.4 ±0.2	4.4 ±0.1	21.6 ±2.2	34.0 ±2.5	26.1 ±1.5

WHAT WE ACHIEVED THEN

- good MEASURED knowledge of the beam (maybe VERY good, MARK?)
- better knowledge of BL geometry after surveys (some corrections still to be implemented in the simulation(s))
- good agreement MC/DATA:
    - understood maps for G4Beamline Q456789
    - some discrepancy G4Beamline/G4MICE persists … why?
        - not clear how (good) muons are defined in G4MICE and if comparison is fair
        - the discrepancy in momentum (3-4 MeV/c) makes me think of a poor definition of the Cherenkov material budget in G4Beamline (I believe G4MICE is more detailed)
    - we did not have time to scrutinize the differences between the two
- how do we control the momentum scale?
    - when D2 is set to P2, do we really get it? Any bias?
    - did not analysed, may be we need to re-do a measurement if possible
    - comment from Mark?
- can we “forge” the beam at our convenience?
    - yes to some extent: scan runs tell us how to modify e.g. Q789 to rotate the beam in phase space
    - in practical terms this is not a fast procedure at the moment

- is the beam optimized as we wanted?
    - did not complete this, in the sense we did not check in detail if Ph-Space at TOF1US IS the one we expect from a certain configuration (I might be wrong, maybe Mark did it)

- we measured emittance (Mark's plot) and it seems a bit higher than thought …

- we achieved to measure the track reconstruction rate and assessed a factor ~5 difference between the +/- configurations