Simulation Study for RFFAG Decay Rings by g4beamline

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FFAG12 workshop
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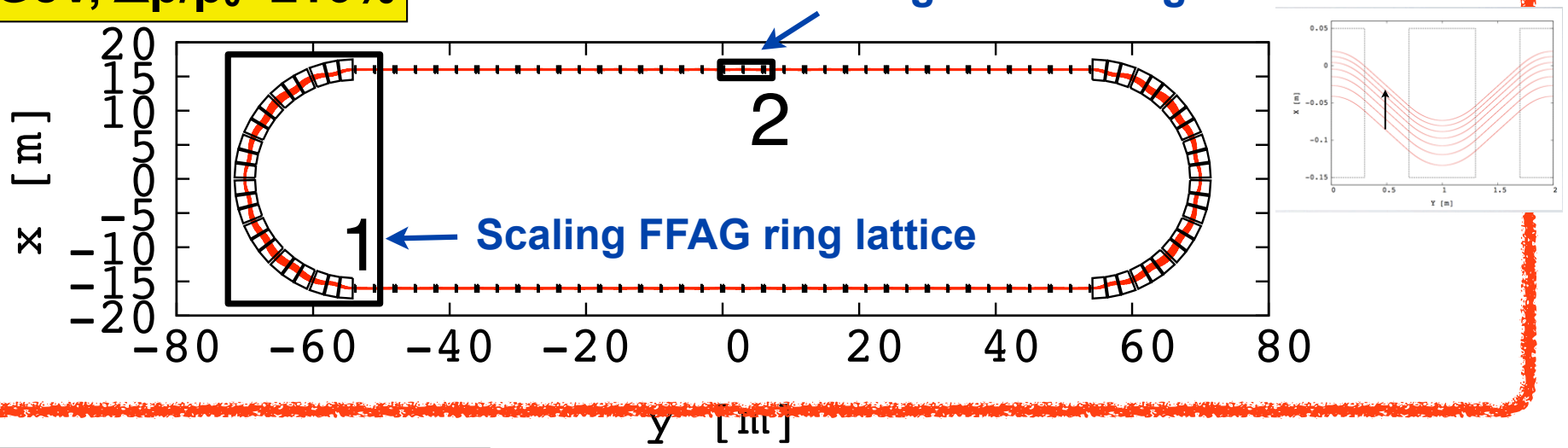
25+5 min

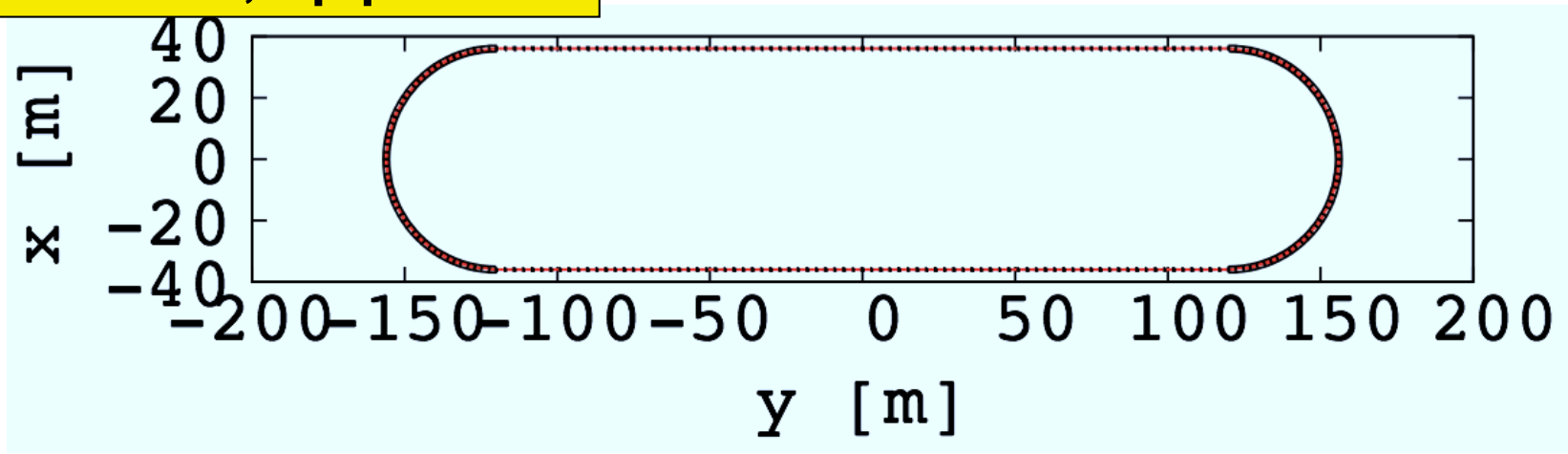
Study of Racetrack FFAGs for vSTORM

- J.B.Lagrange and Y.Mori proposed two racetrack FFAG for the decay ring.

E_μ=2GeV, $\Delta p/p_0$=±16%

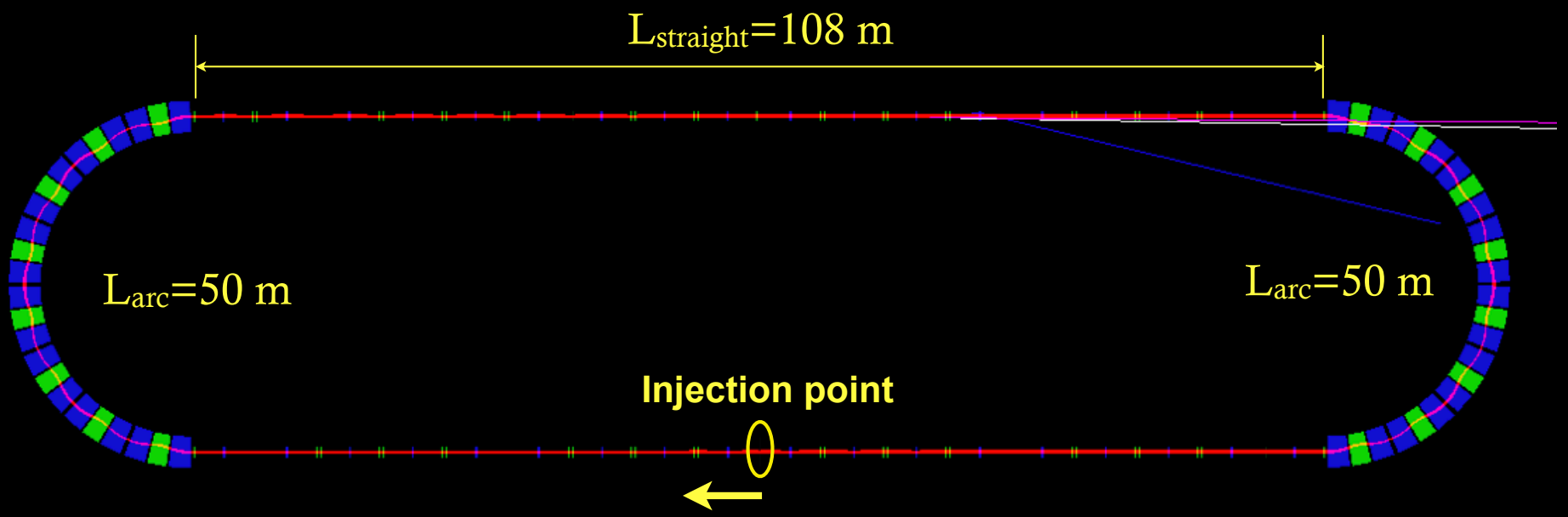


p_μ=3.8GeV/c, $\Delta p/p_0$=±16% in the vSTORM LoI



- They studied performance of these FFAGs by their original tracking code, which cannot study decay of muon.

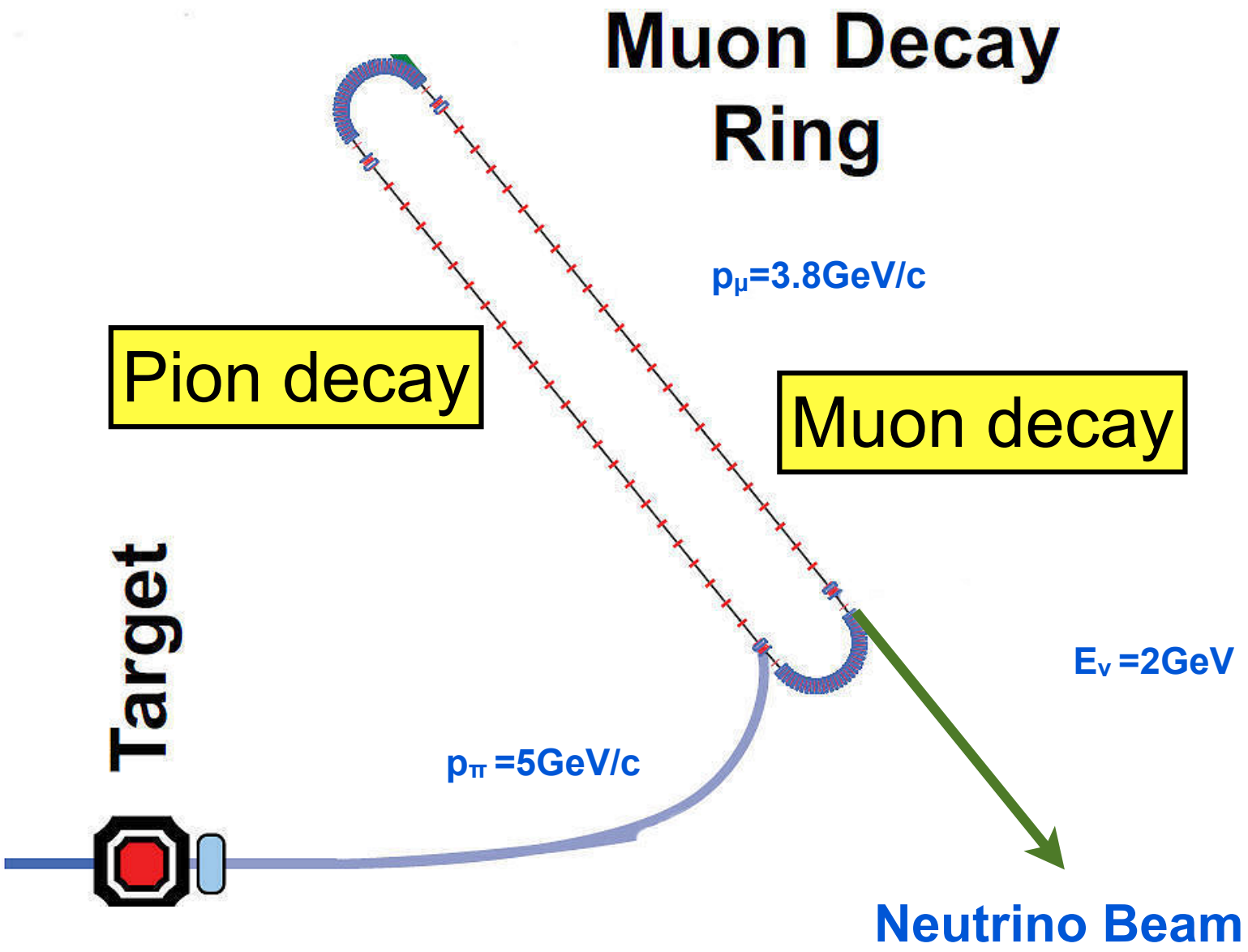
Tracking of JB's 2GeV Ring by g4beamline



red: μ^- blue:e^- white:ν_e magenta:anti-ν_μ

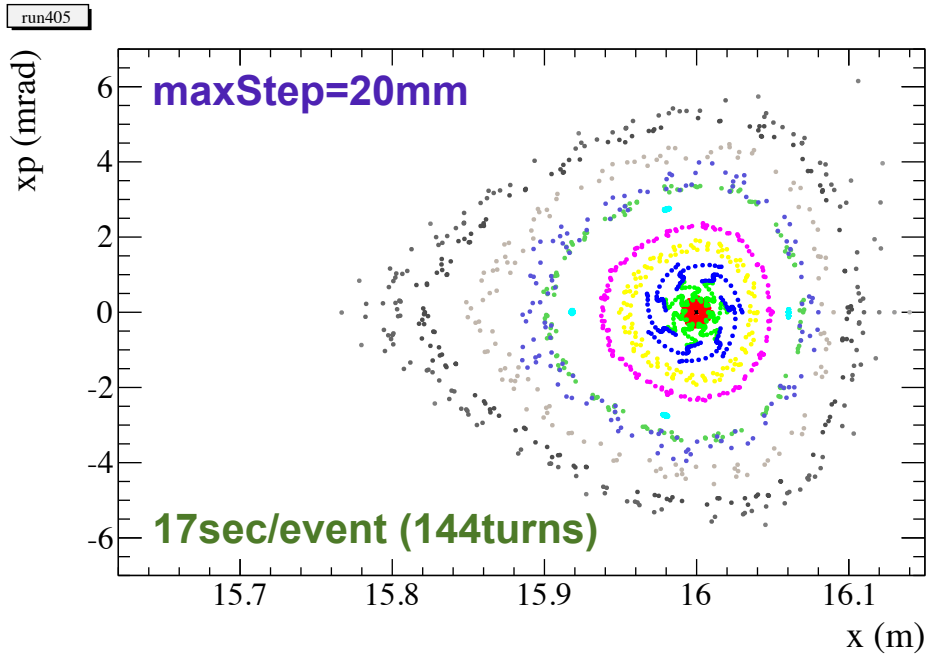
Study of Racetrack FFAGs with g4beamline

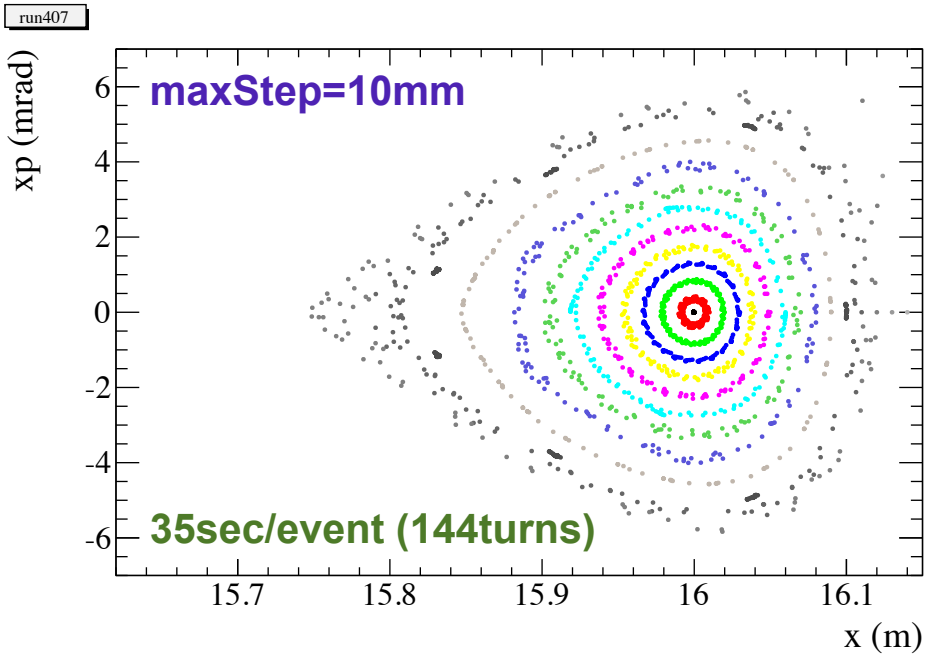
- I study production of neutrino beam from the racetrack FFAGs for vSTORM using g4beamline.
- The g4beamline
  - is very useful and easy to use. It is a geant4 based code.
    - particle interaction with materials,
    - tracking in magnetic fields,
    - particle decays
  - But it uses Runge-Kutta for tracking, not-symplectic
    - not the best code to get accurate tracking result, in particular tracking in a very long channel.
    - tiny step size makes better tracking results, but needs long running time.
- with 2GeV RFFAG ring
  - I compared g4beamline's tracking results with JB's results to get a reasonable step size.
  - Then, I studied neutrino beam production from the FFAGs.


Muon Decay Ring
p_μ=3.8GeV/c
Pion decay
Muon decay
Target
p_π =5GeV/c
E_ν =2GeV
Neutrino Beam

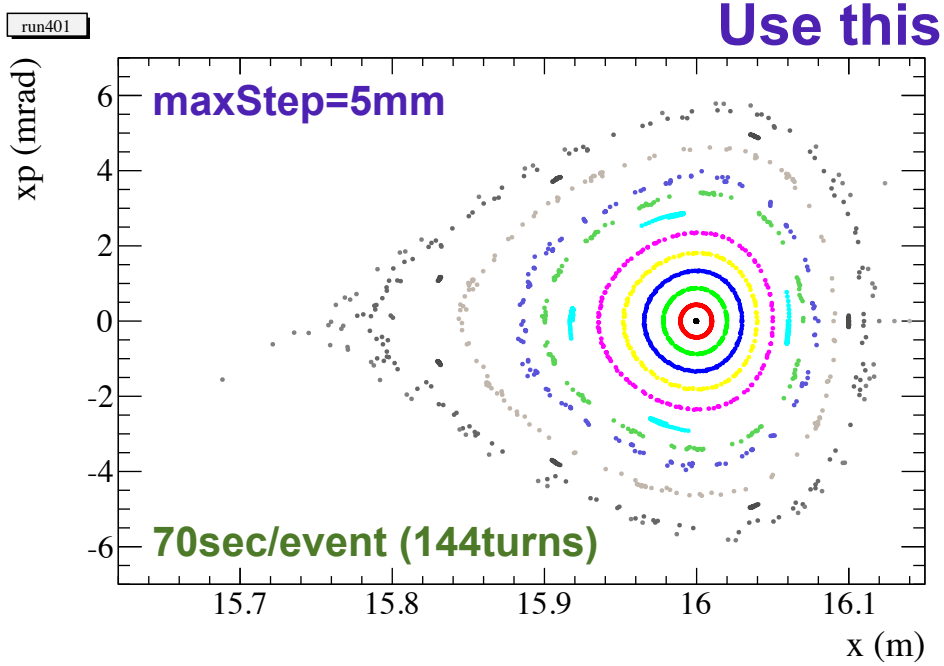
Step size effects on the tracking

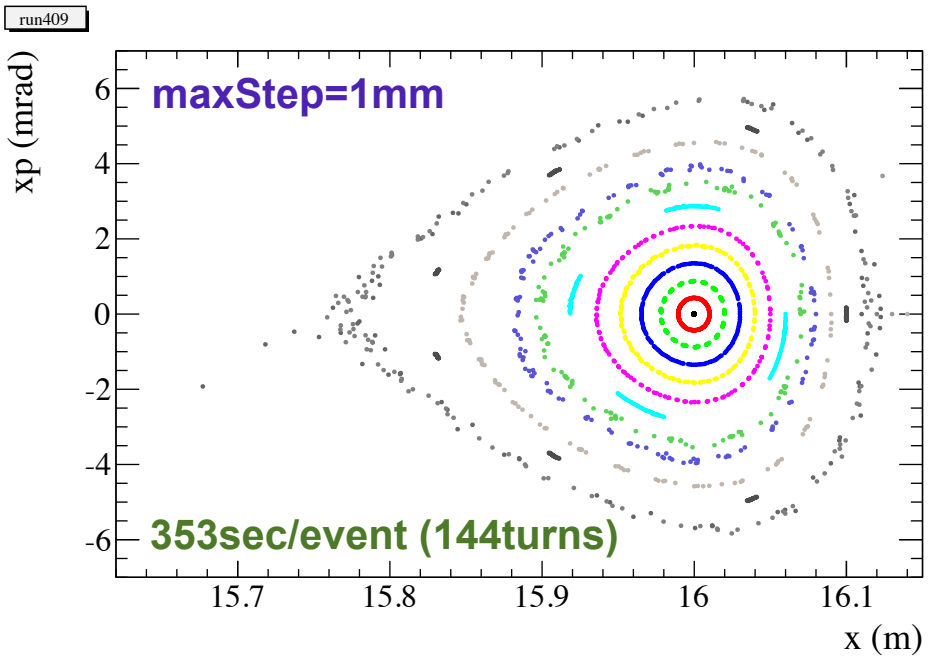
Horizontal





Use this





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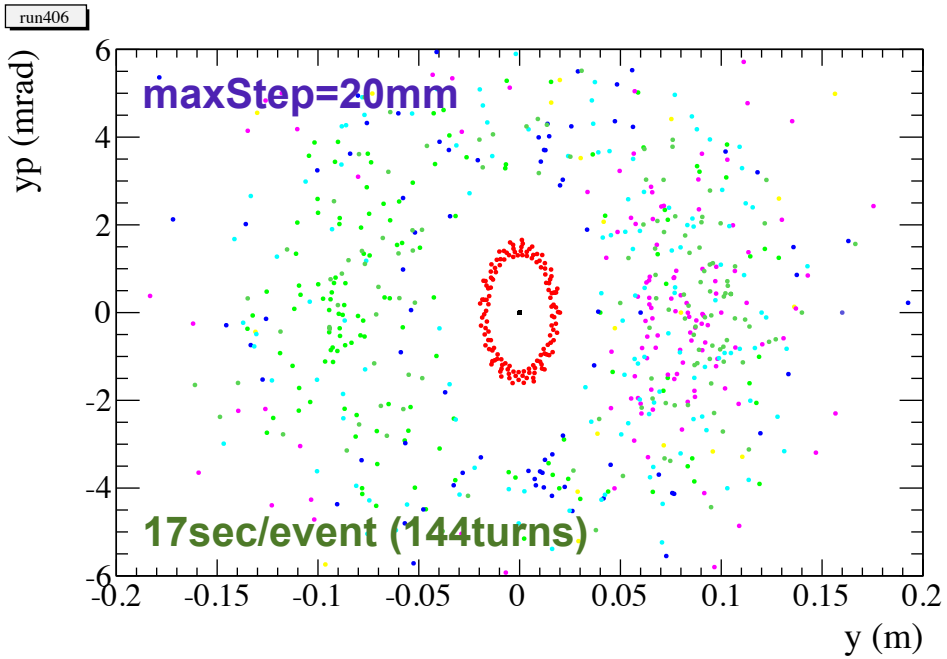

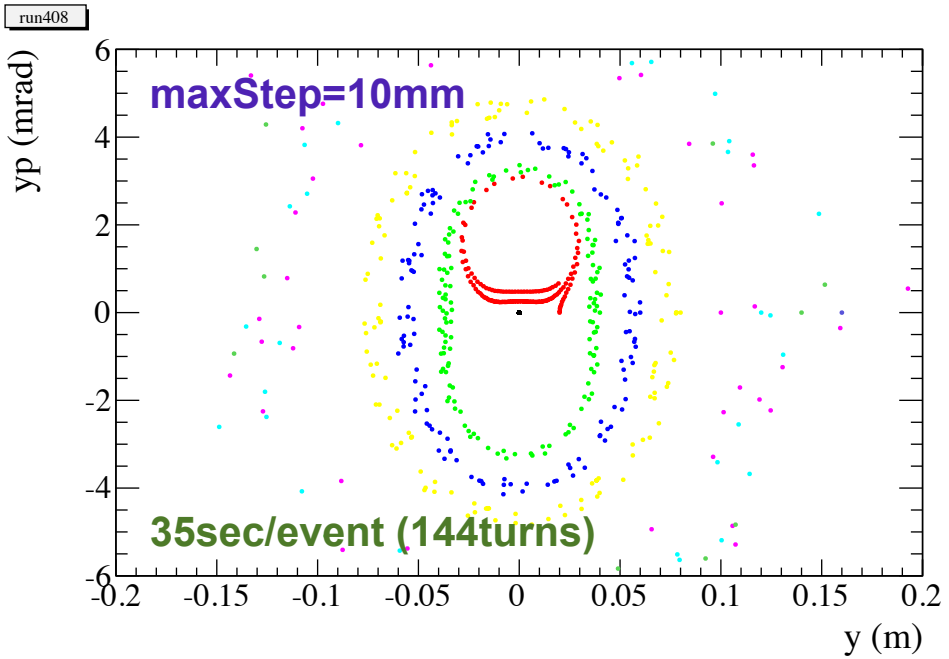

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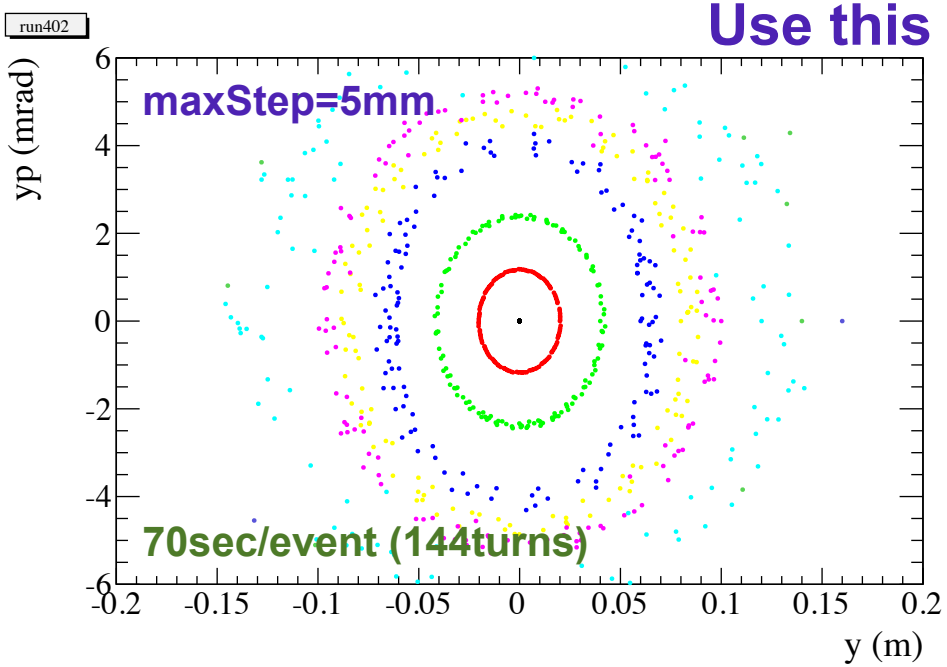
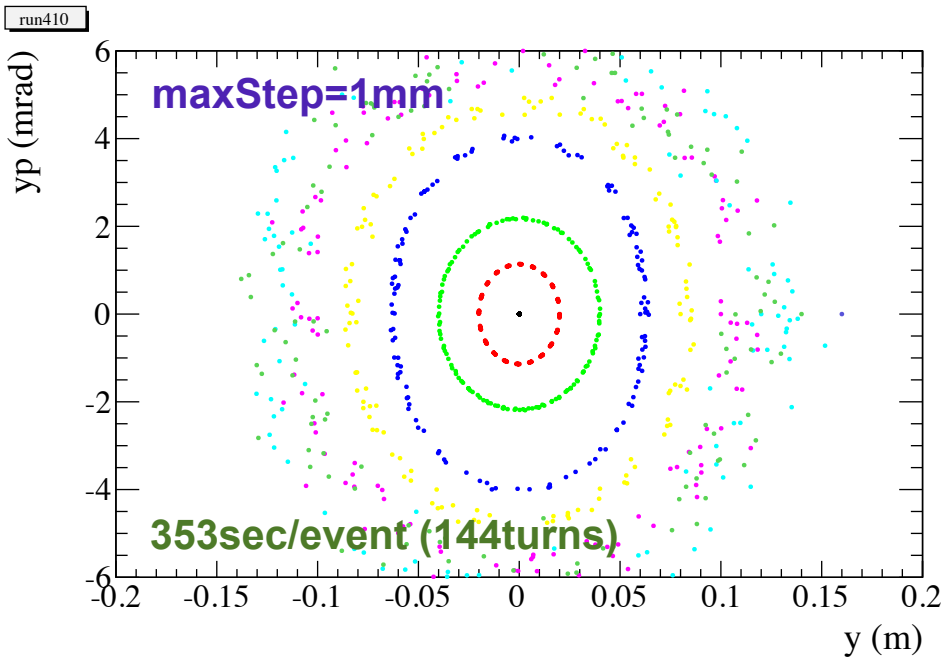
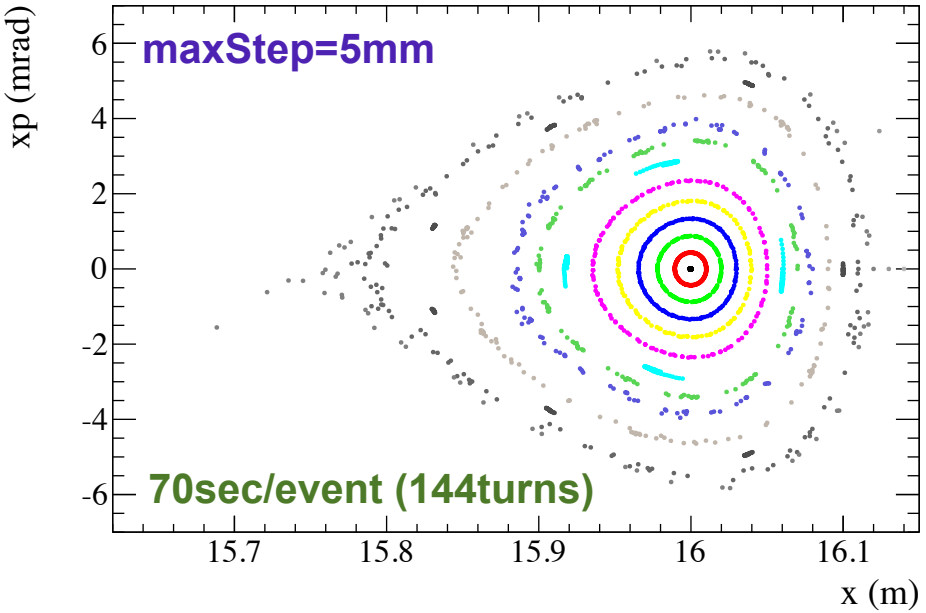
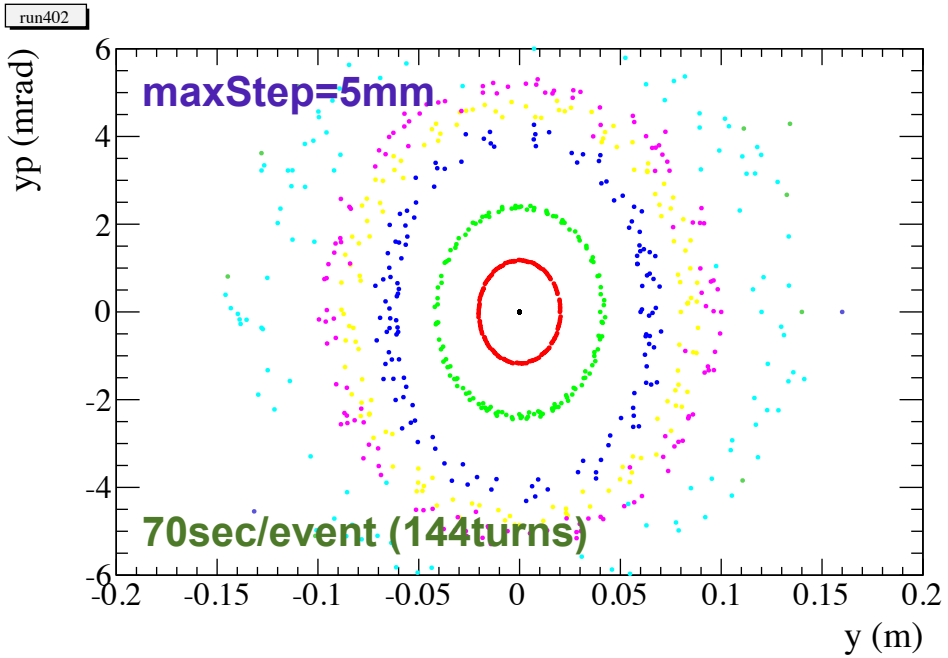




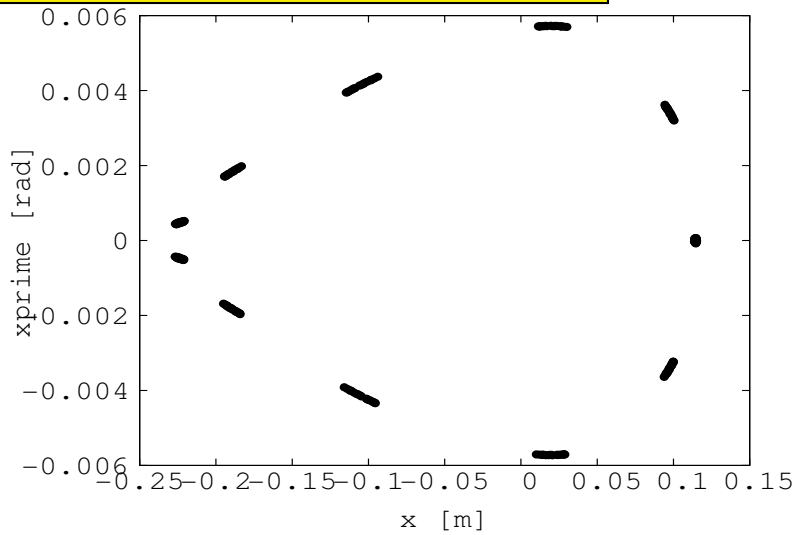
Comparison with JB's tracking results

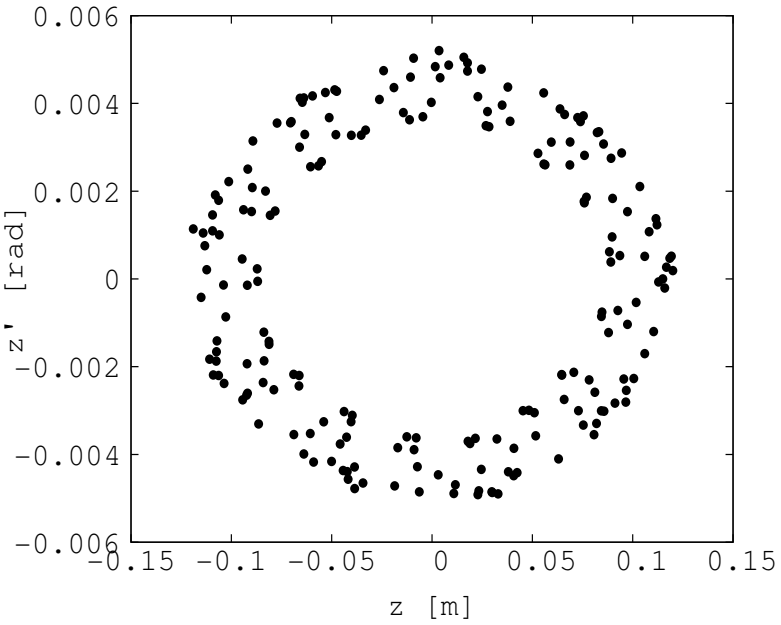
g4beamline



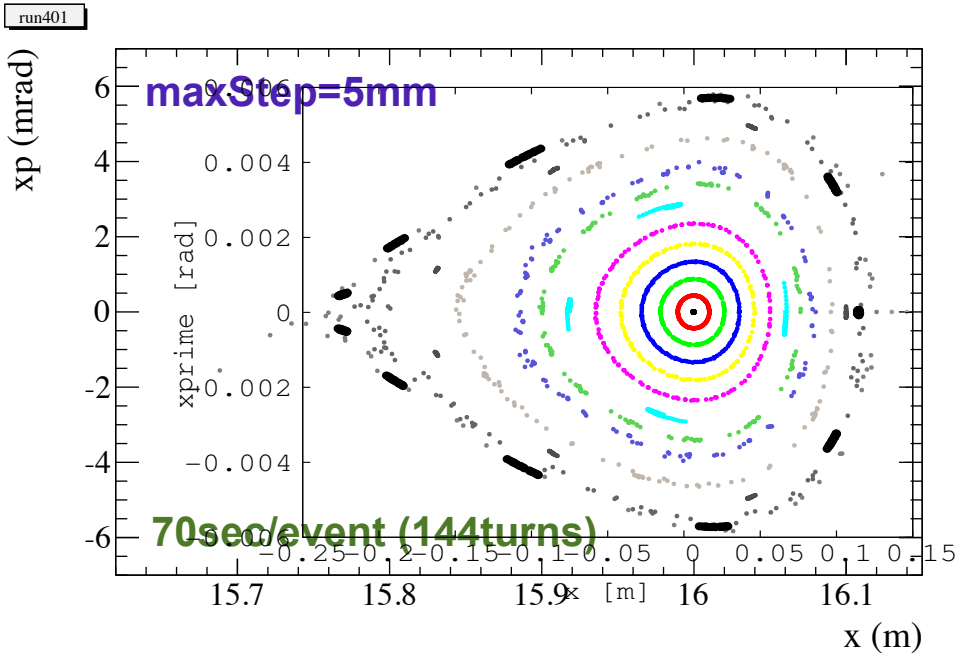


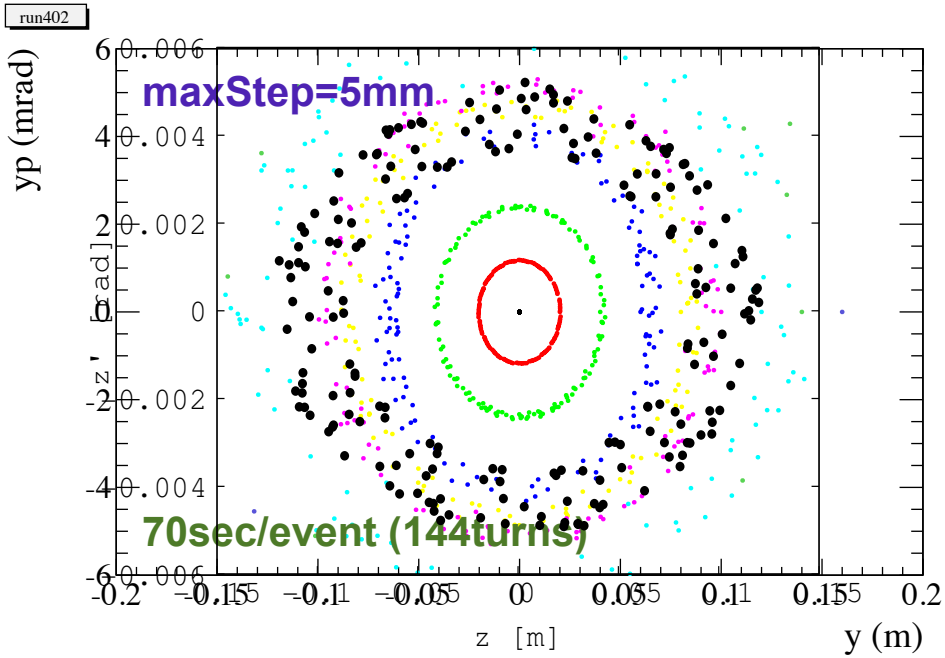
JB's original tracking code





Comparison b/w JB's results

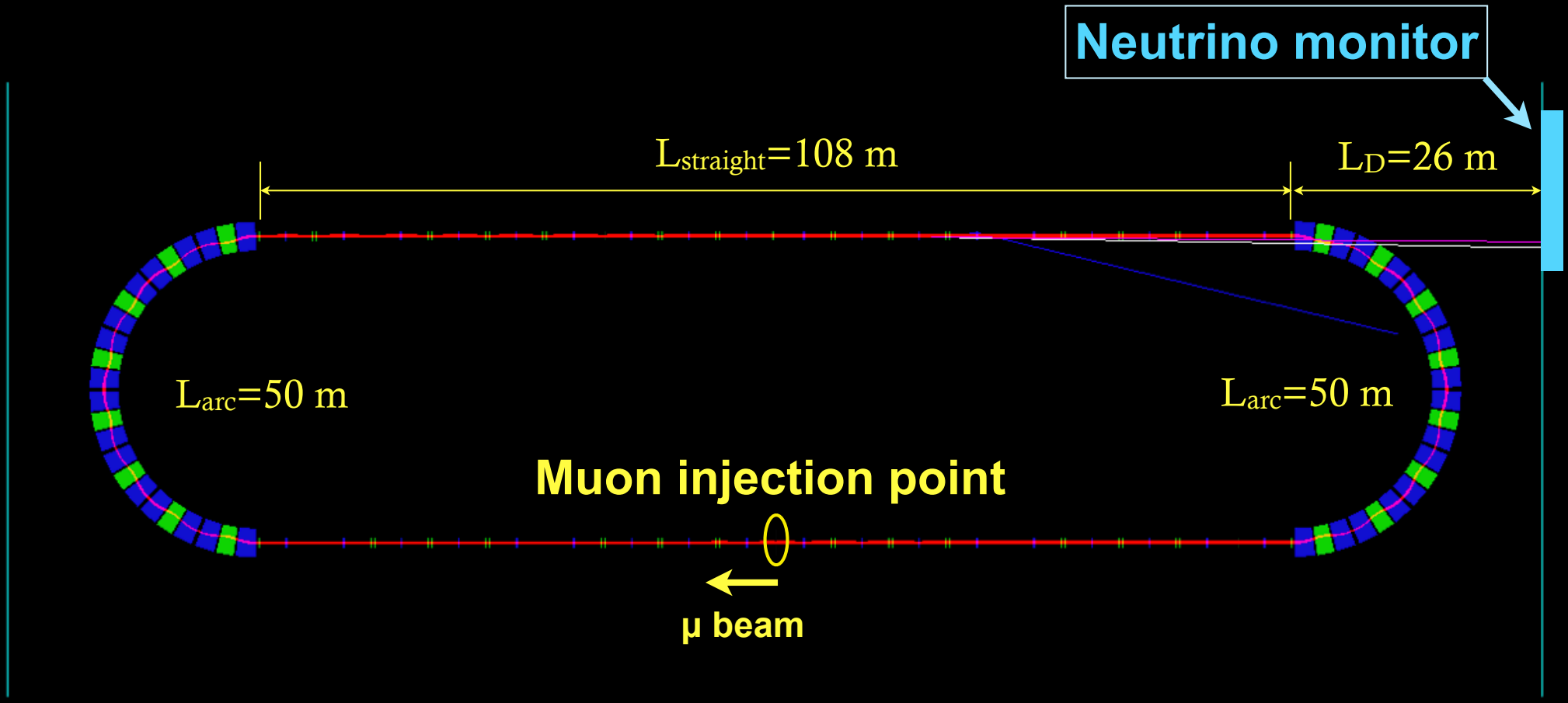




- The tracking results of g4beamline show very good agreement with the JB's result.
- I use maxstep=5mm in the following tracking.
  - note: The grid size of magnetic field maps must be also enough small to get reasonable accuracy.

Then, I turned the muon decay switch on to product neutrinos.

Neutrino production with JB's 2GeV Ring by g4beamline

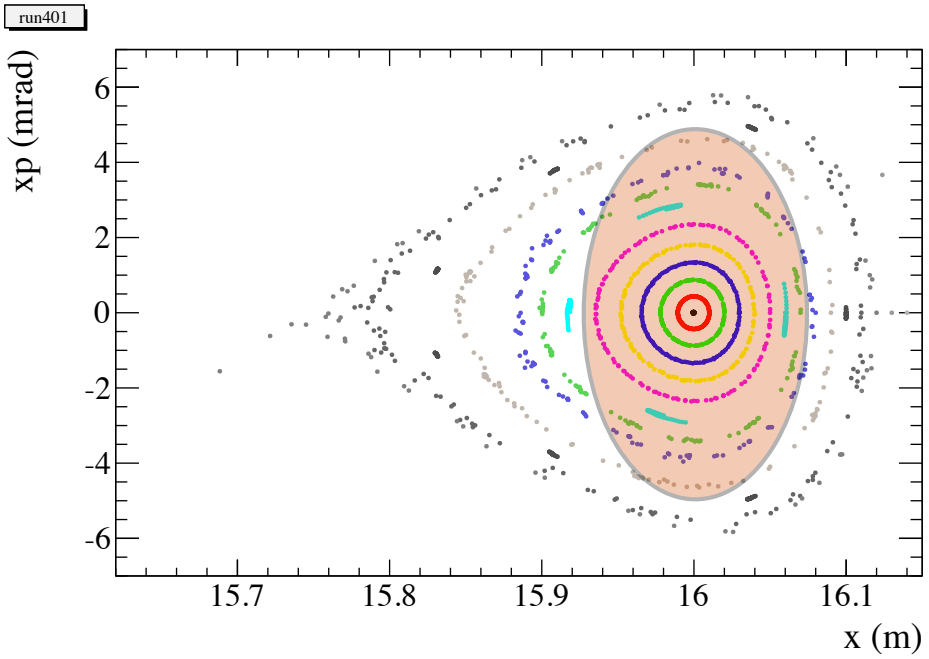


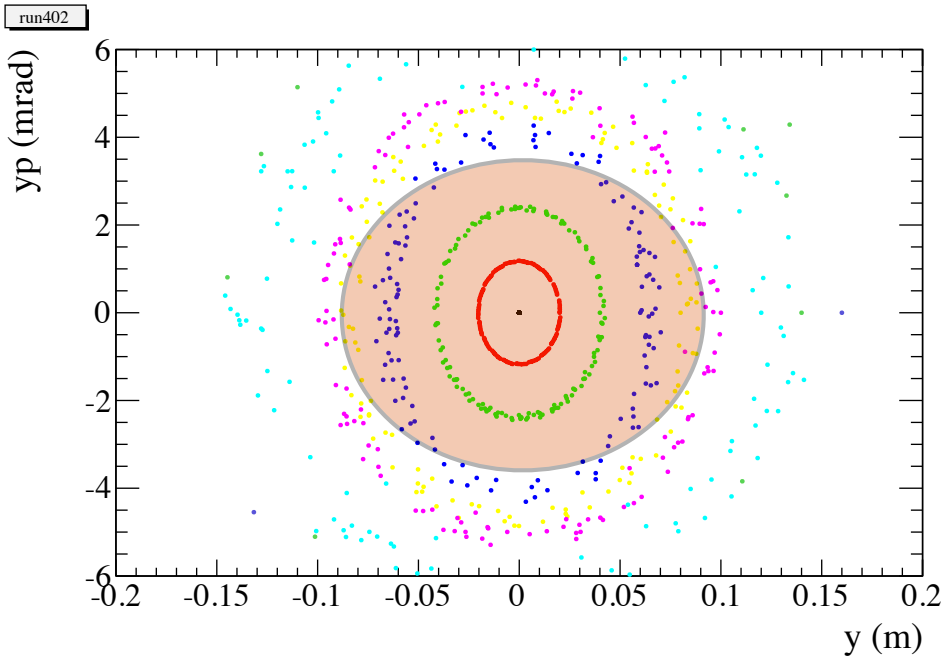
red: μ^- blue:e^- white:ν_e magenta:anti-ν_μ

Initial beam emittance of the muon

- Ellipse beam which is randomly generated on (X,Xp), (Y,Yp) with uniform density. (by g4bl command: *beam ellipse*). I tried two cases:
  - **E = 2.0 GeV**
    - ΔX : 0.075 m, ΔXp : 0.0050 rad
    - ΔY : 0.090 m, ΔYp : 0.0035 rad
    - ΔE : 0 GeV, Δt : 0ns
  - **E = 2.0 GeV ± 16%**
    - ΔX : 0.125 m, ΔXp : 0.0050 rad
    - ΔY : 0.090 m, ΔYp : 0.0035 rad
    - ΔE : 0.32 GeV, Δt : 0ns

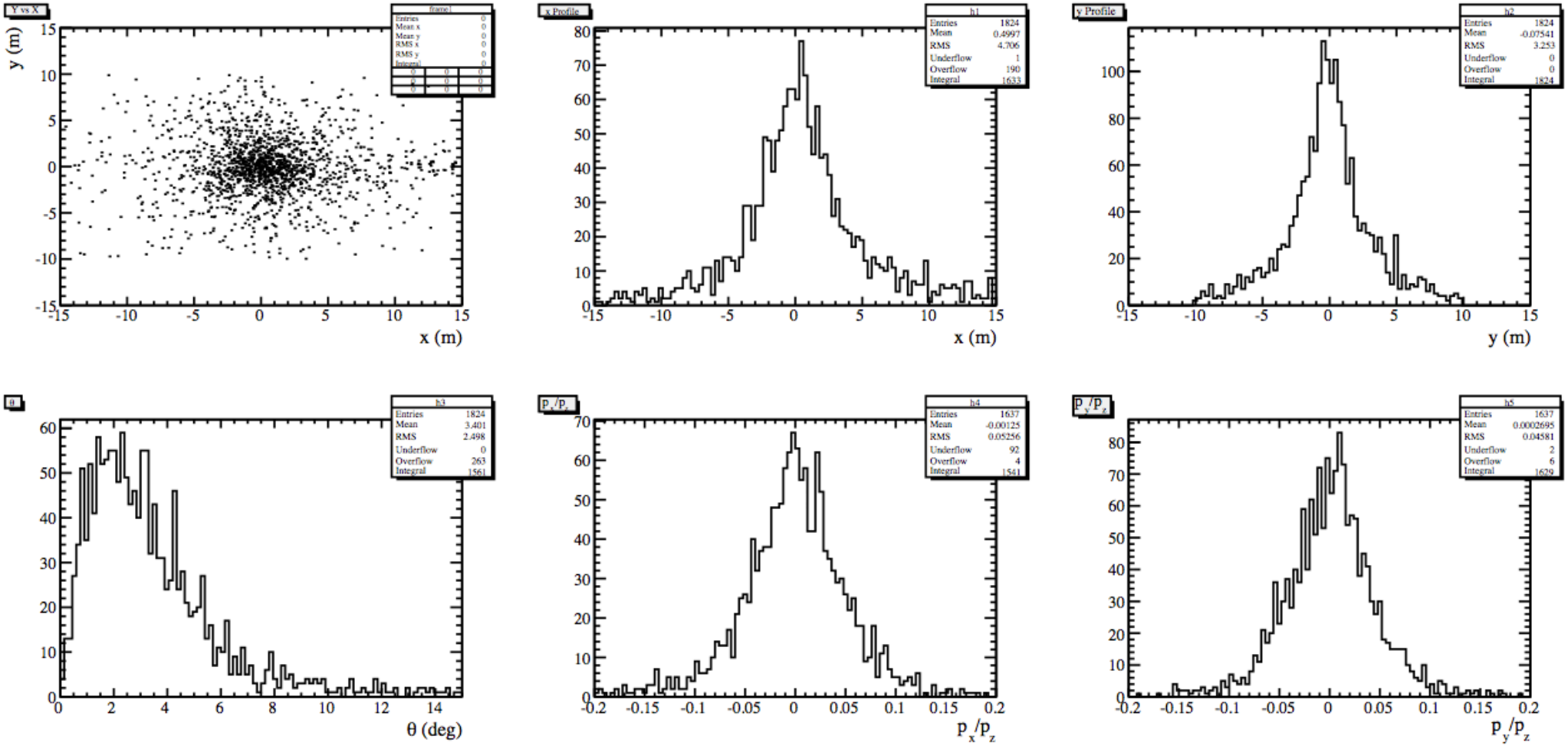
Beam size for E_μ=2GeV±16% is decided from the dispersion, but no dispersion matching was made in this simulation.





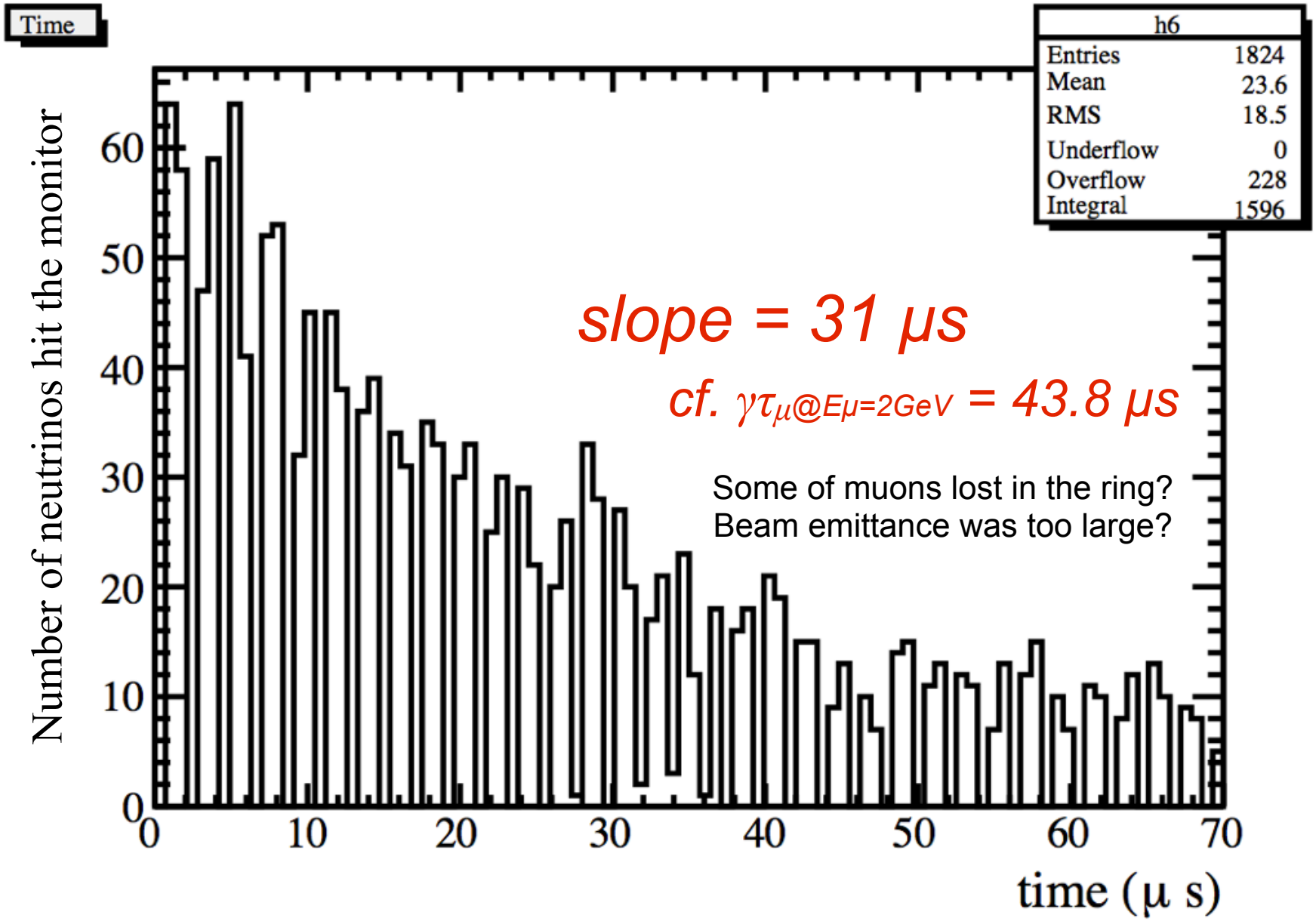
Neutrino beam at the monitor : E_μ=2.0GeV ± 0%

L_S=108 m, L_D=26 m



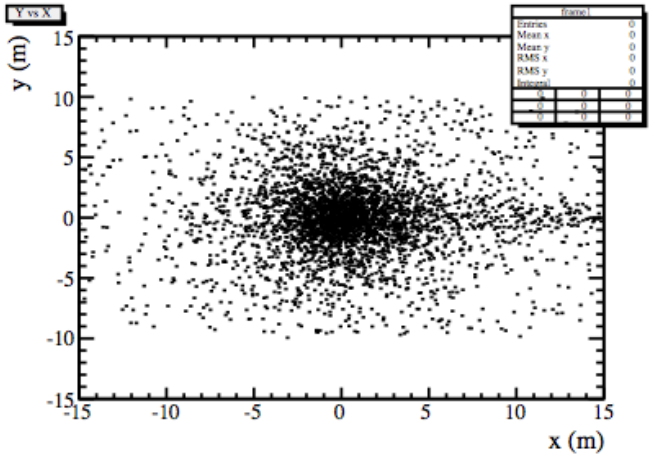
13 sec/event on icore7

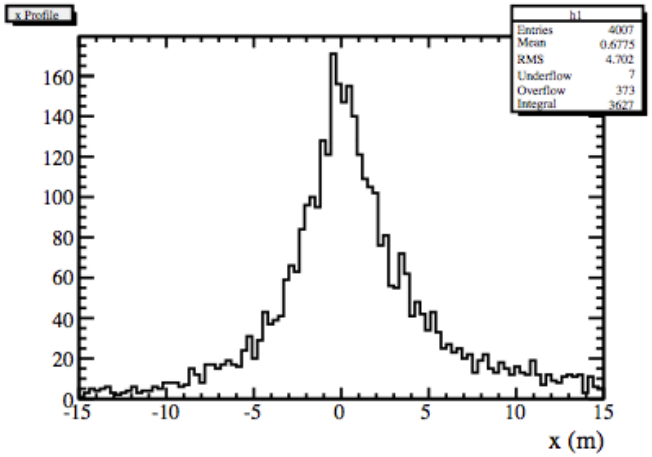
Neutrino beam at the monitor : E_μ=2.0GeV ± 0%

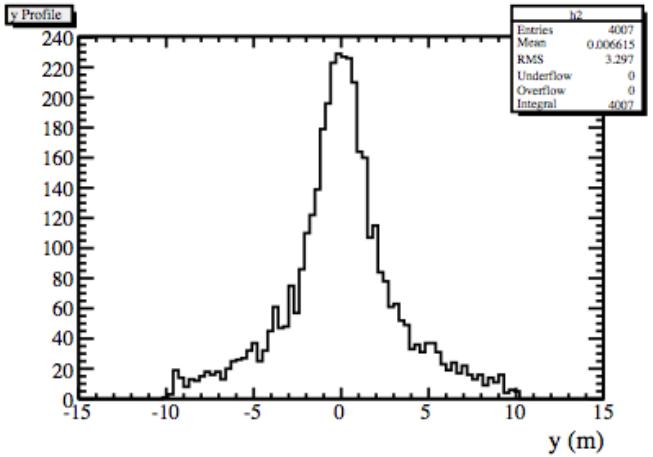


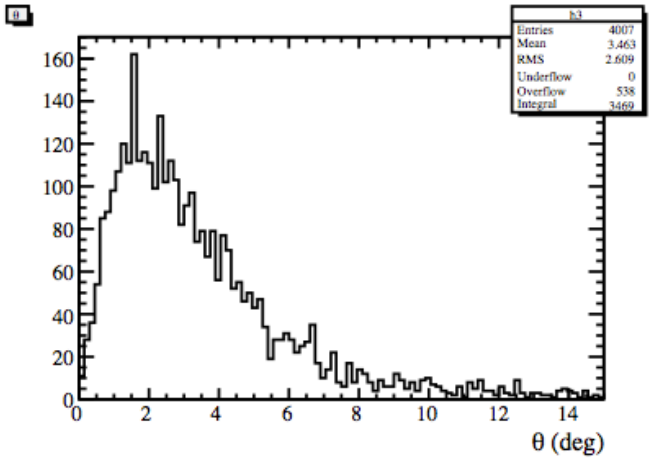
Neutrino beam at the monitor : E_μ=2.0GeV ± 16%

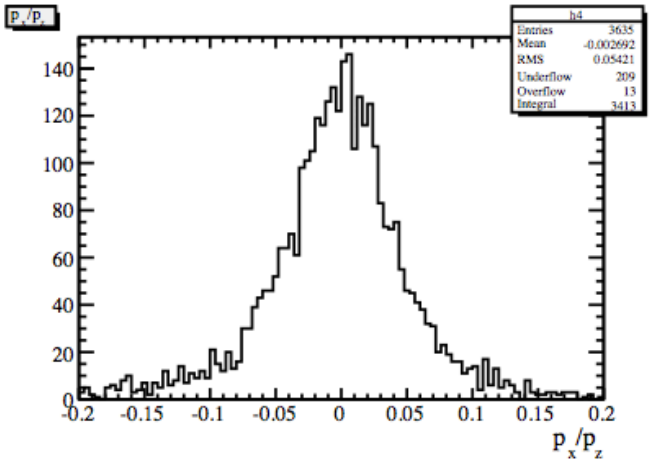
L_S=108 m, L_D=26 m

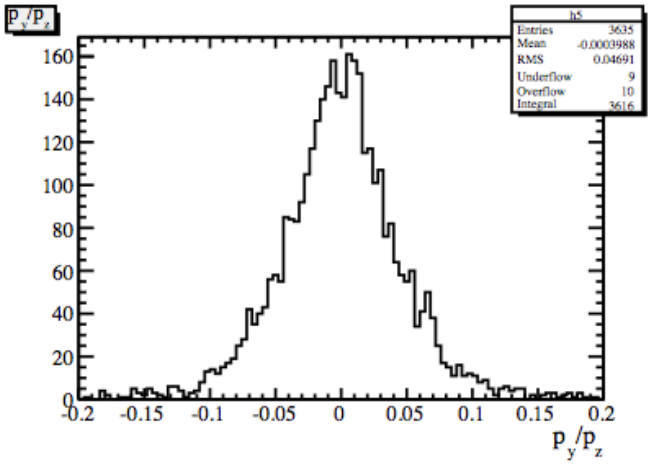












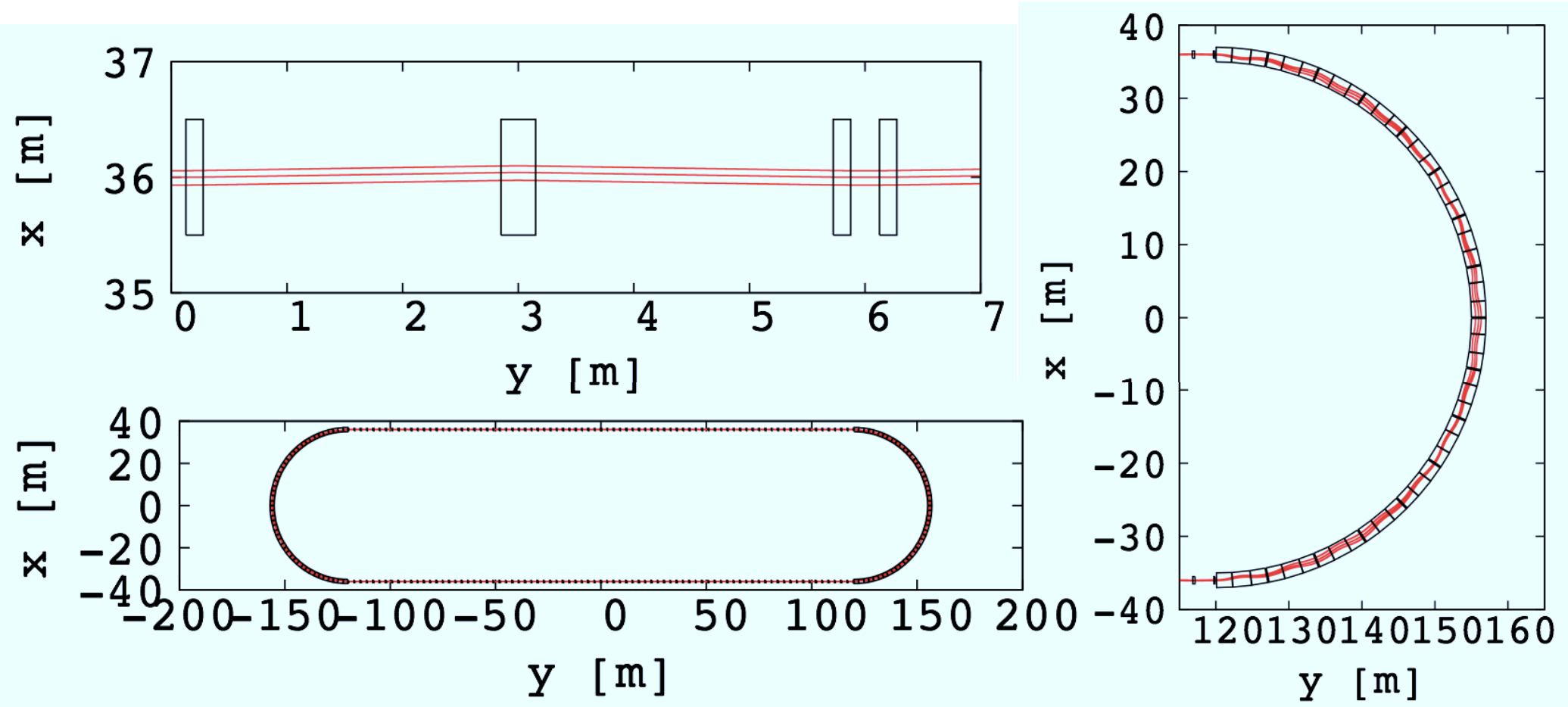
Muon decay Racetrack-FFAG ring for vSTORM (p_μ=3.8GeV/c, $\Delta p/p_0$=±20%)

designed by JB. Lagrange and Y. Mori (KURRI)

from JB.Lagrange and Y.Mori, acc-kurri-0731-03-2012

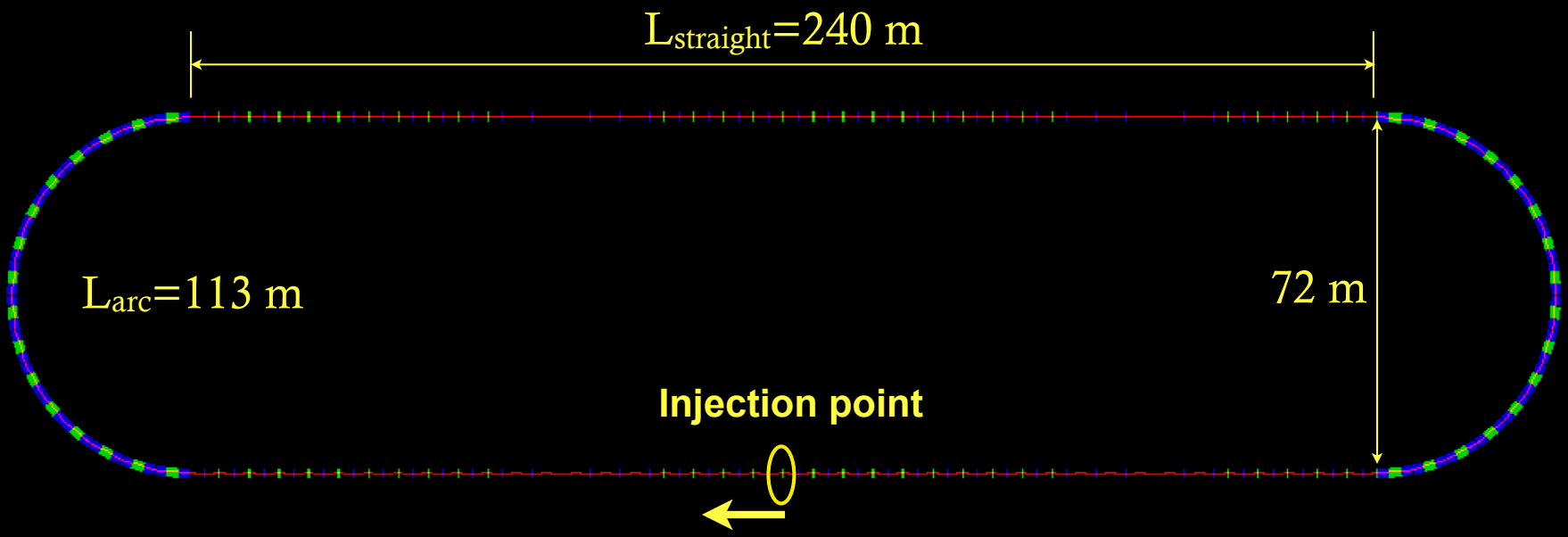
JB's Lattice for p_μ=3.8GeV/c, $\Delta p/p_0$=±20%

Advanced Scaling FFAG Muon decay ring with long straight sections.



from JB.Lagrange and Y.Mori, acc-kurri-0731-03-2012

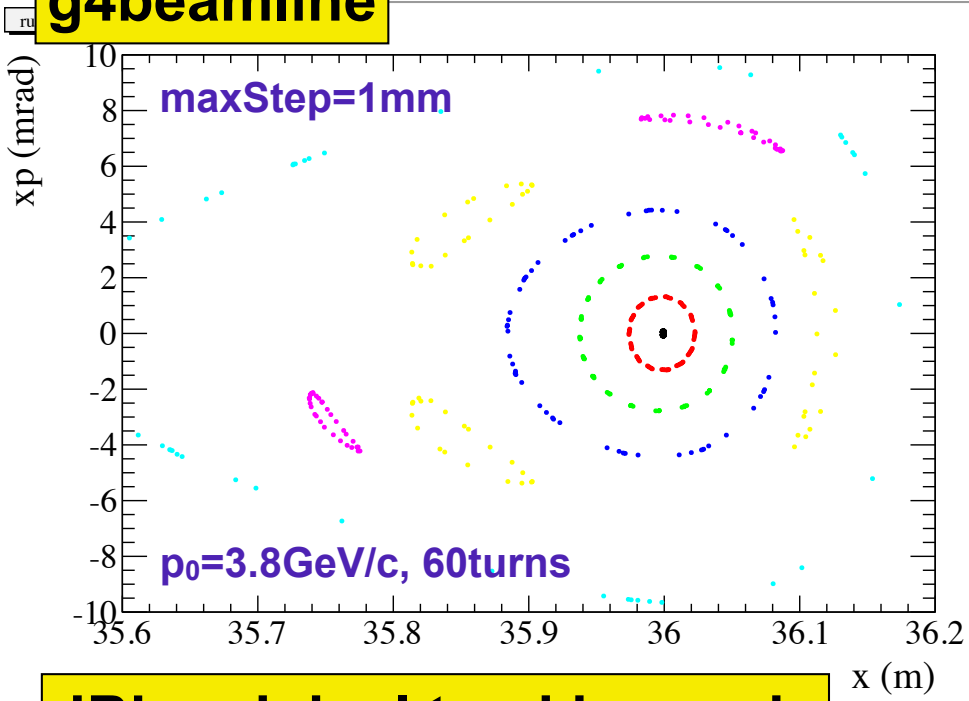
Tracking of JB's 3.8GeV/c Ring by g4beamline

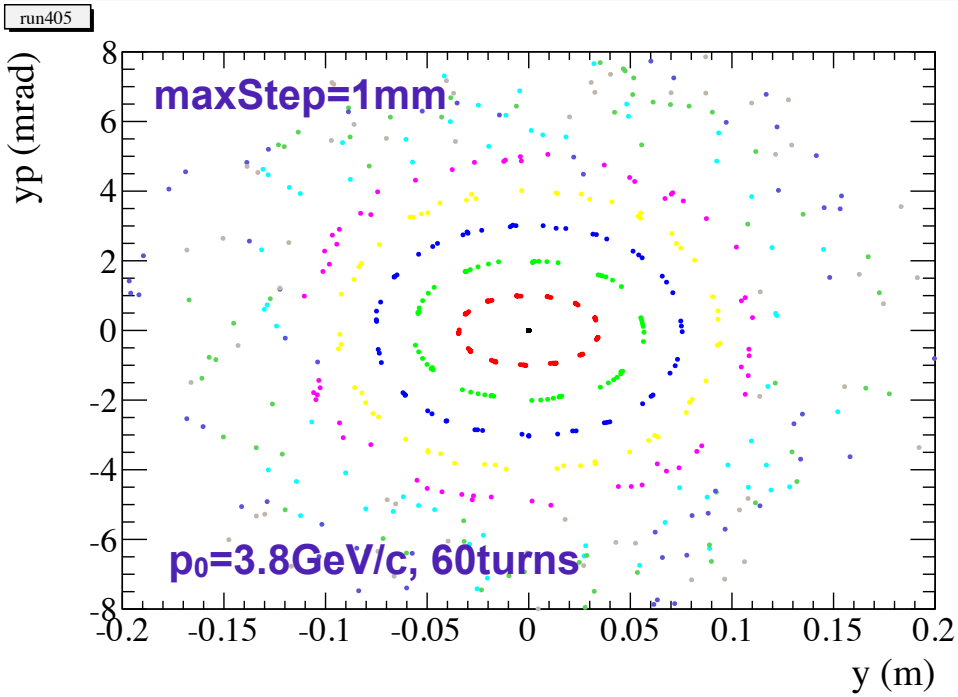


red: μ^- blue:e^- white:ν_e magenta:anti-ν_μ

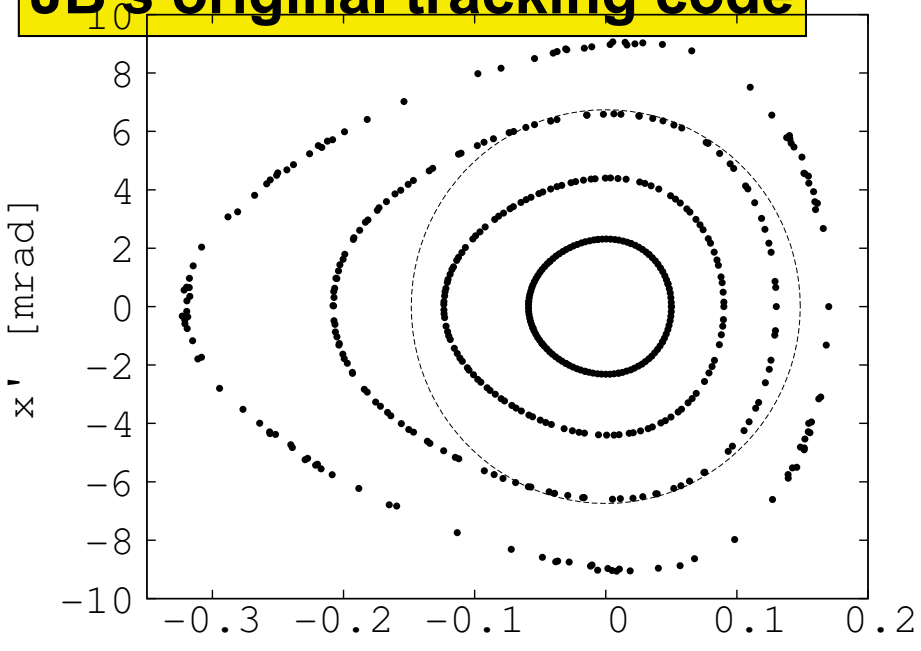
Comparison with JB's tracking results ($p=p_0=3.8$GeV/c)

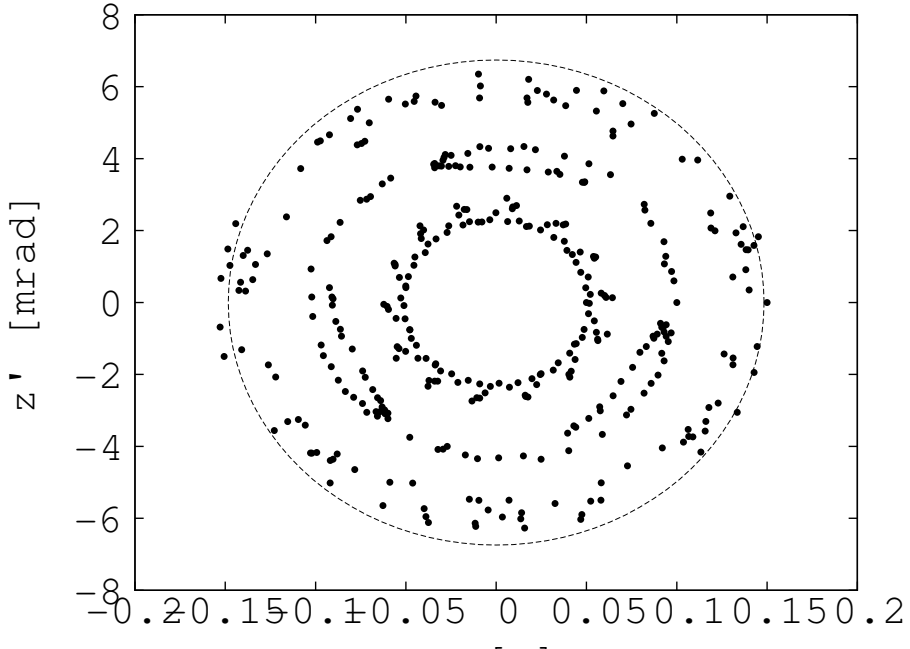
g4beamline



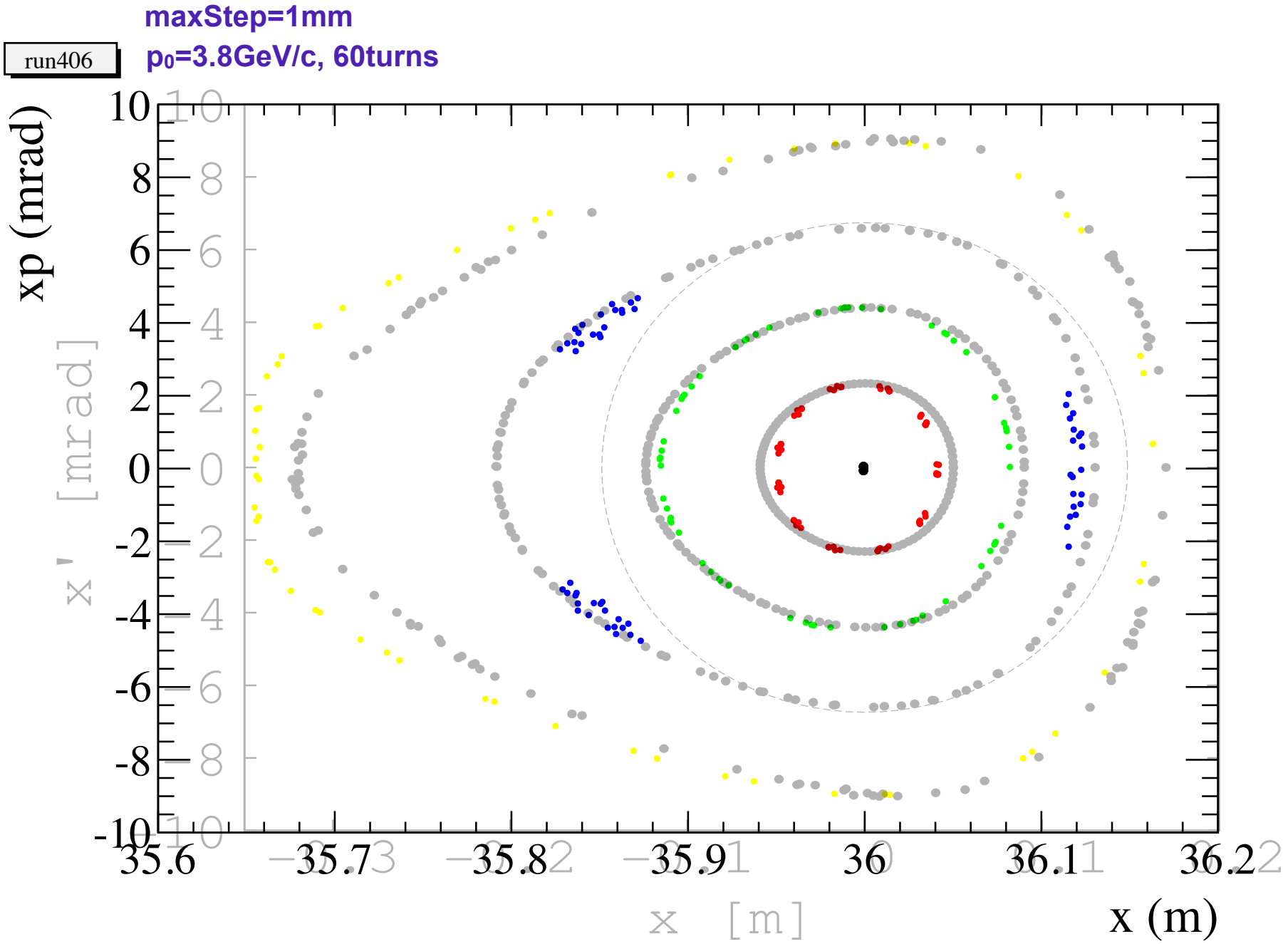


JB's original tracking code





Comparison with JB's tracking results ($p=p_0=3.8$GeV/c)



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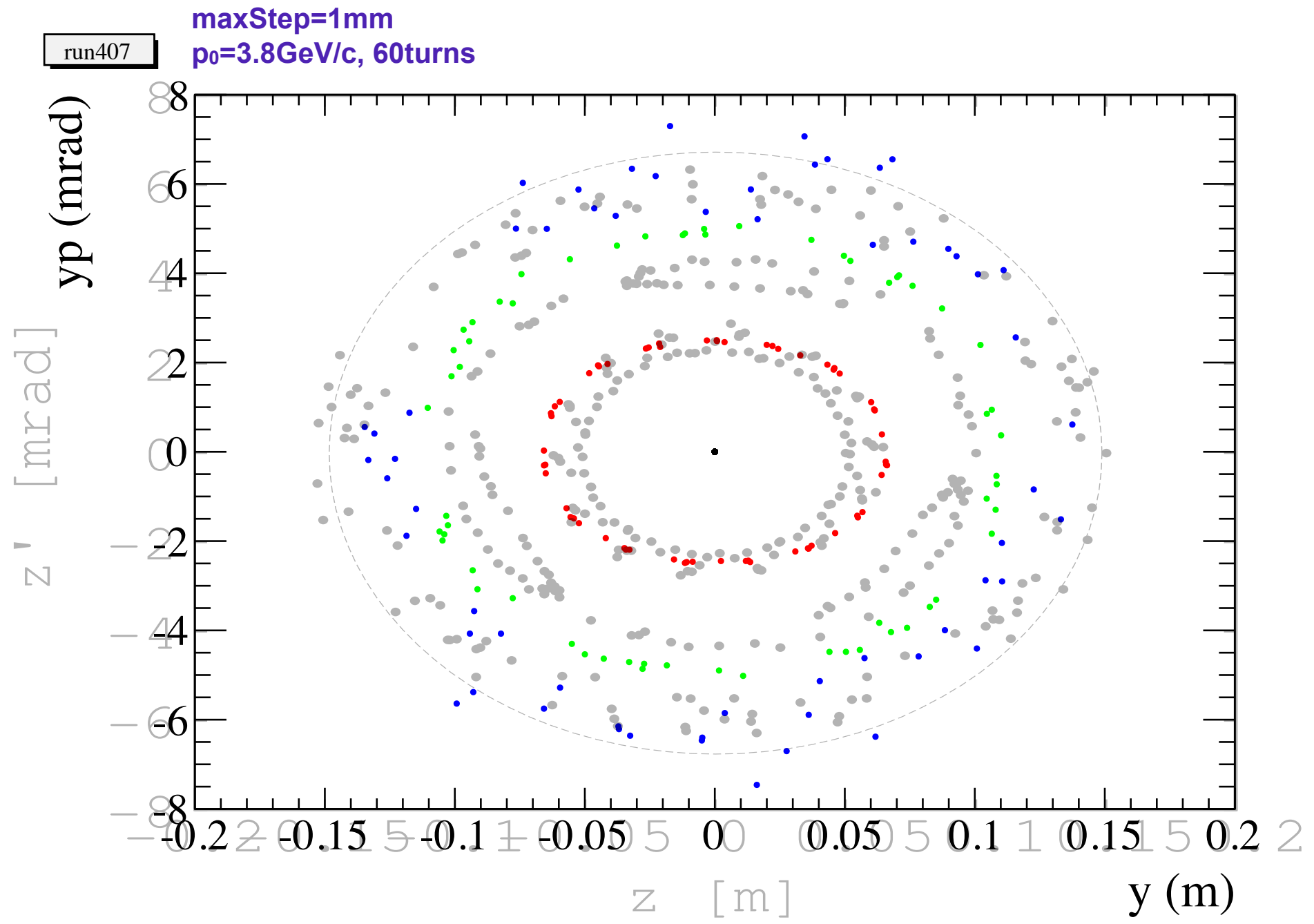
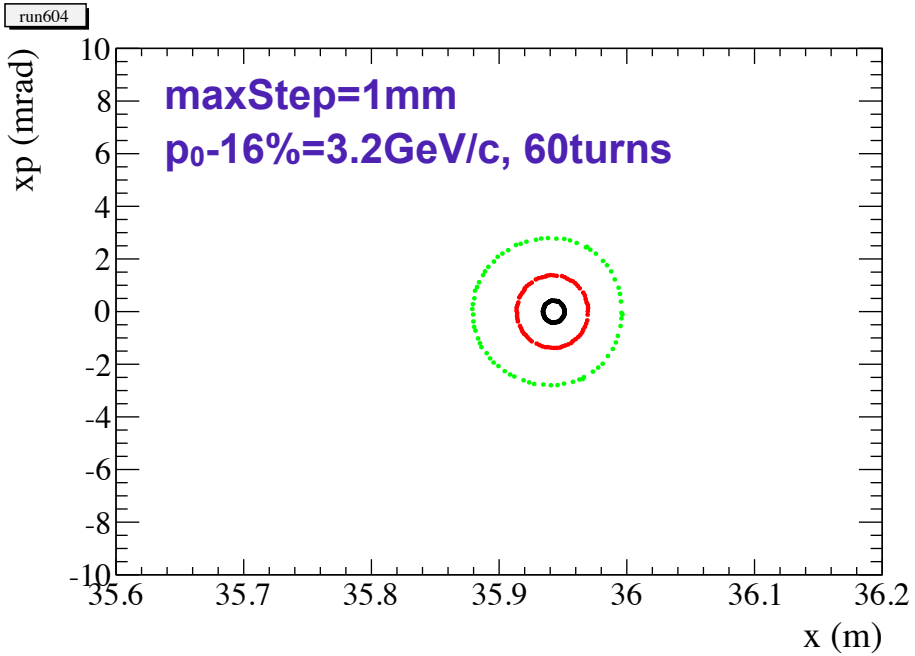
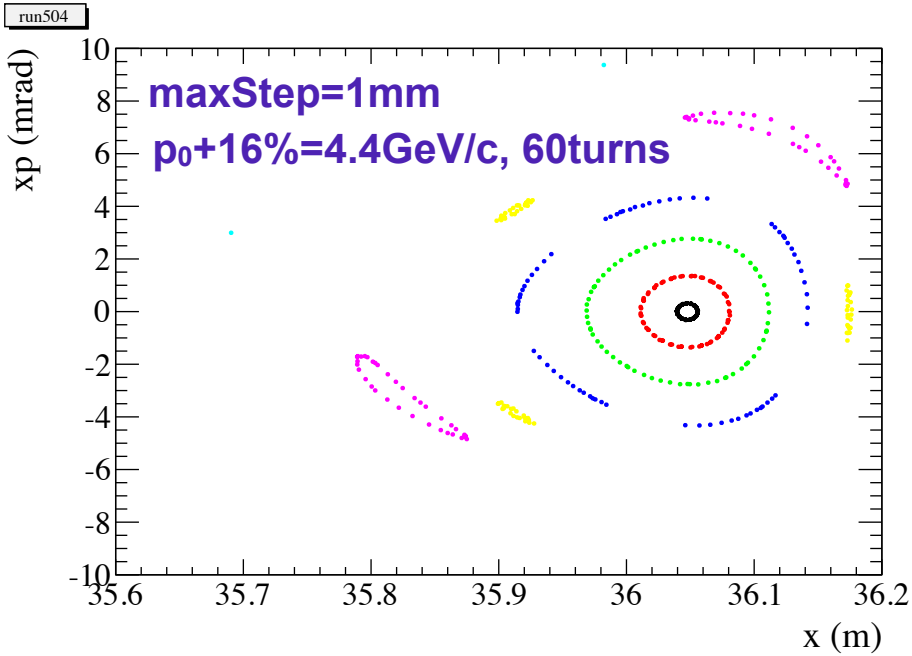
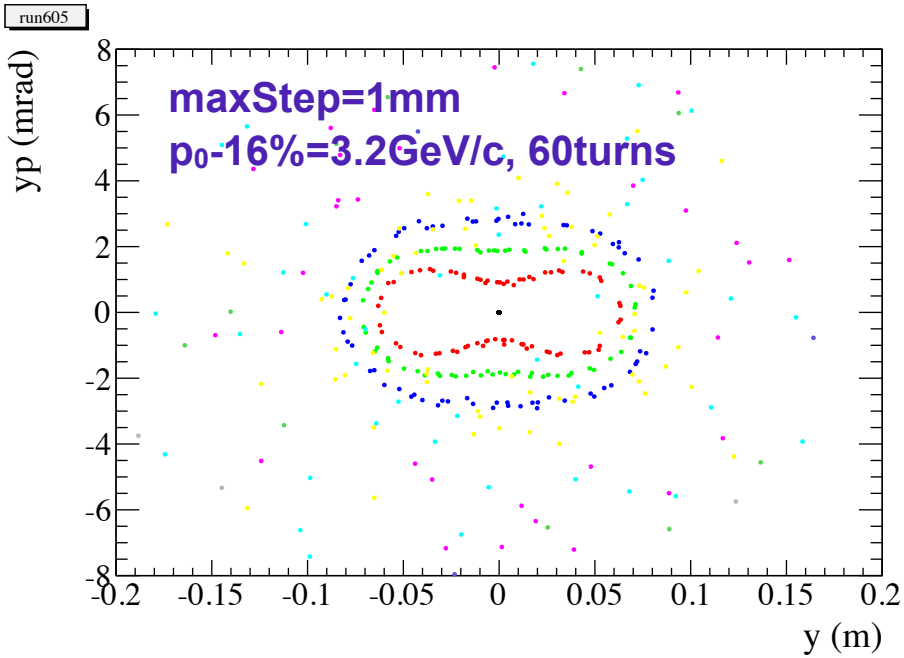
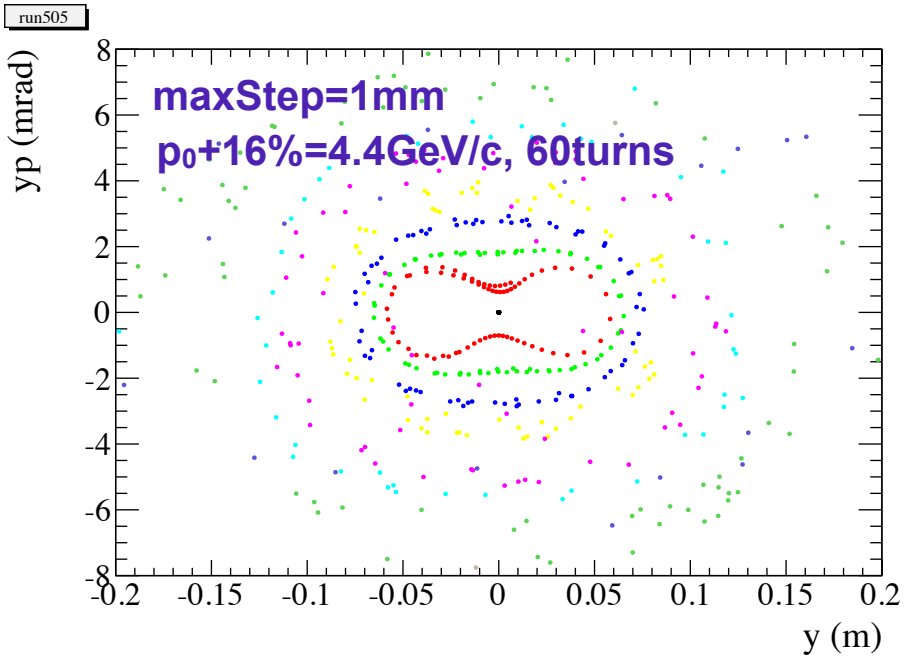


G4beamline results: p= p_0-16% and p_0+16%

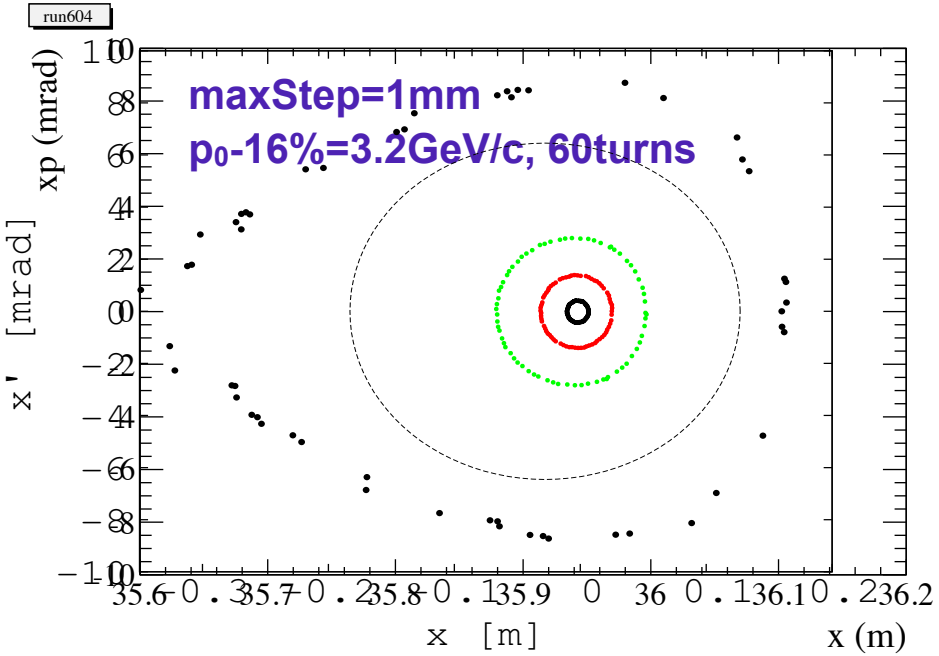


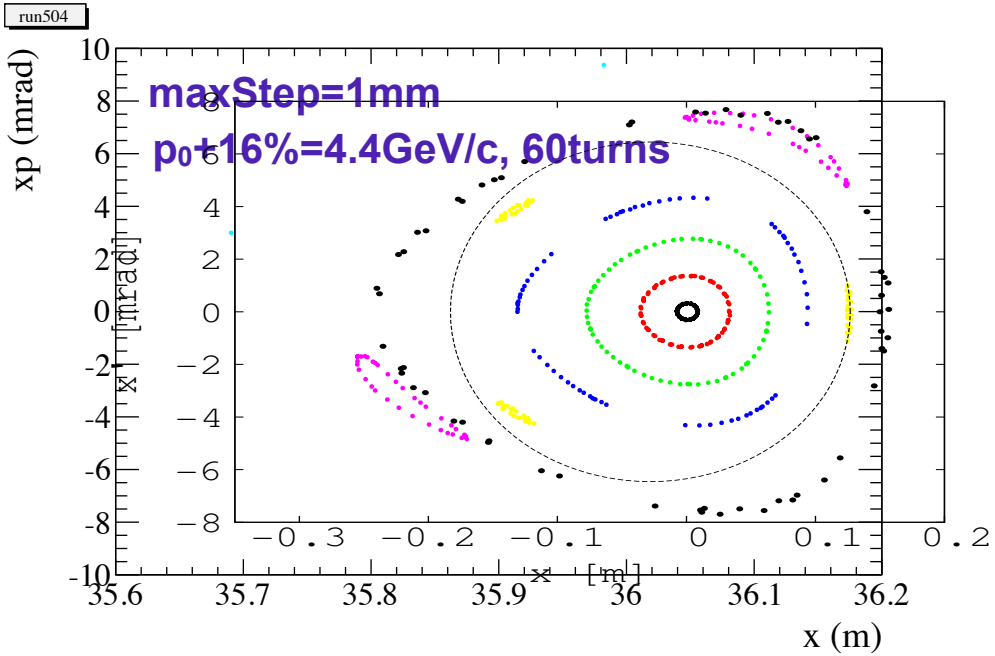


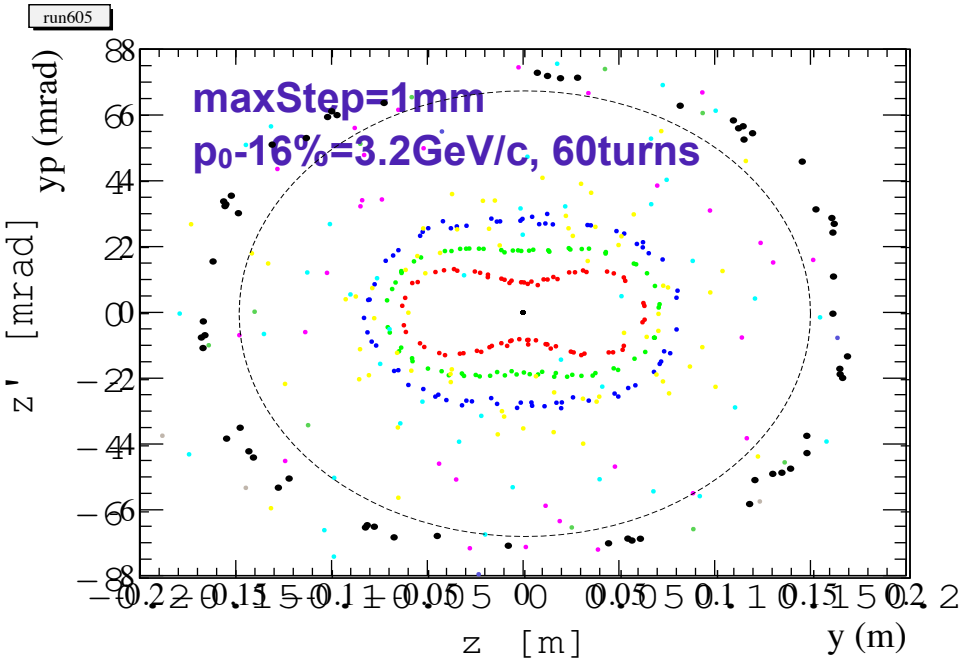


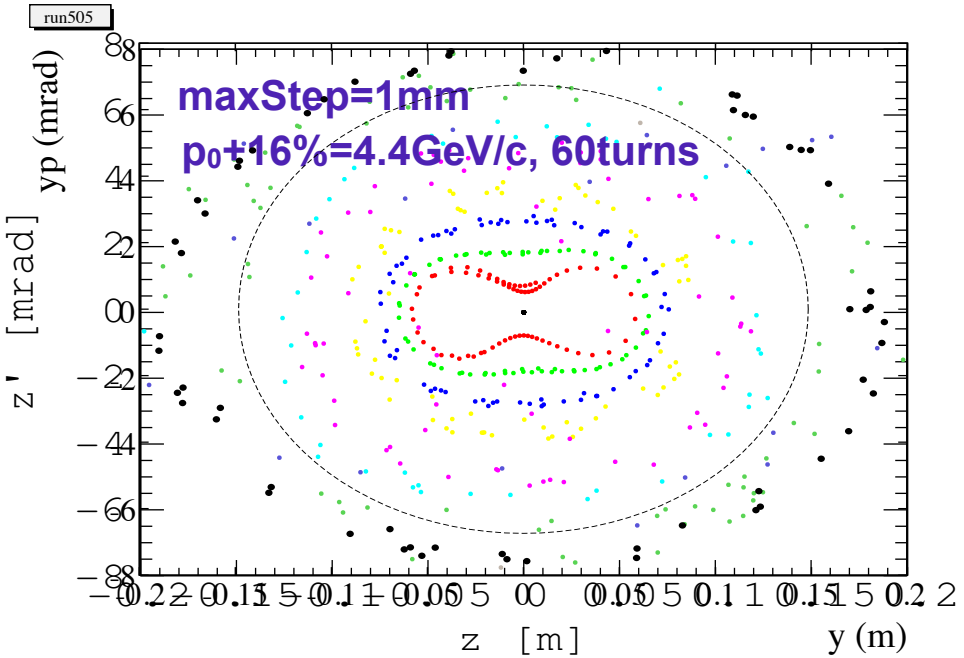


G4beamline results: p= p_0-16% and p_0+16%

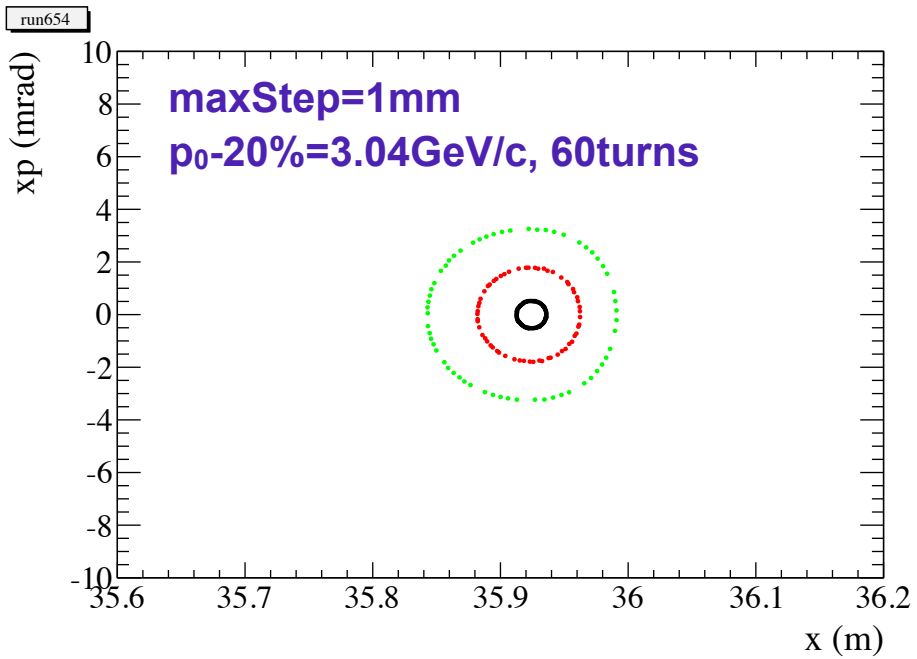


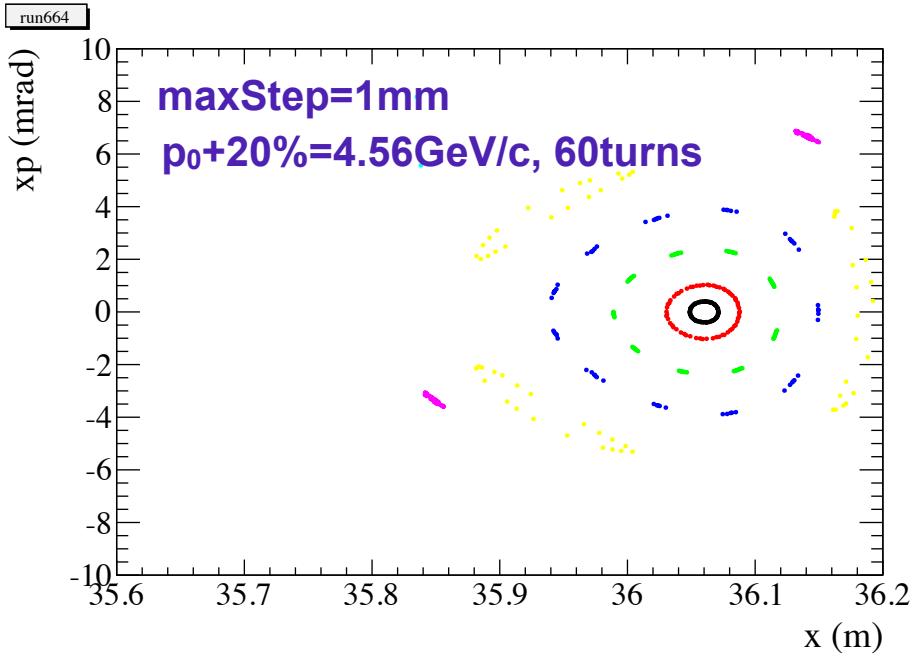


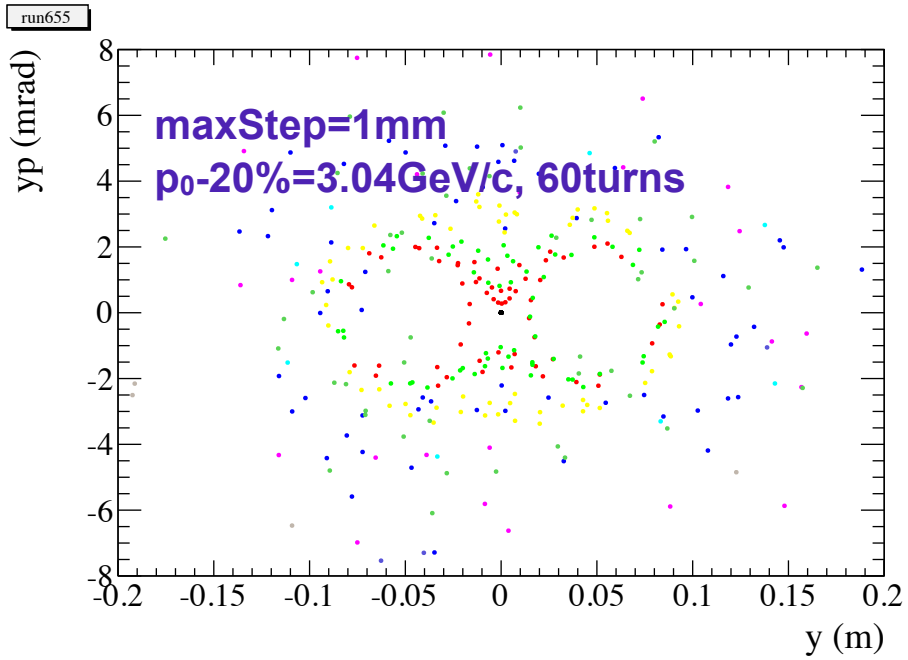


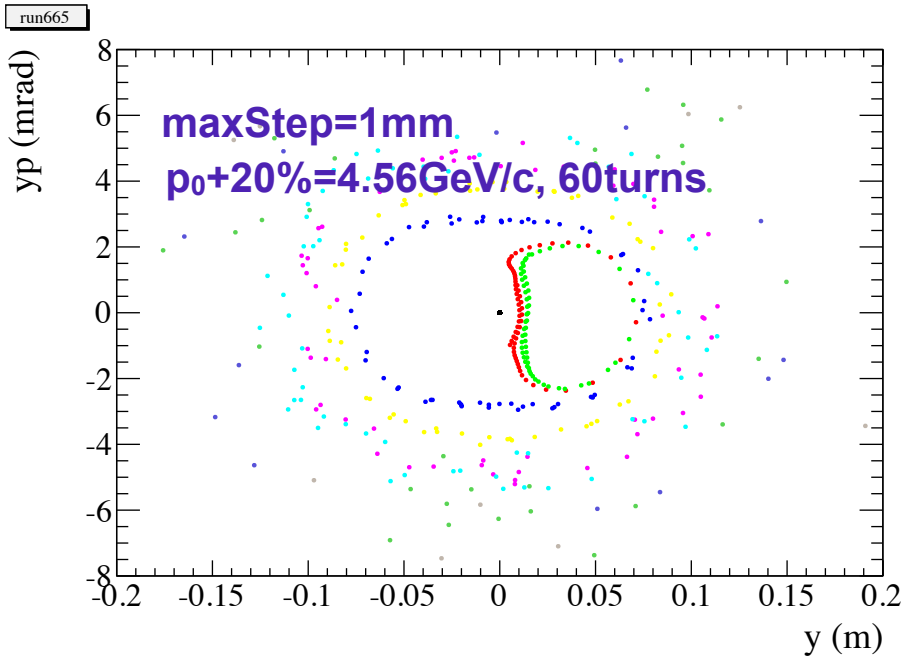


G4beamline results: p= p_0-20% and p_0+20%



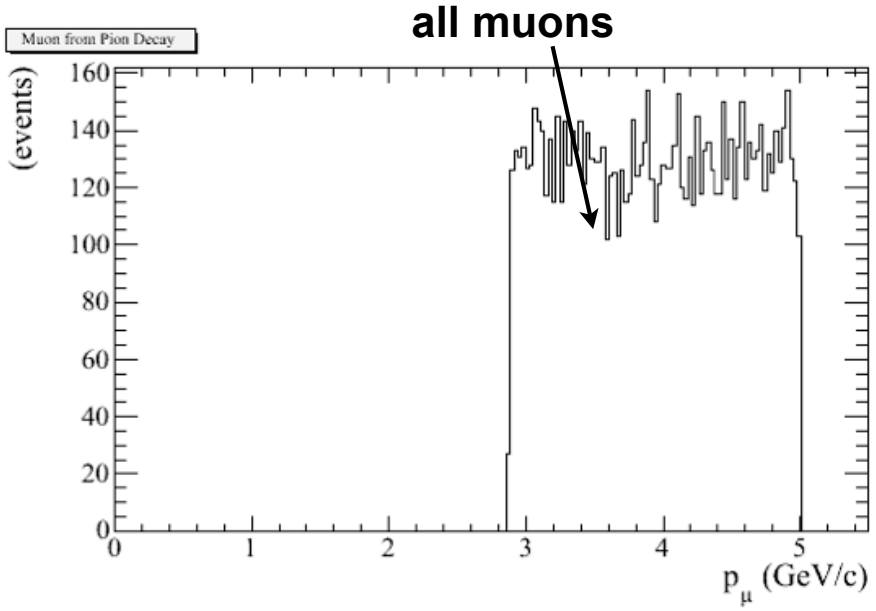


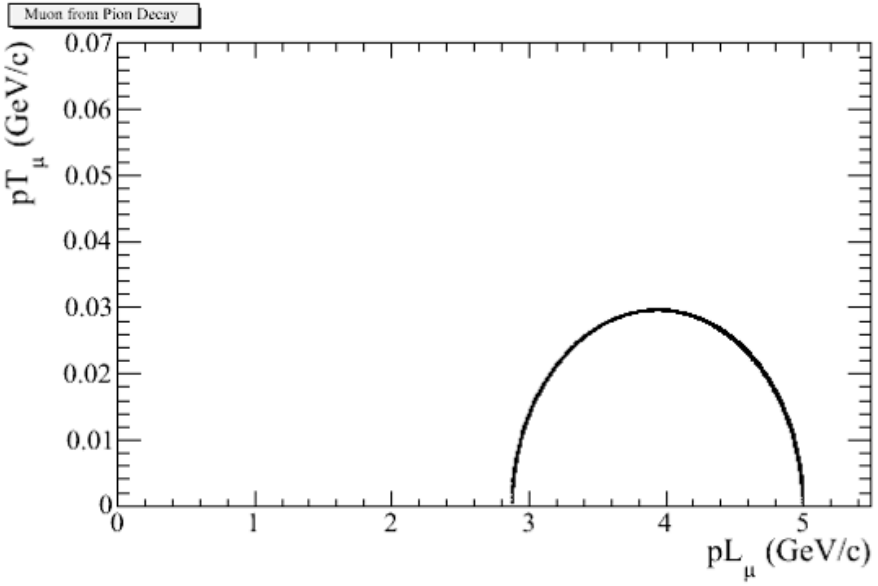


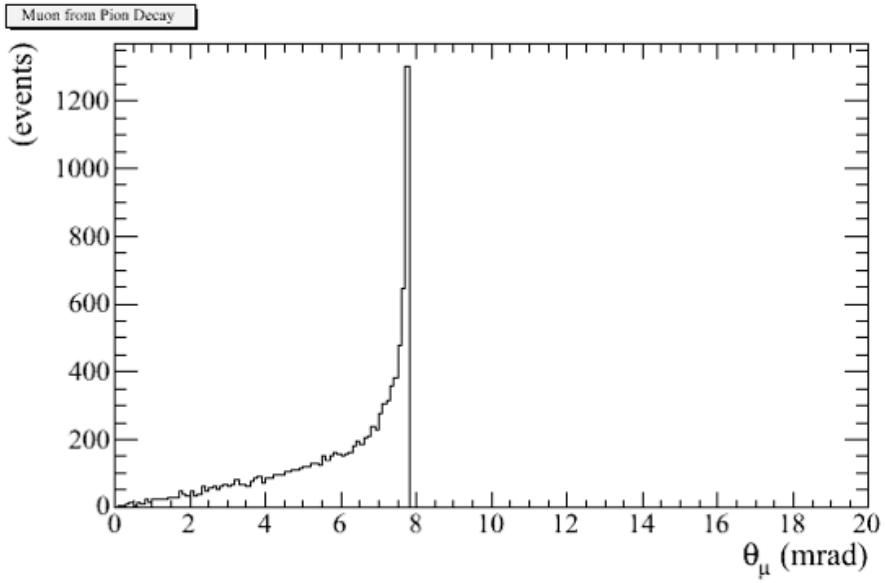


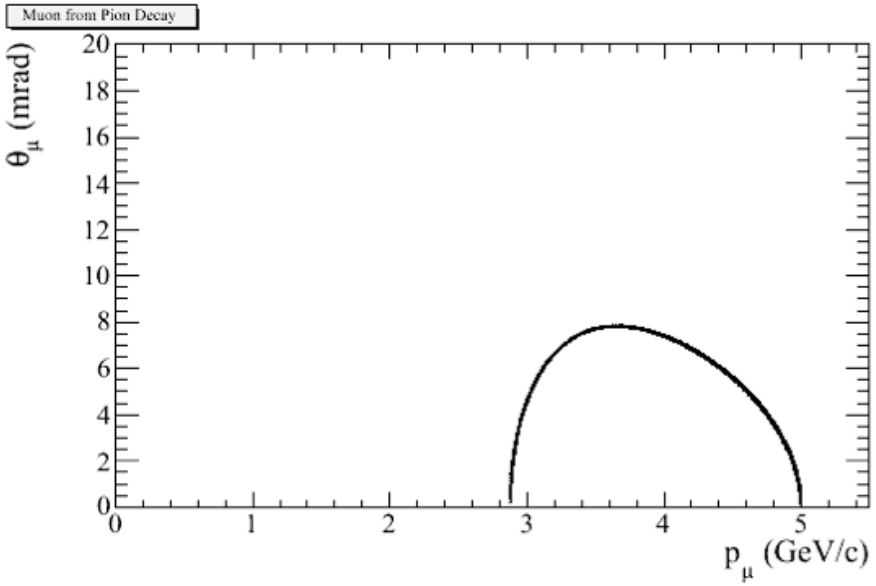
G4beamline simulation :
from pion injection to neutrino production

muon from 5GeV/c pion decay with ε_π=0

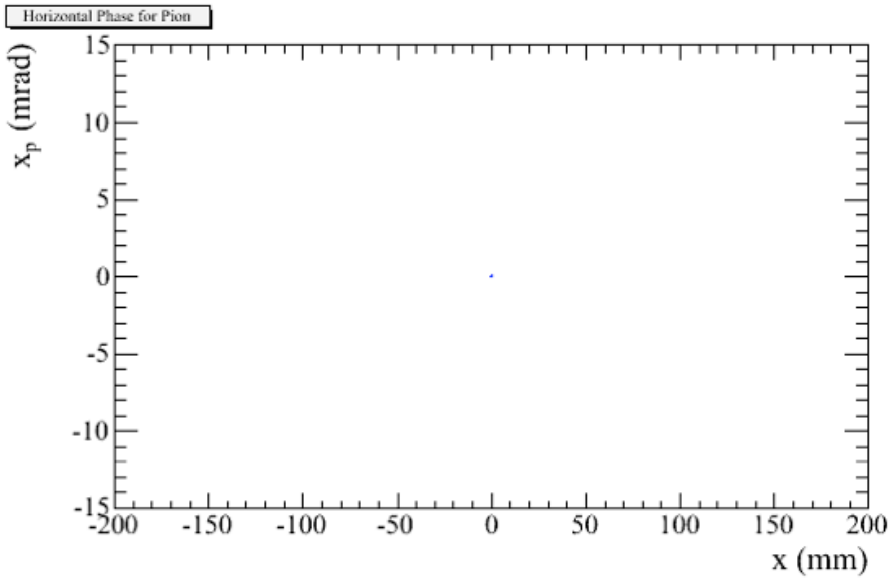


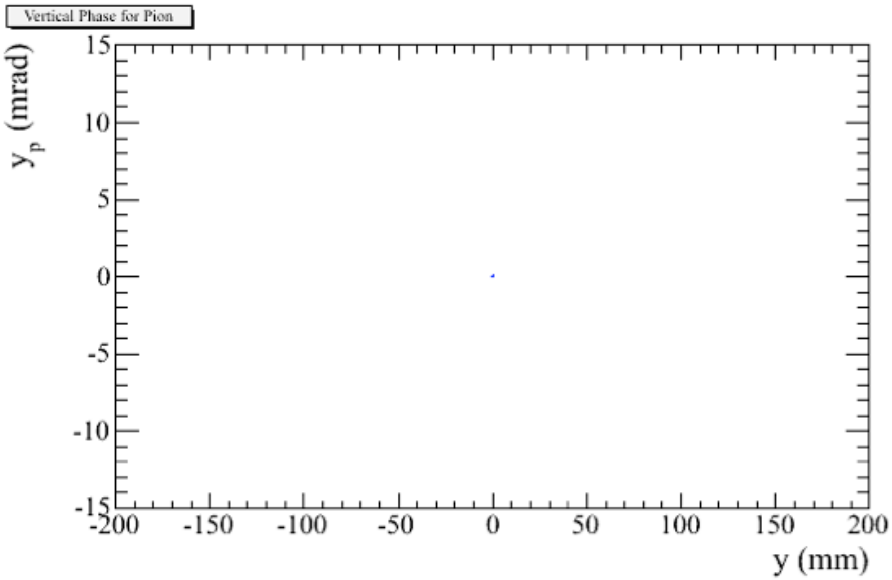


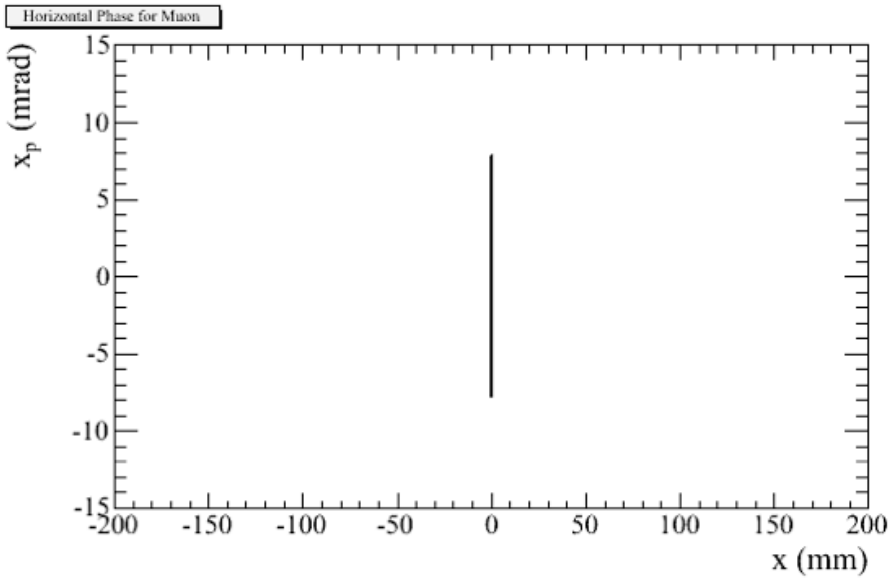


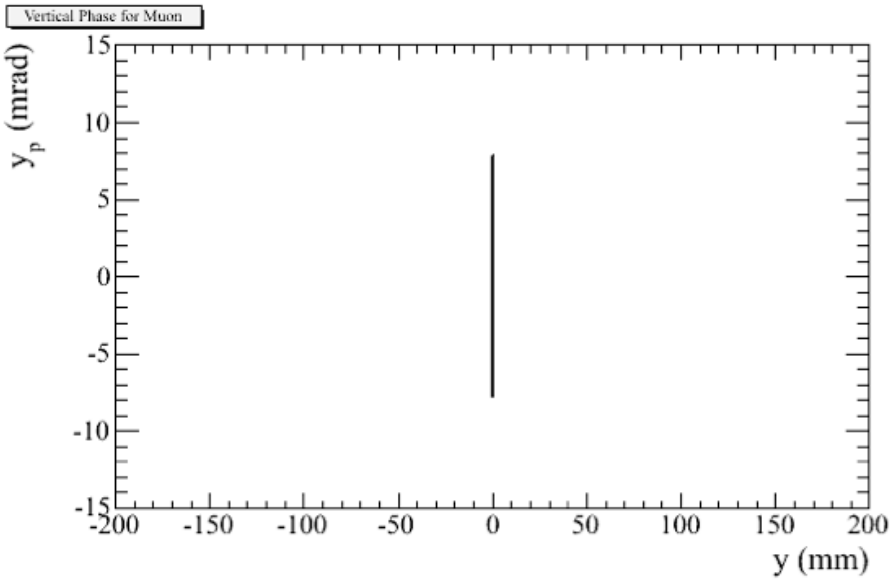


muon from 5GeV/c pion decay with $\varepsilon_{\pi}=0$

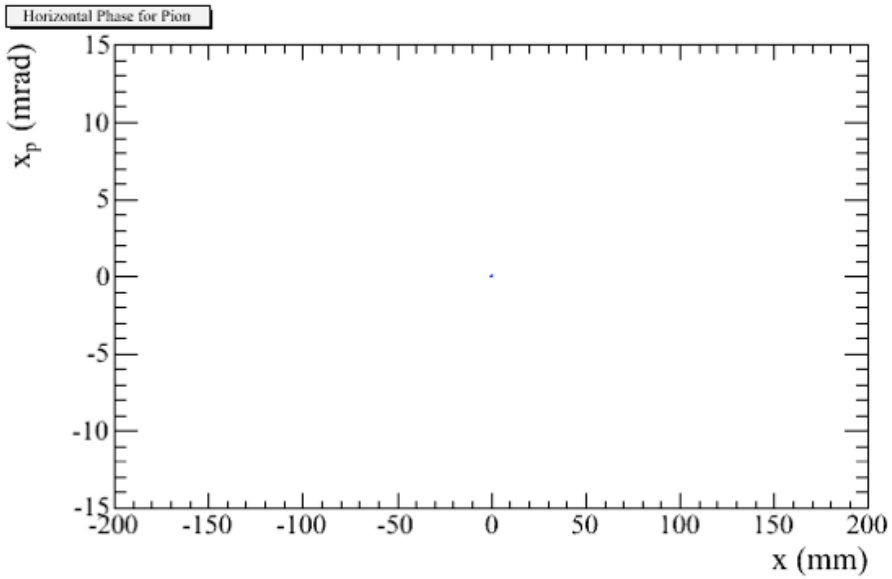


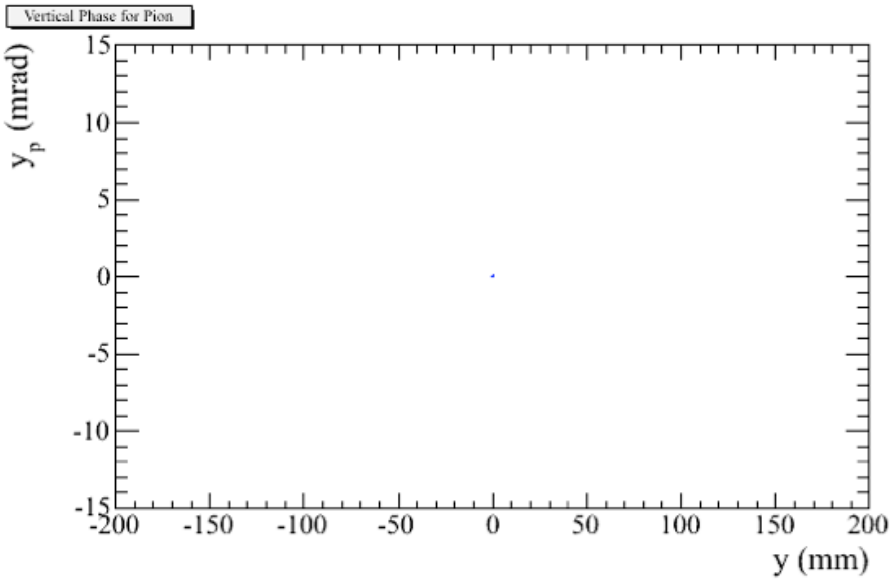


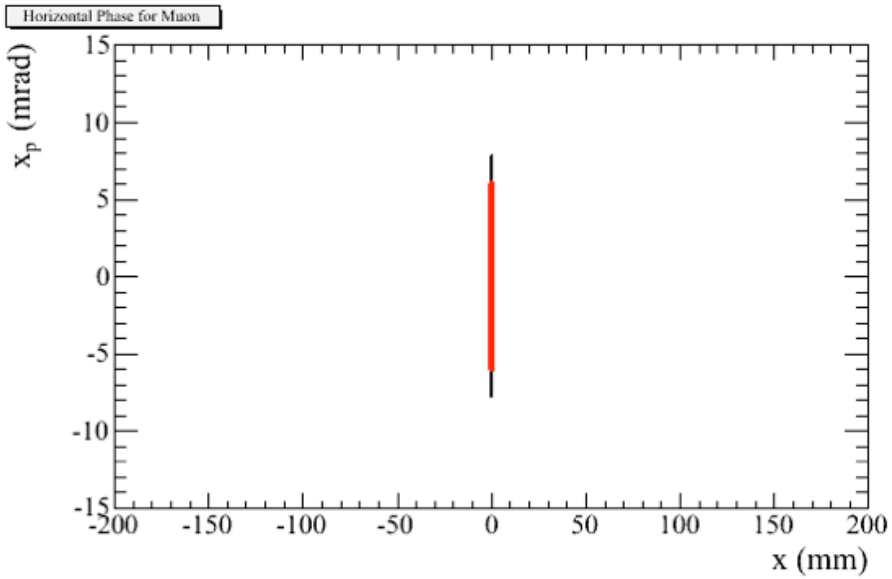


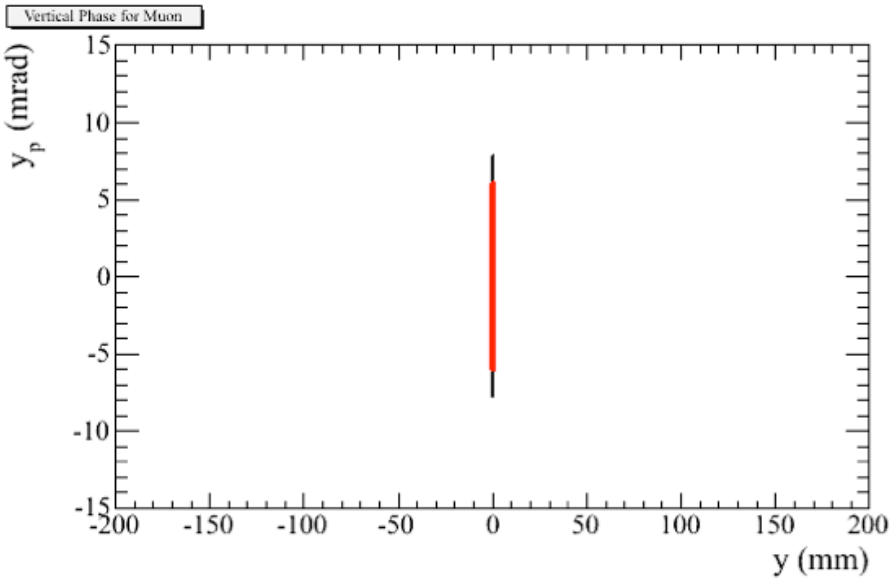


muon from 5GeV/c pion decay with $\varepsilon_{\pi}=0$



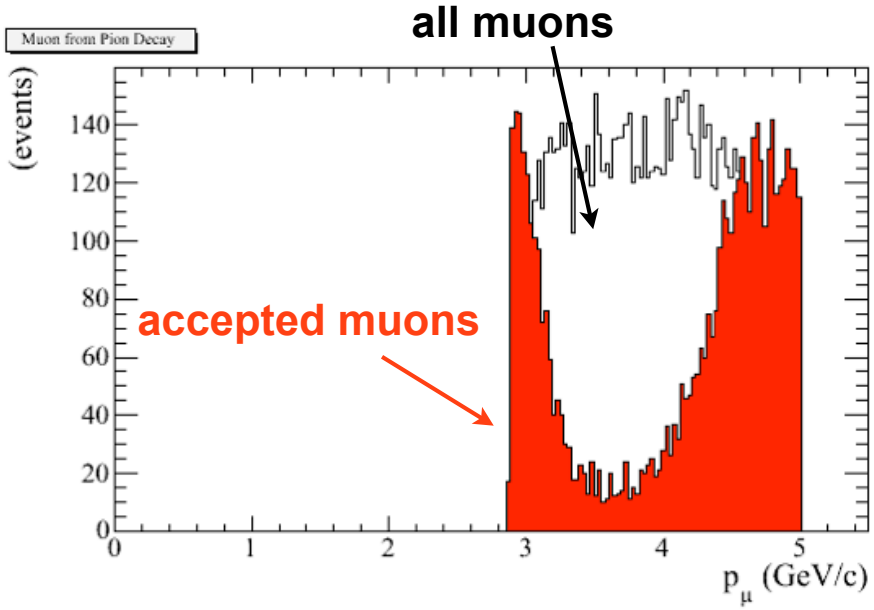


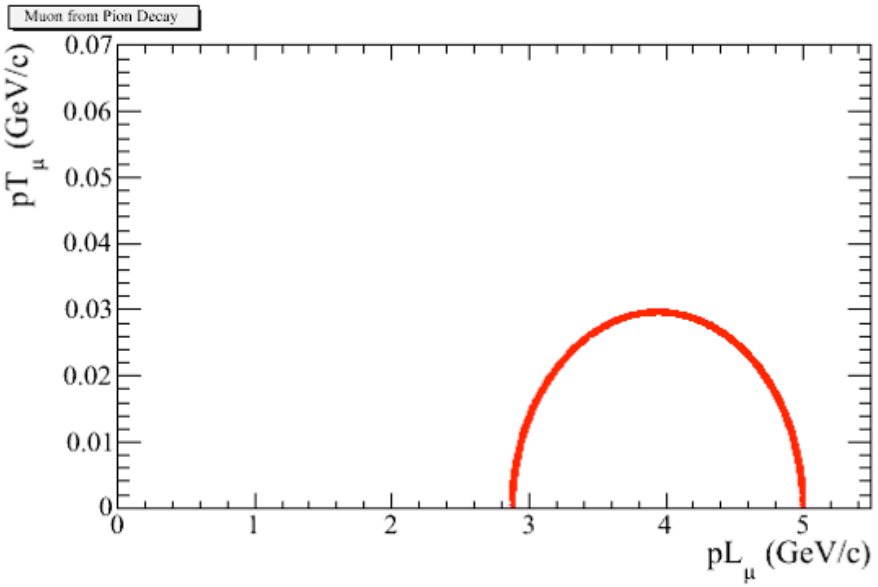


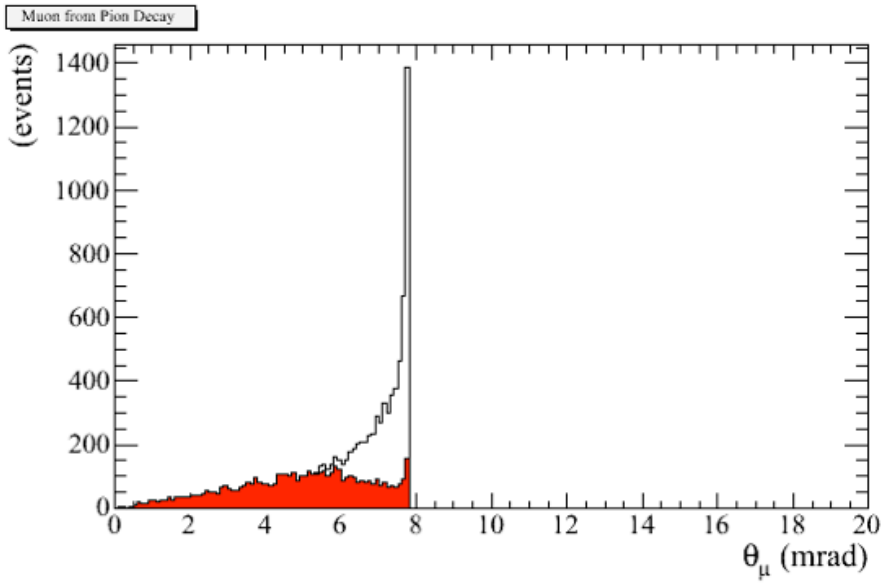


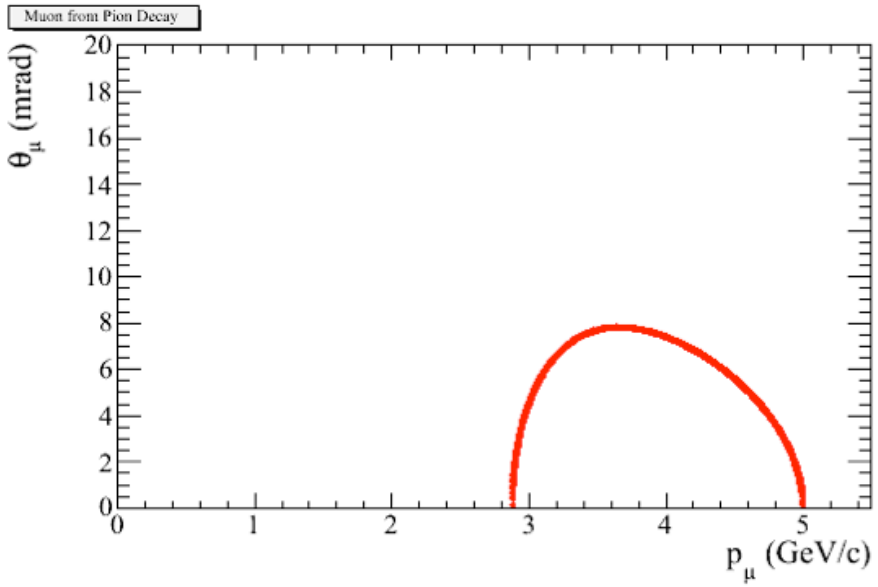
acceptance = 0.5

muon from 5GeV/c pion decay with ε_π=0

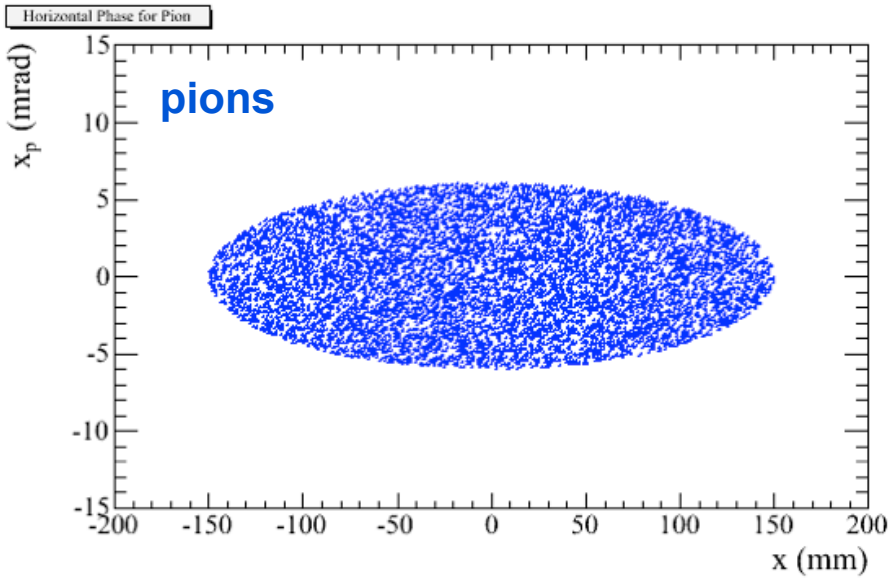


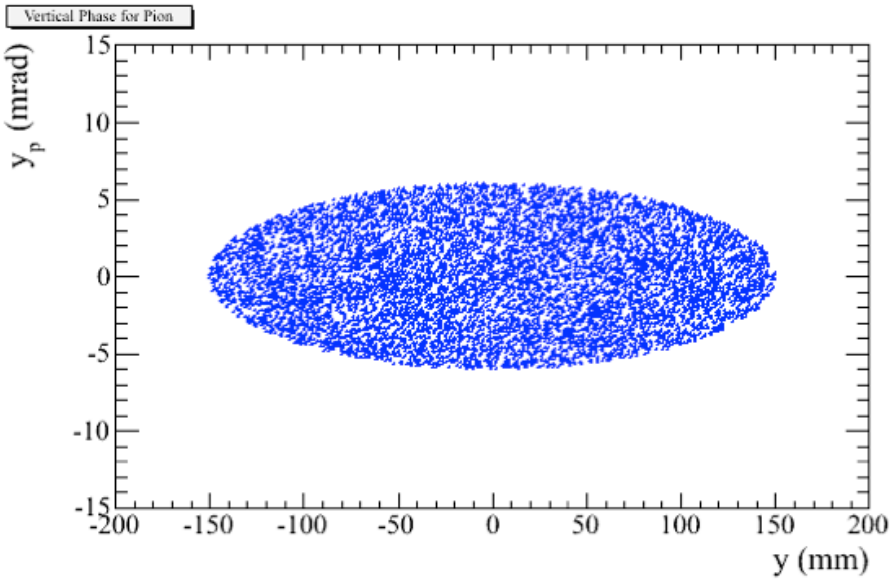


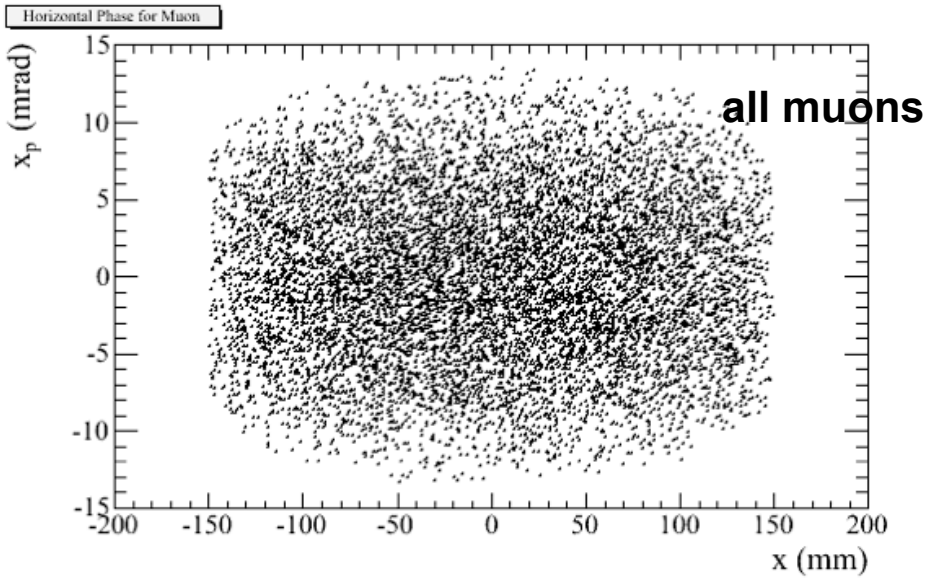


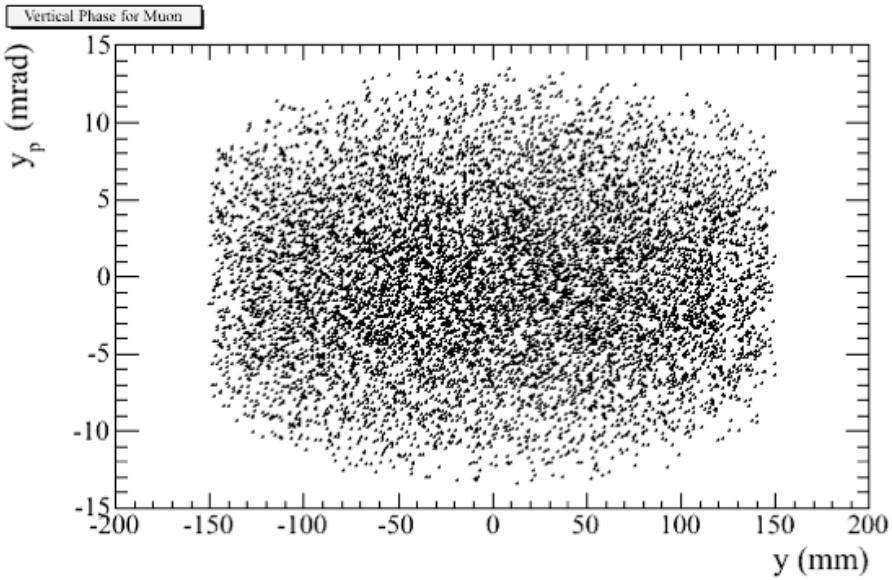


muon from 5GeV/c pion decay with ε_π=1000 π mm mrad

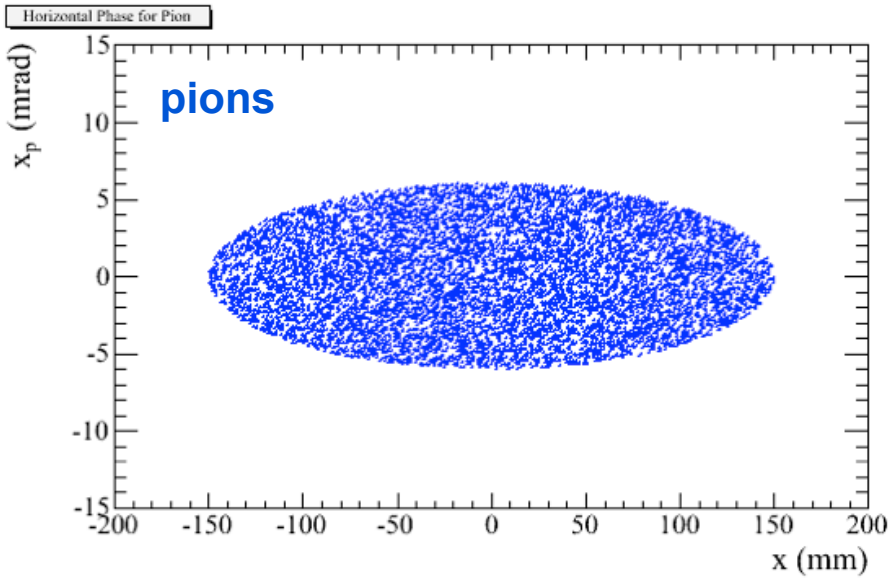


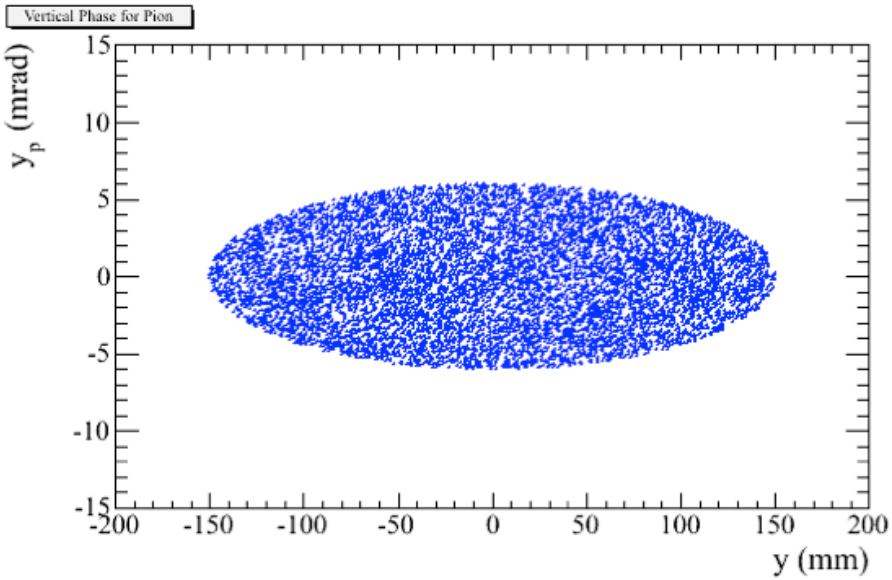


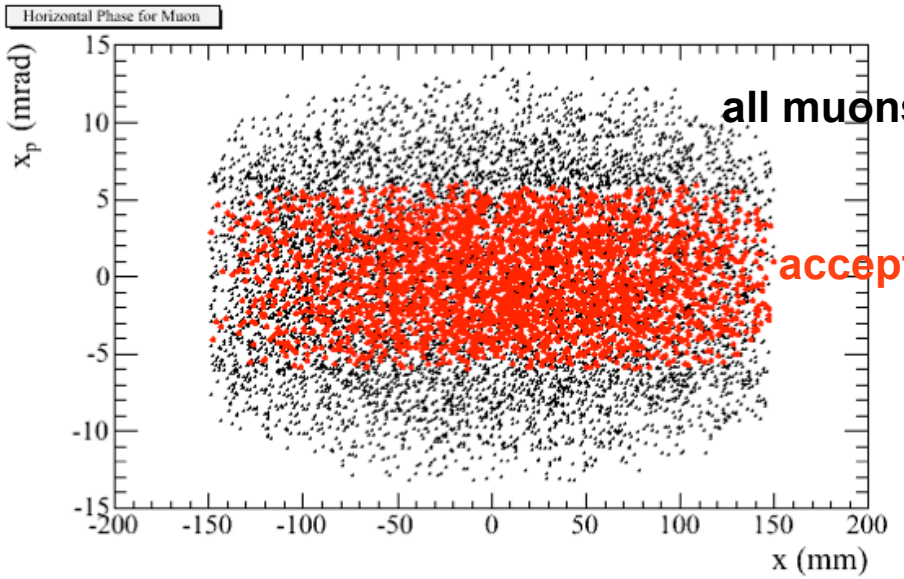


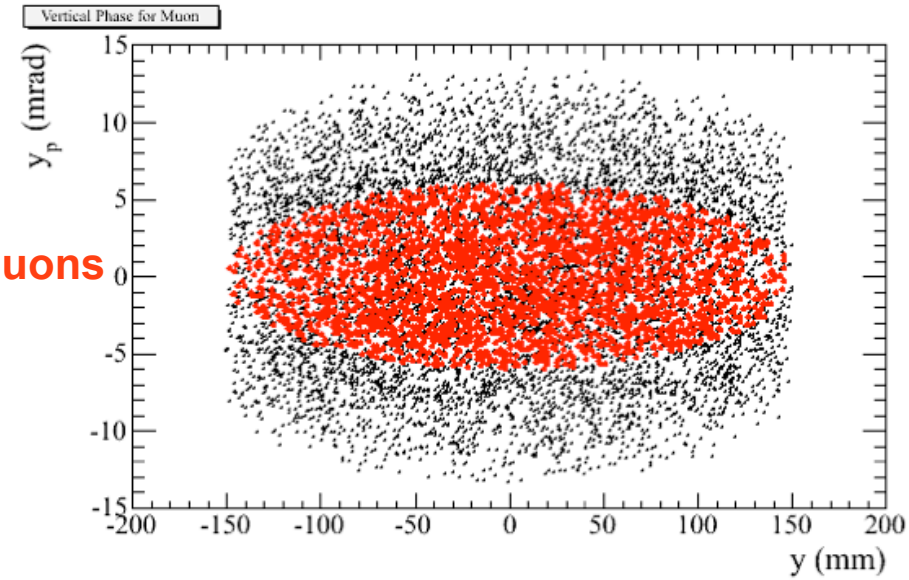


muon from 5GeV/c pion decay with ε_π=1000 π mm mrad



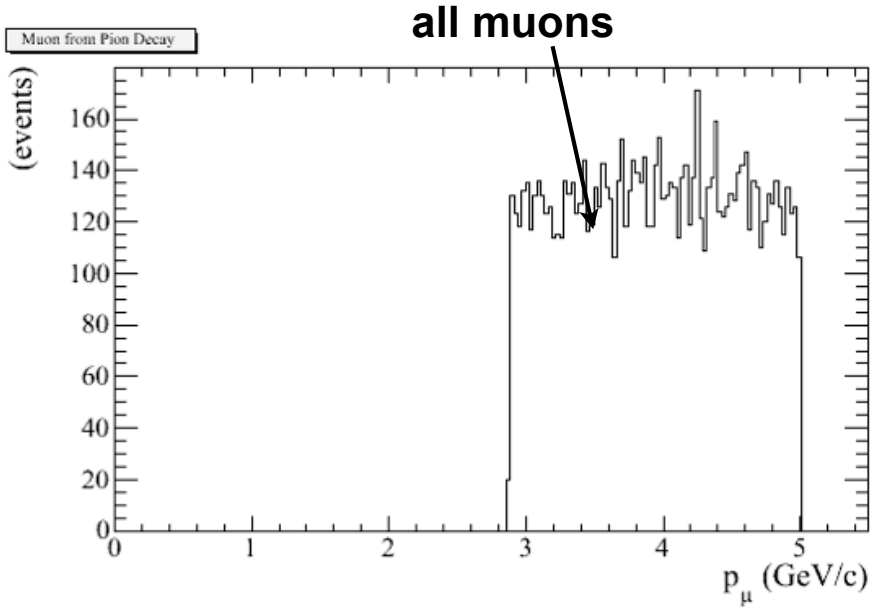


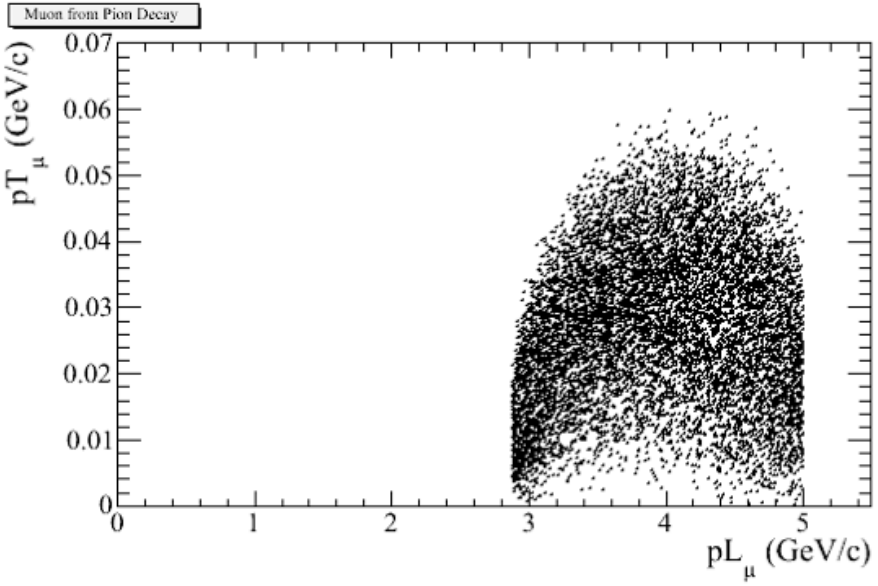


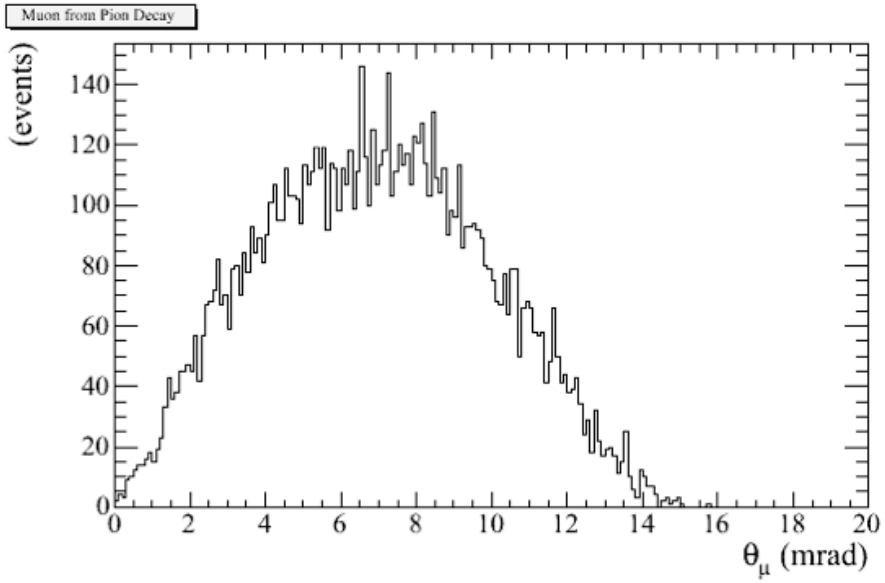


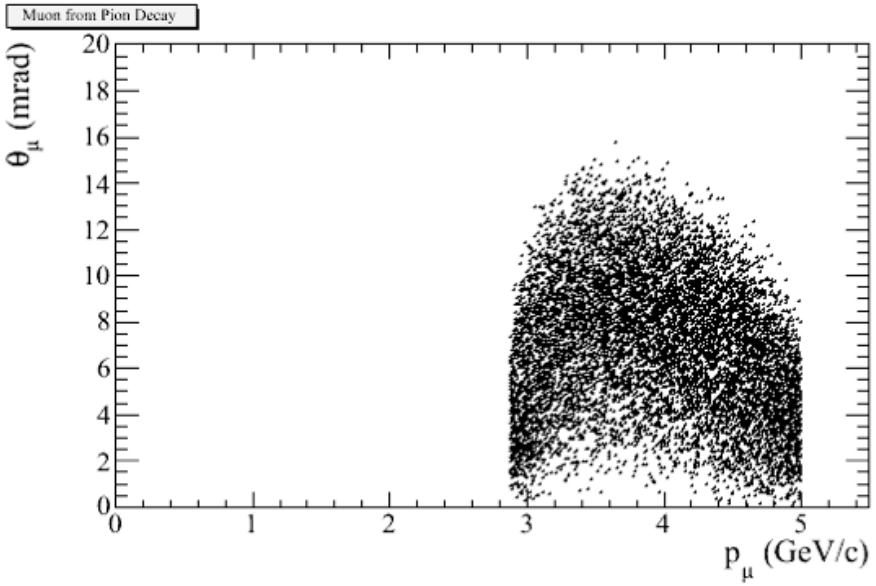
acceptance = 0.3

muon from 5GeV/c pion decay with ε_π=1000 π mm mrad

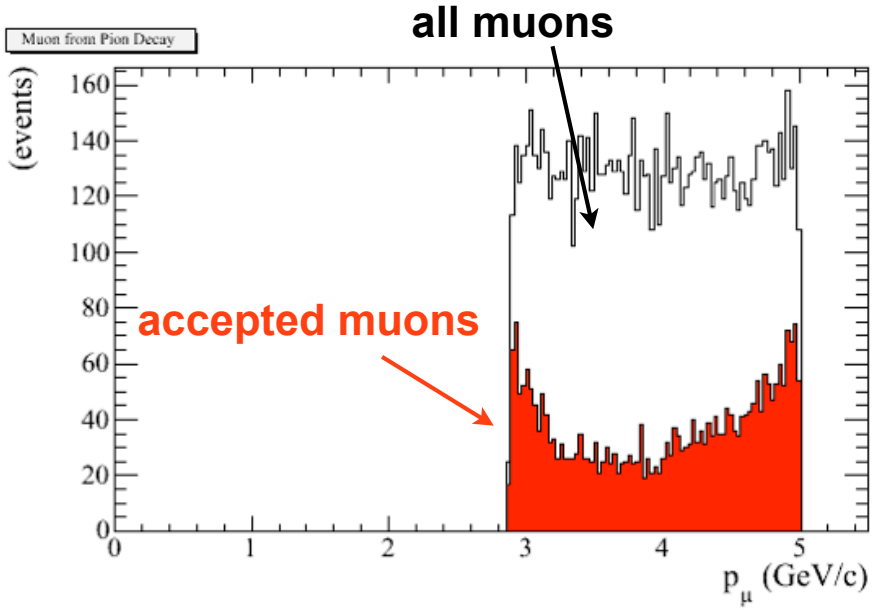


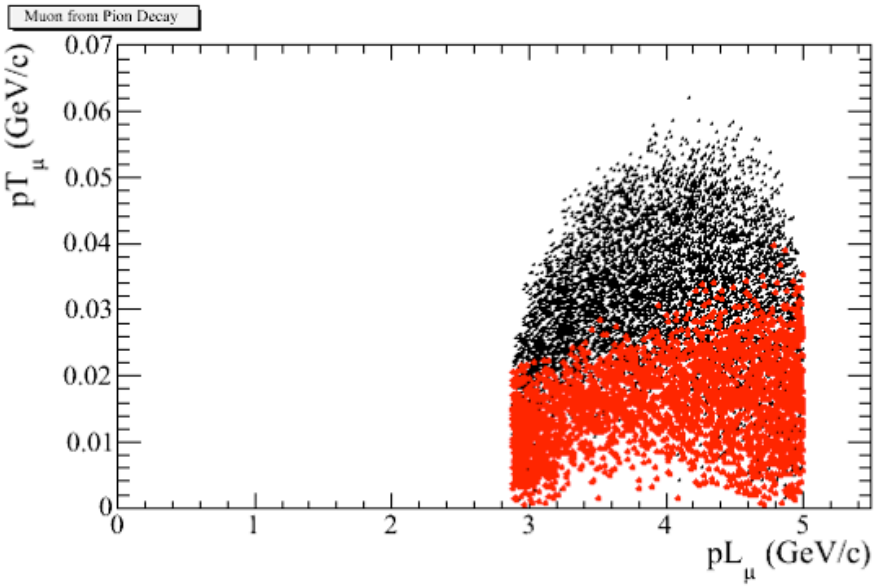


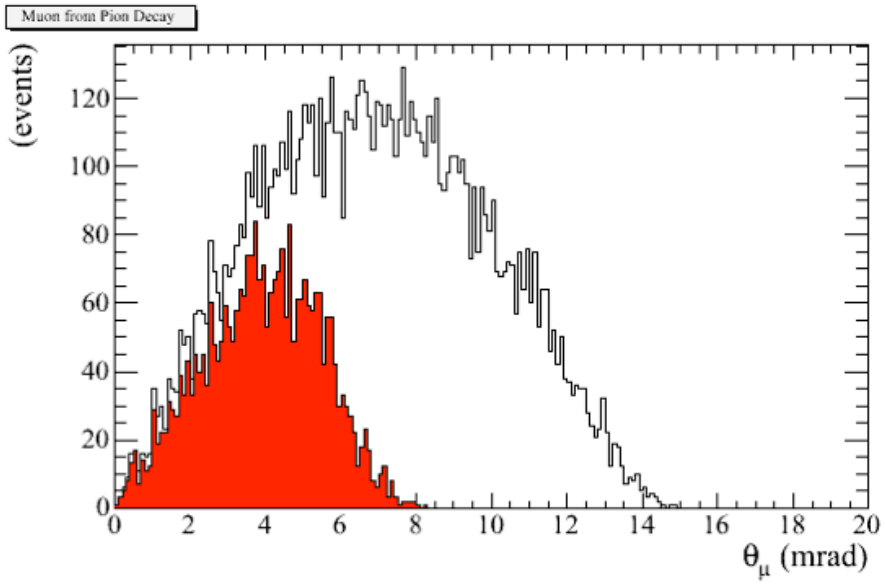


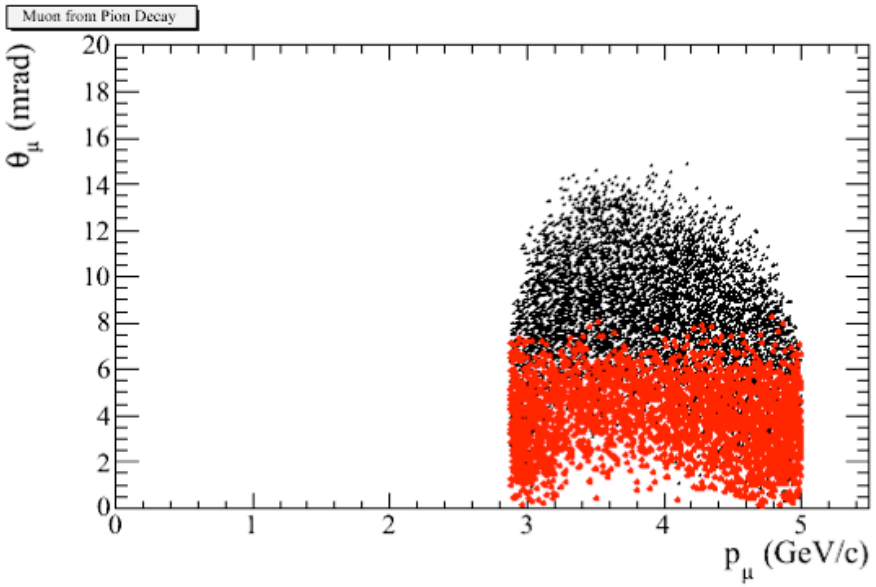


muon from 5GeV/c pion decay with ε_π=1000 π mm mrad

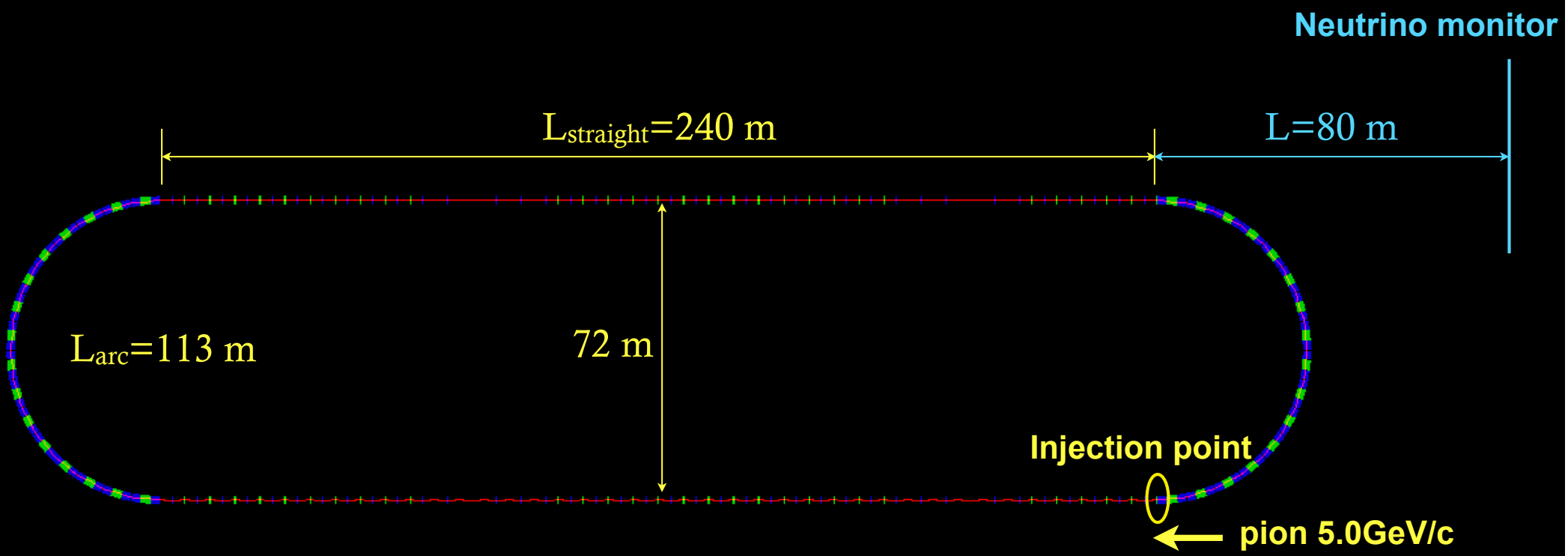








Tracking of the 3.8GeV/c RFFAG Ring by g4beamline

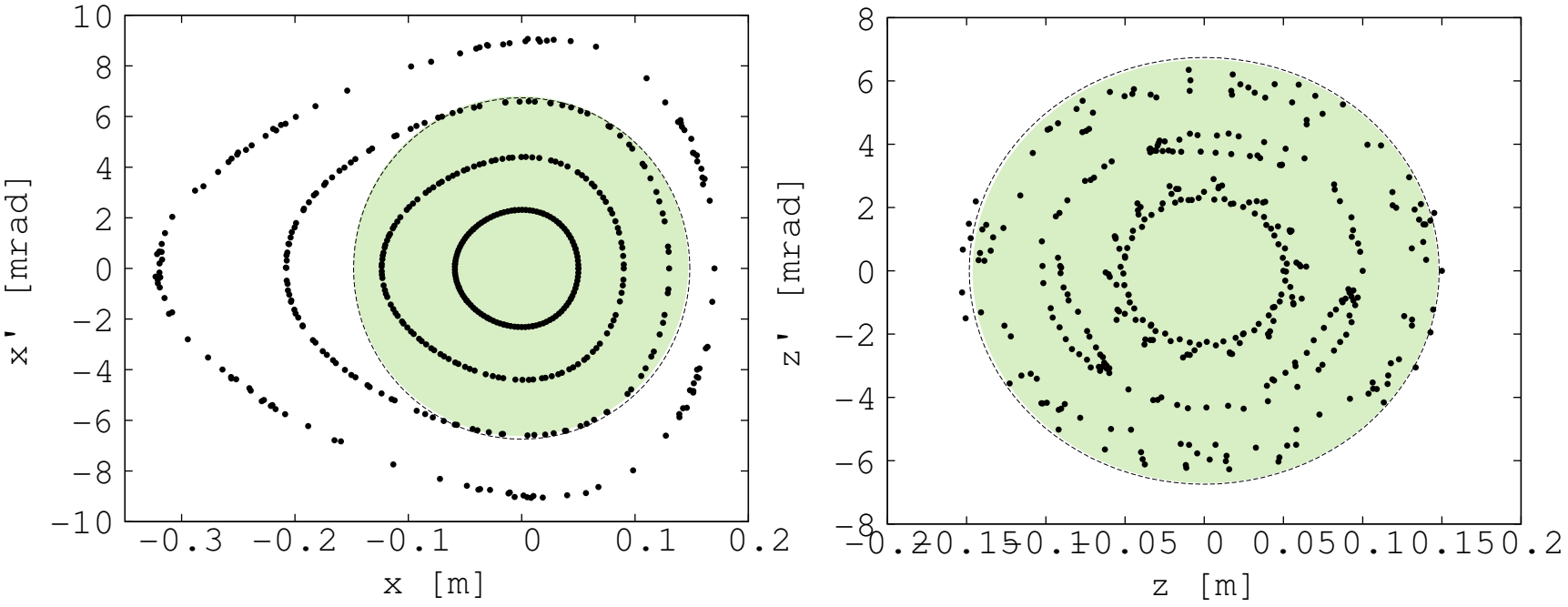


red: μ^- blue:e^- white:ν_e magenta:anti-ν_μ

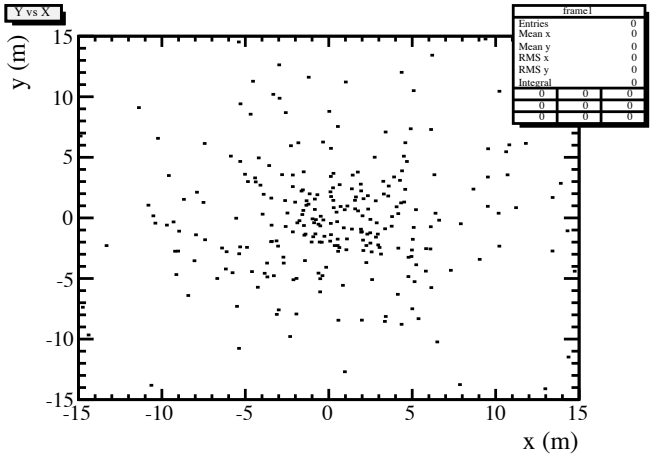
Initial beam emittance of the pions

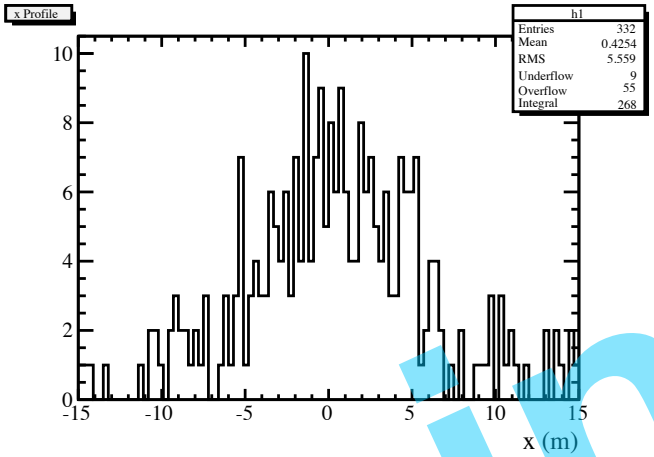
- Ellipse beam which is randomly generated on (X,Xp), (Y,Yp) with uniform density. (by g4bl command: *beam ellipse*). I tried two cases:
  - **p_π = 5.0 GeV/c ± 0%**
    - X_0 = 36m (on the closed orbit of 3.8GeV/c muon)
    - ΔX : 0.150 m, ΔXp : 0.0060 rad
    - ΔY : 0.150 m, ΔYp : 0.0060 rad
    - Δp : 0 GeV/c, Δt : 0ns

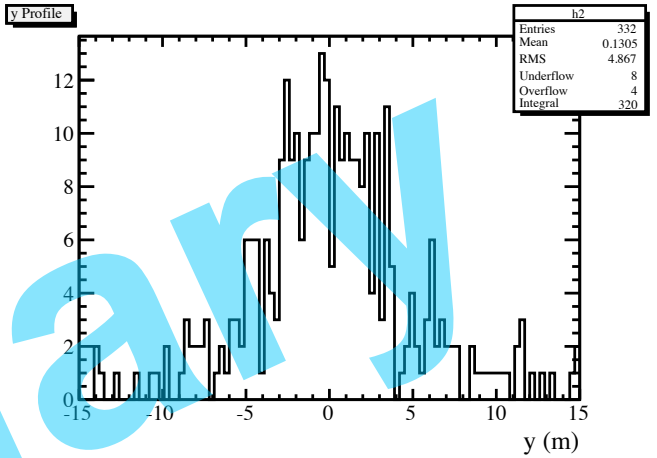
- Number of pions injected = 8 x 10^3

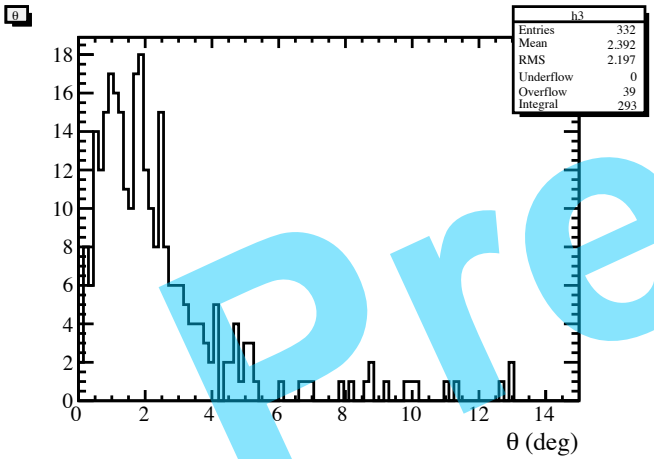


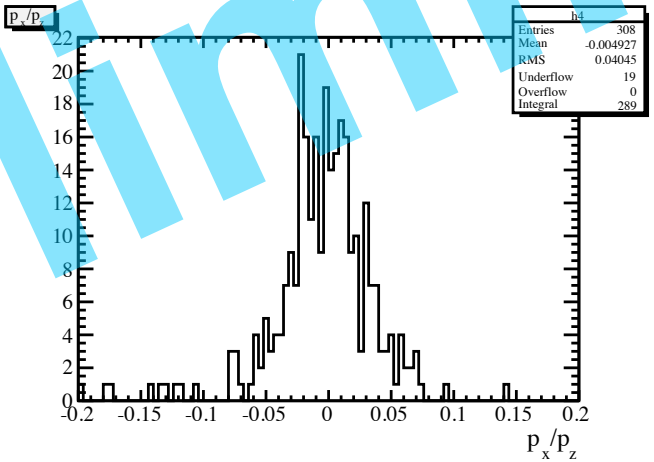
Tracking results

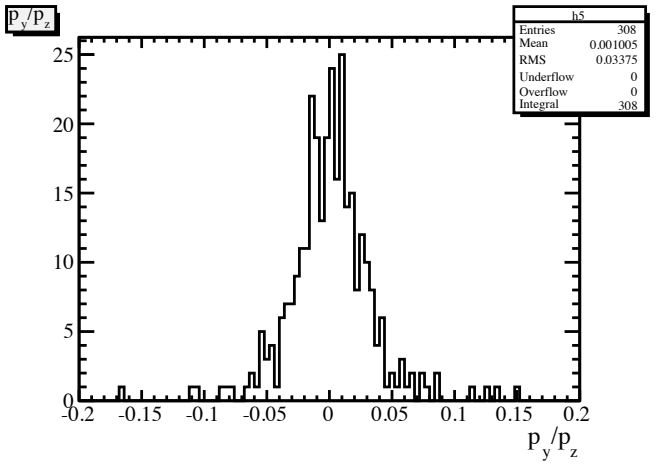






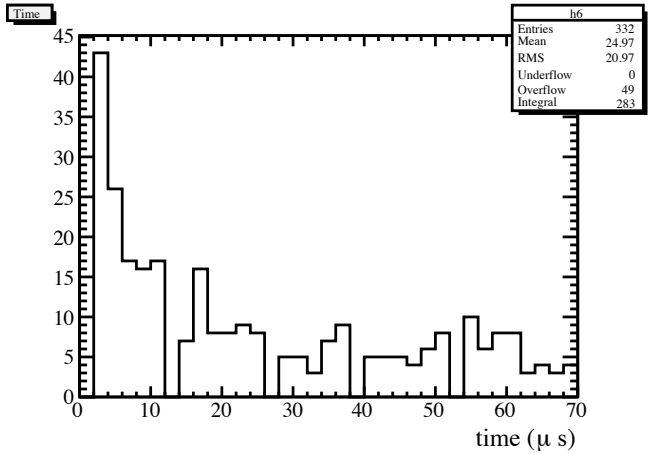


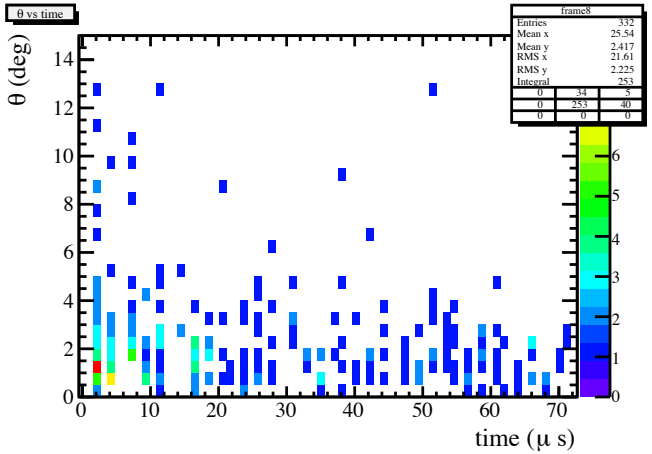


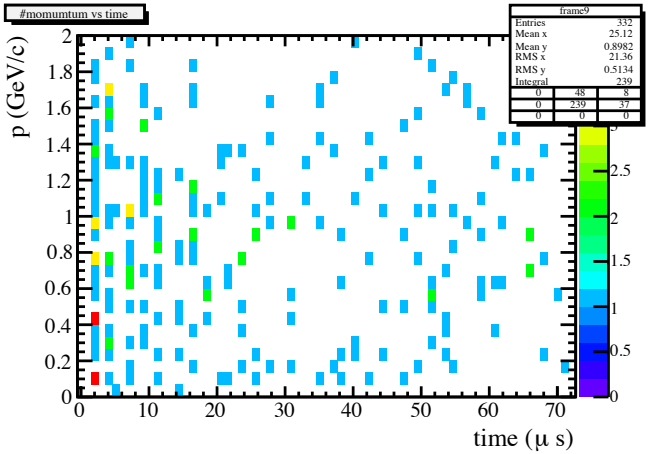


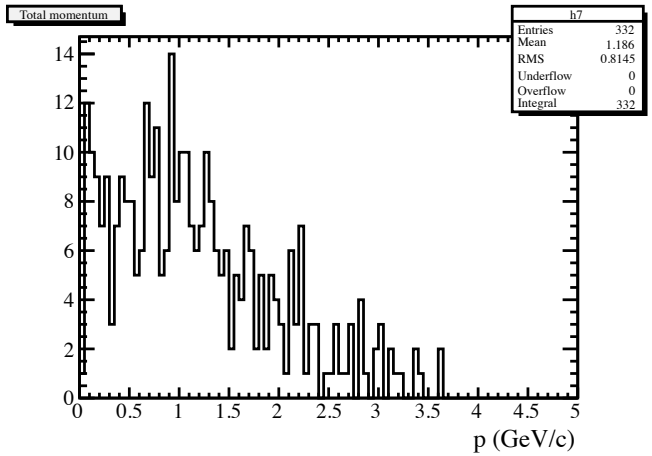
$N_{\nu@monitor}/N_{\pi\text{-injected}}$ = 308/8000 = 0.04

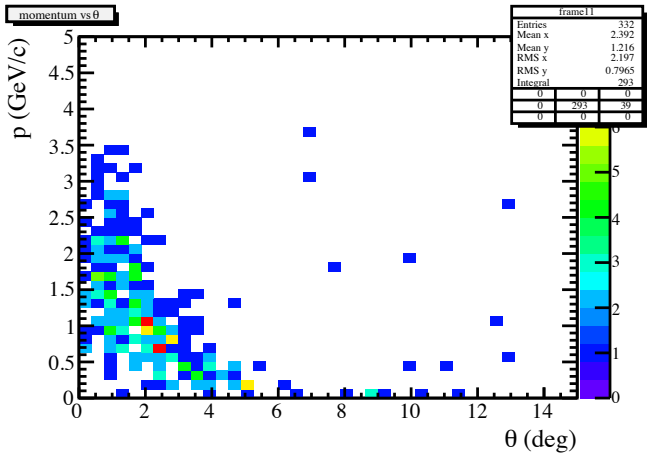
Tracking results











Conclusions

- **Advanced scaling Racetrack-FFAG rings have been designed by JB. Lagrange and Y. Mori as a muon decay ring for the vSTORM.**
  - 2GeV ring: 2GeV±16%, L_S=108m, L_A=50x2m
  - 3.8GeV/c ring: 3.8GeV/c±16%, L_S=240m, L_A=100x2m
- **Tracking by g4beamline for the Racetrack-FFAG rings has been performed. But we found some disagreement b/w JB's results and g4beamline results for the 3.8GeV/c ring.**
  - **detail comparison between JB's tracking and g4beamline is underway.**
- **After understand and correct this disagreement, I will try**
  - **neutrino production**
    - **from muon decay in the ring**
    - **from pion injection**