PSI Research Committee January 28, 2014

MUon proton Scattering Experiment (MUSE) R-12-01.2 Progress Report

Ron Gilman* (Rutgers University)

Physics - investigate proton radius puzzle through μ (and e) scattering

What's happened during the past year?

What's happened in the past year?

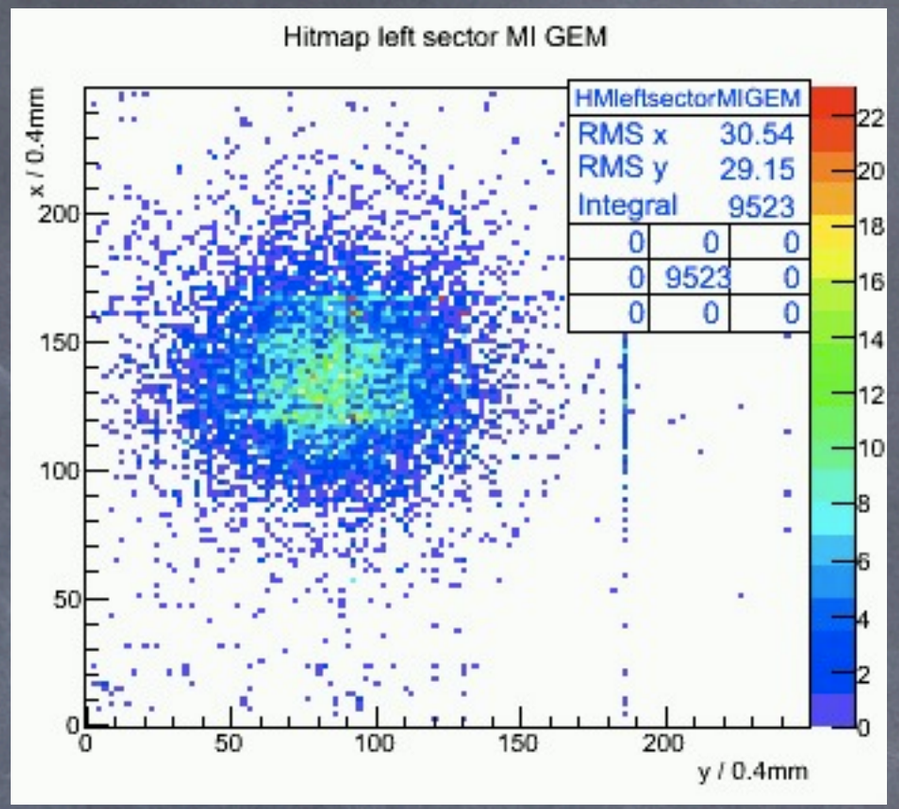
March: after speaking with NSF/DOE about possible funding, generated White Paper posted to http://arxiv.org/abs/1303.2160

April: ordered components to build beam Cerenkov prototype for testing in πM1.

May: packed up GEMs from OLYMPUS, brought to PSI, set up for test in beam (hardware and readout with MIDAS)

June: tests in beam of GEMs. Beam Cerenkov set up with Hamamatsu R9779 PMT and initially tested. Various beam tests. But GEM / PMT data read out on different front ends with event mismatch errors between front ends.

First beam spot from GEMs



What's happened in the past year?

June: ordered Photek PMT240-MCP, as used in Fermilab tests. Better matched to Cerenkov photons than the Hamamatsu - quantum efficiency peaks near 300 nm. 5 month lead time.

June/July: various studies under way related to experiment. Data analysis, truncation error study.

July: ordered new set of sapphire and quartz Cerenkov bars.

August: arranged to borrow TRB3.

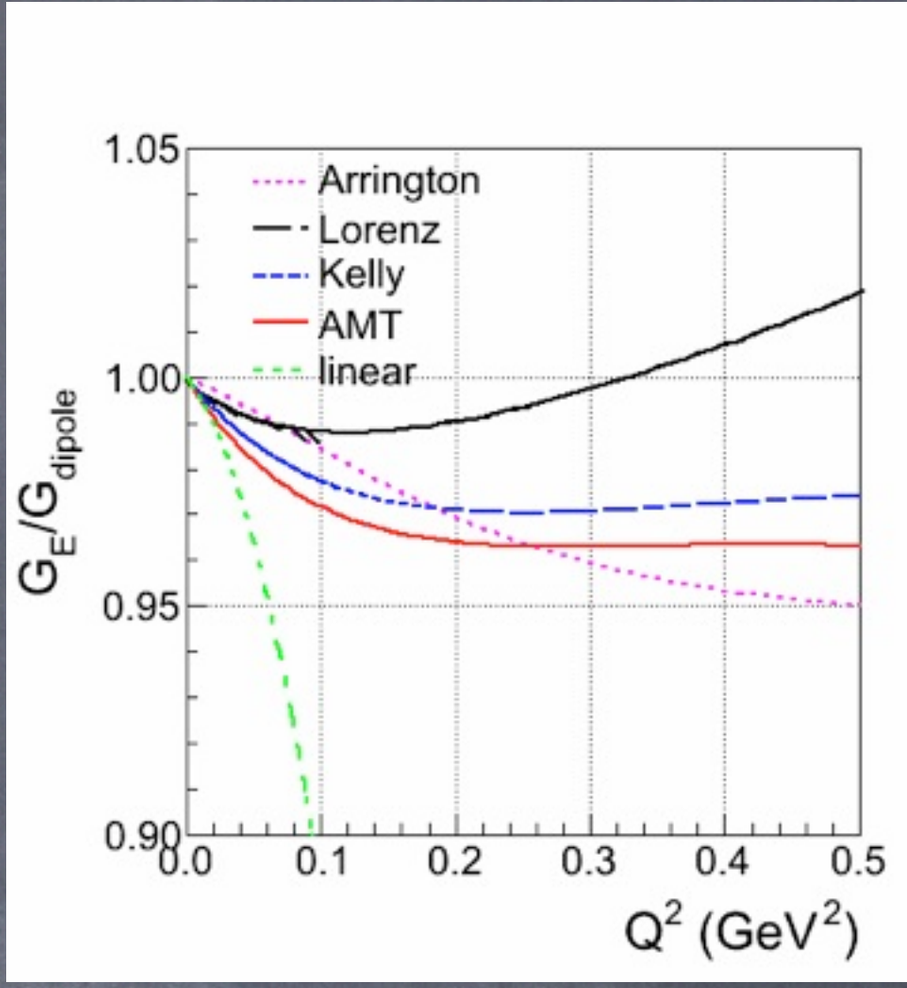
Summer & Fall: Ongoing SciFi prototyping at Tel Aviv.

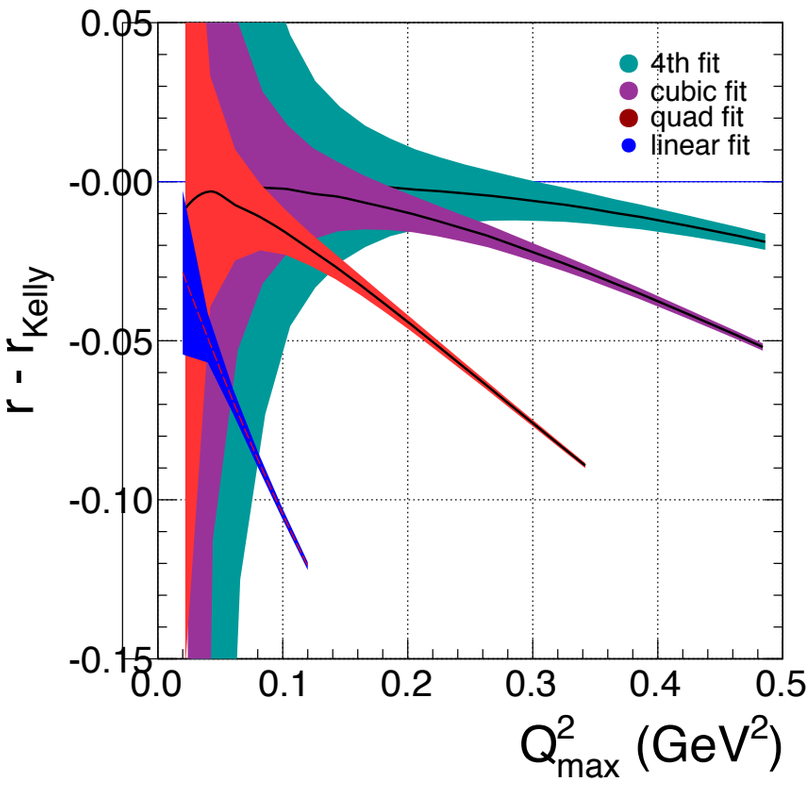
September: learned how to work with TRB3, wrote MIDAS driver

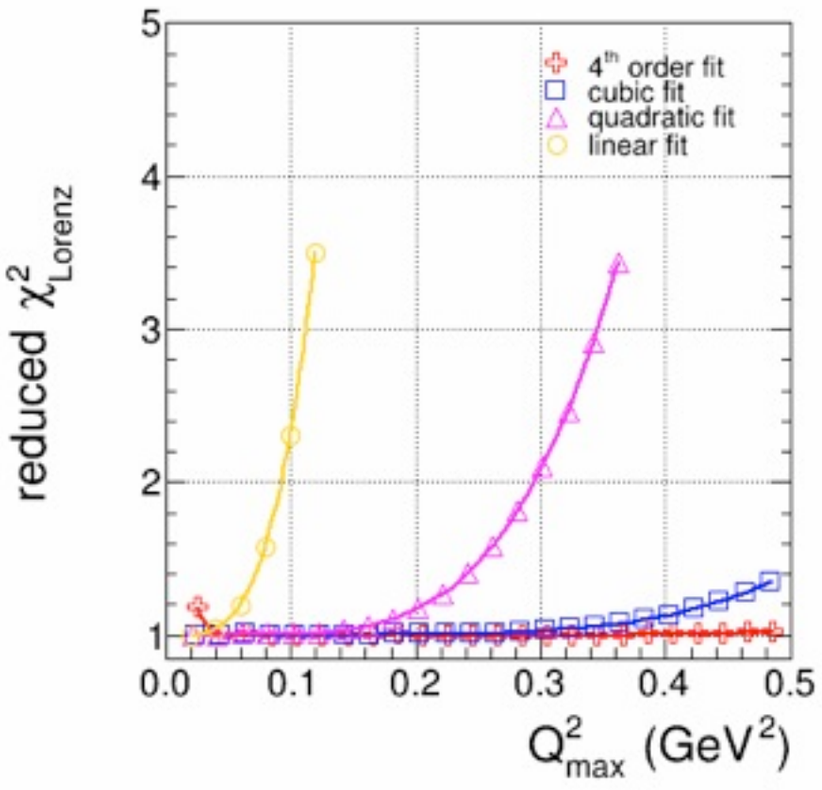
Truncation Errors

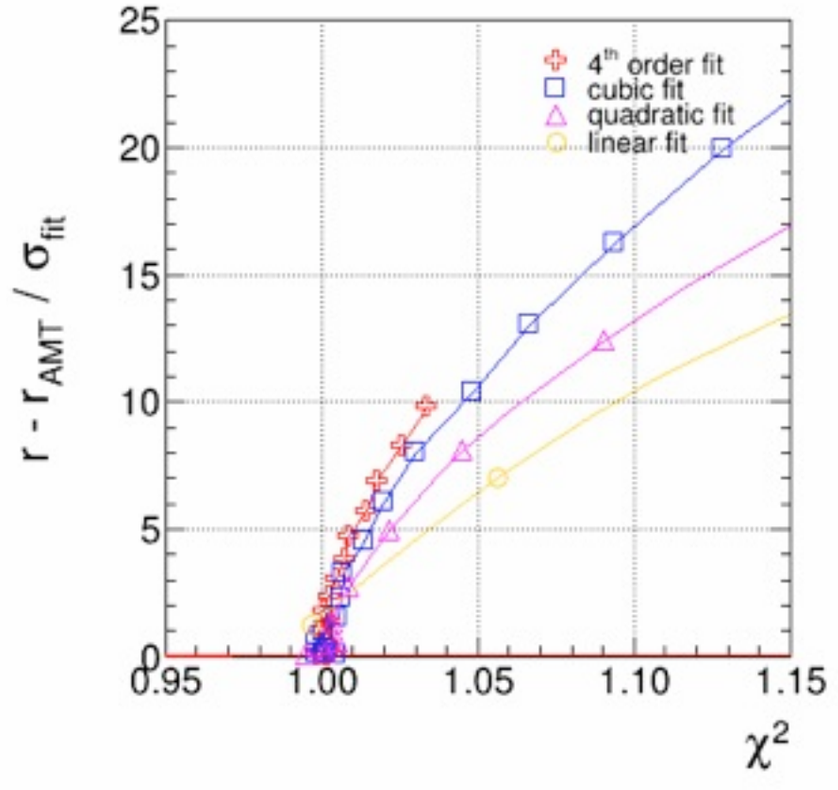
We studied truncation errors in Taylor series expansions by generating pseudodata from 4 world-data fits, and refitting the data, varying the order of the fit and max Q^2. The pseudodata were similar in density and uncertainties to the Mainz Bernauer data.

We found low Q^2 fits are unreliable - and they always underestimate the radius!









What's happened in the past year?

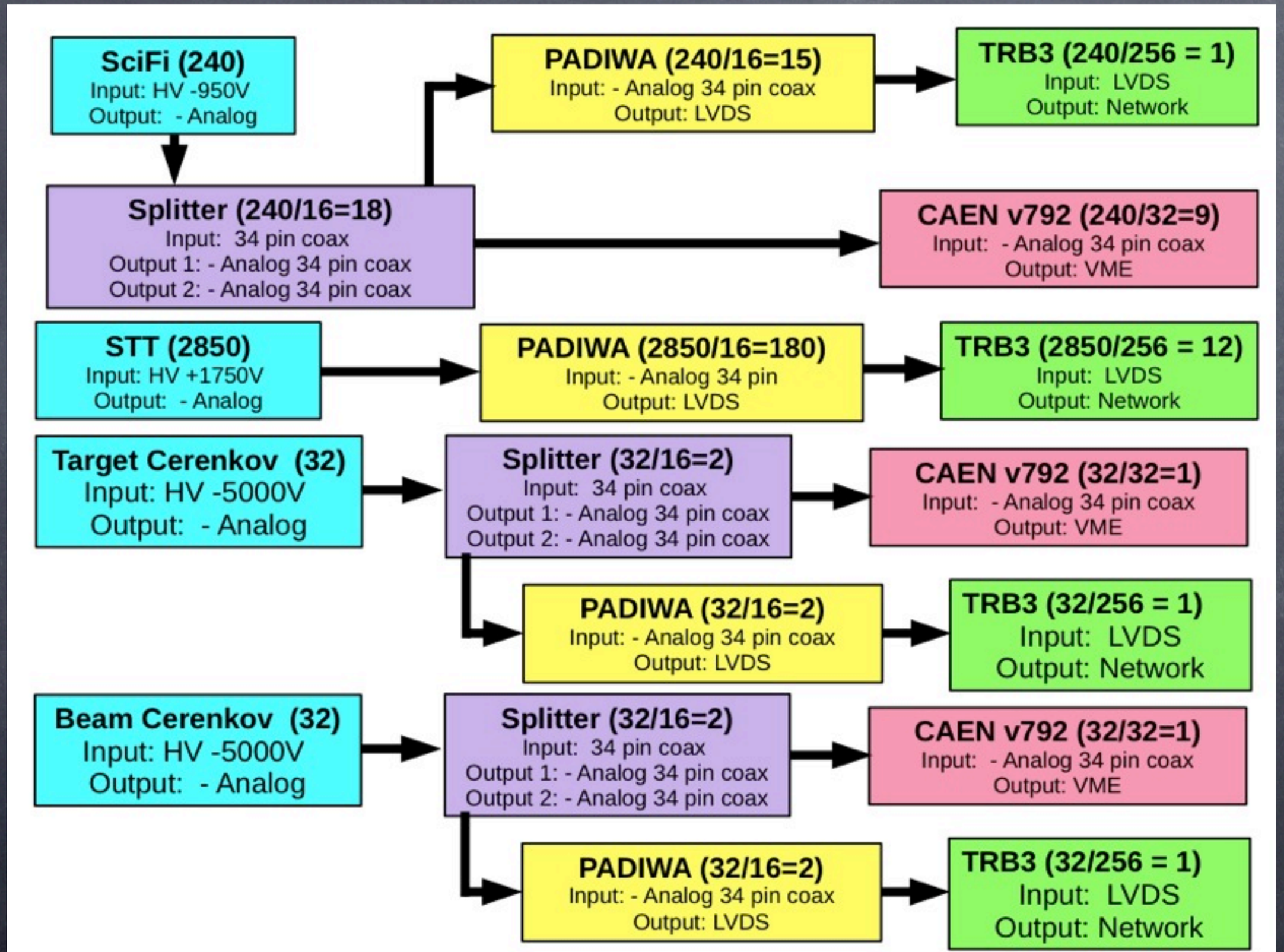
October: tested readout of TRB3 system at πM1. Driver worked and readout successful. Found could trivially obtain 40 ps timing resolution without any attention to detail.

October: gave several presentations at DNP fall meeting in a proton radius puzzle session, shared with PRAD.

October: worked through many details of system and obtained quotes to firm up cost estimate for collaborative funding proposal. Submitted end of October. At NSF's request to know full cost of experiment, proposal included operations funding for out years - now being removed at NSF's request.

October: to formalize collaboration, developed a charter

Part of the Electronics Scheme



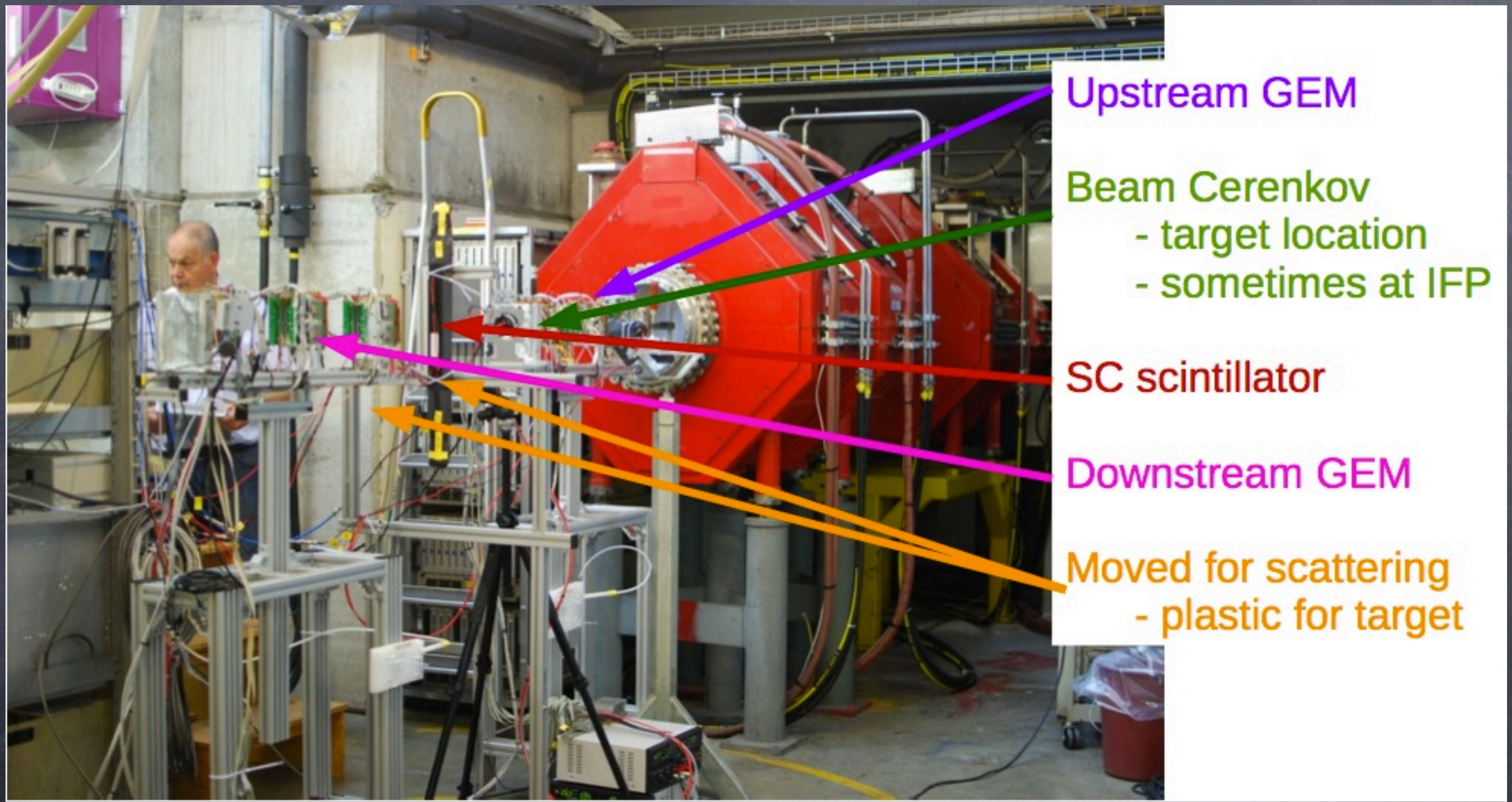
What's happened in the past year?

November: feedback from NSF on proposal - discussions on how and when to proceed with a review, and how to treat risks / contingencies / opportunities.

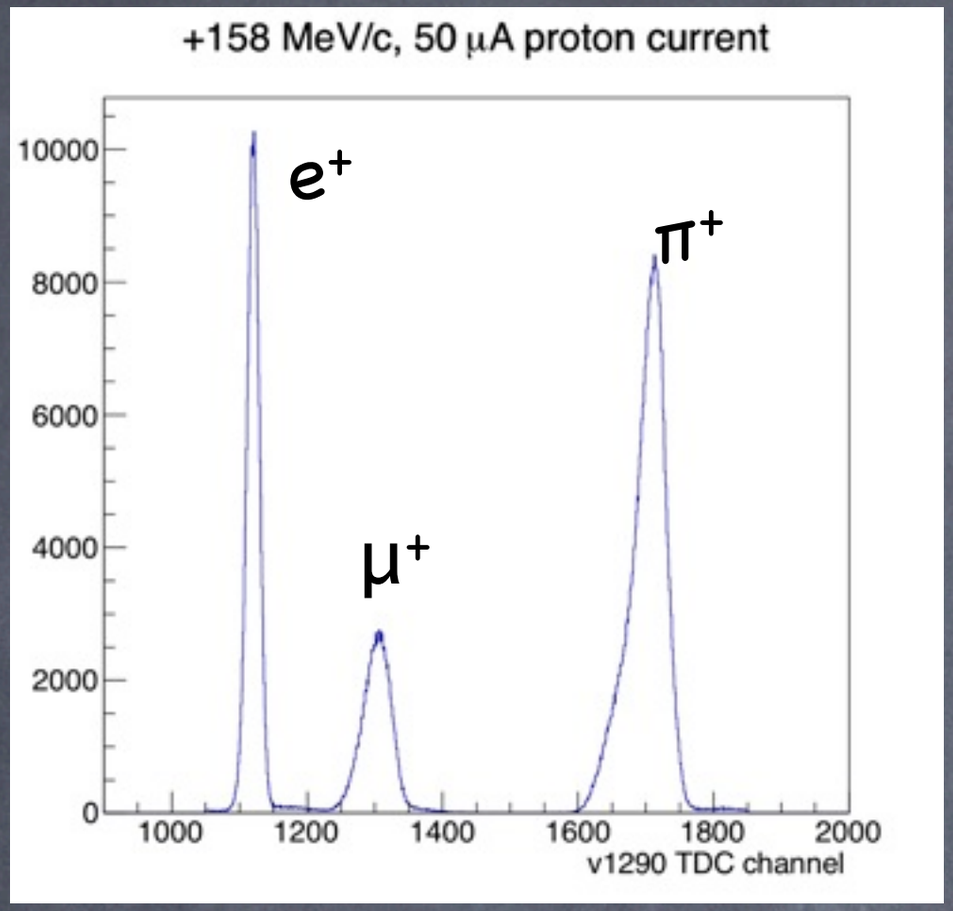
December: test run with improved beam Cerenkov and event alignment bugs in DAQ solved. Studied beam backgrounds and did mini-scattering experiment. Analysis software "upgraded". Photek did not arrive in time.

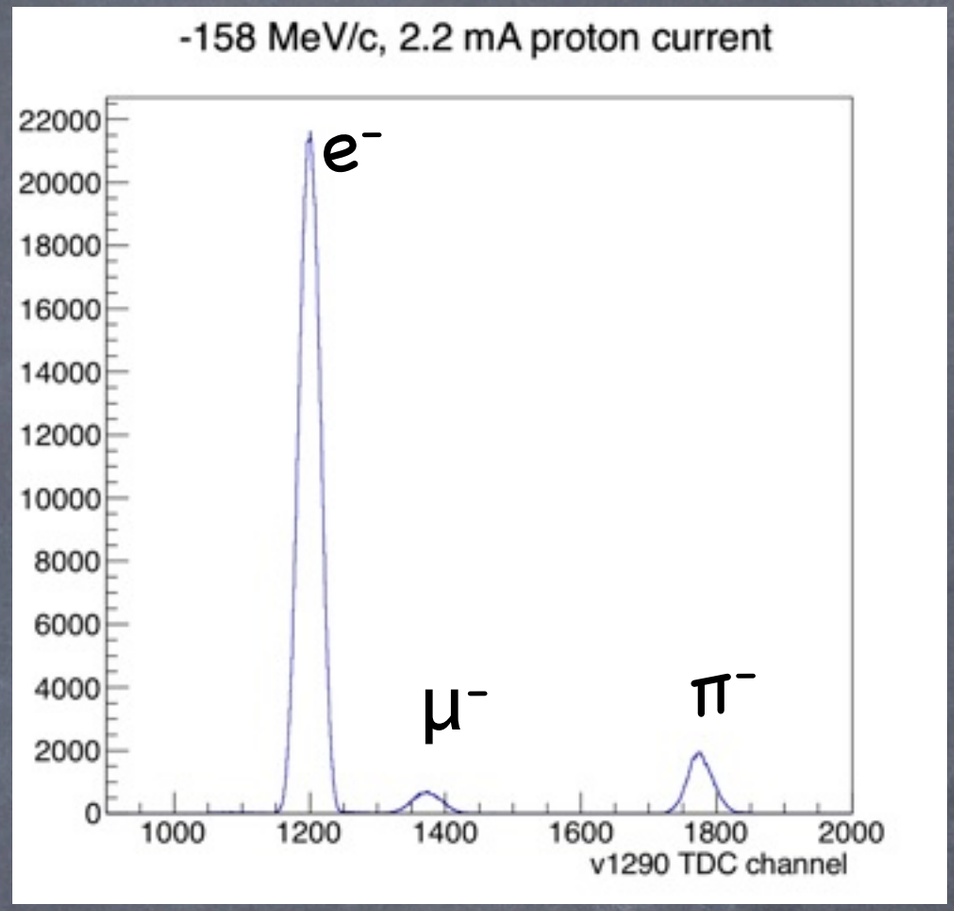
December: started working with Argonne designer on detector table, and on TDR upgrade

Summer 2013 Test Run



πM1 Channel - RF time in target region

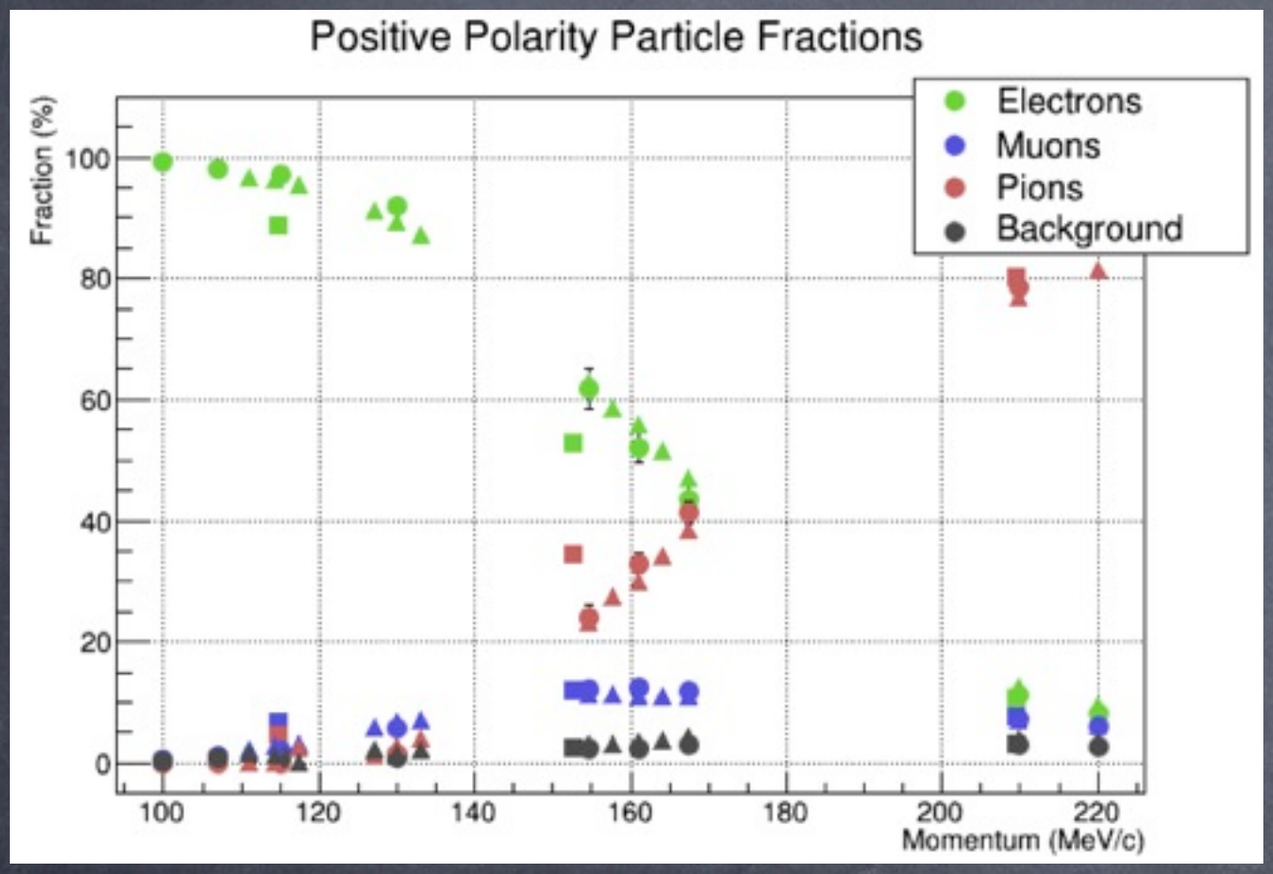


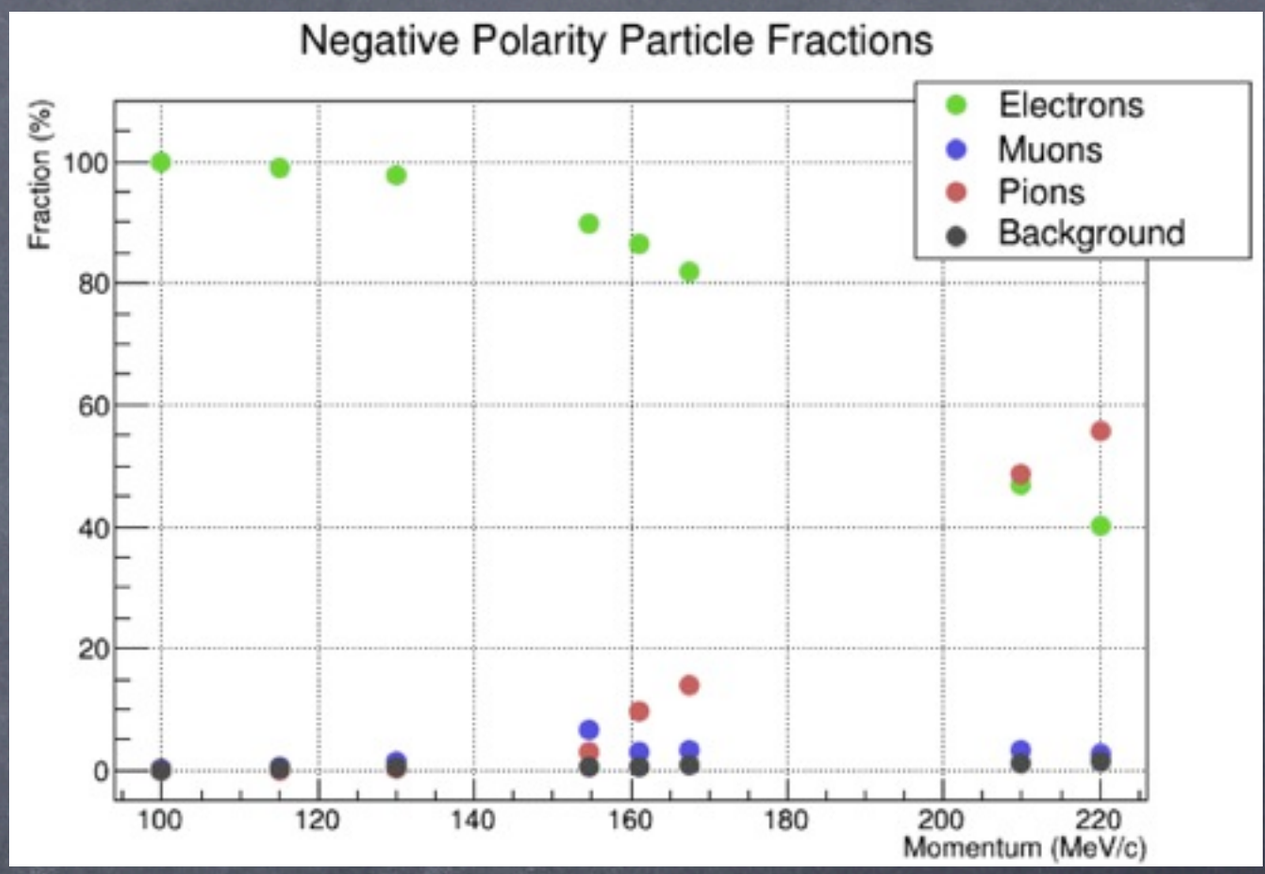


Clean peaks with any backgrounds hard to see.

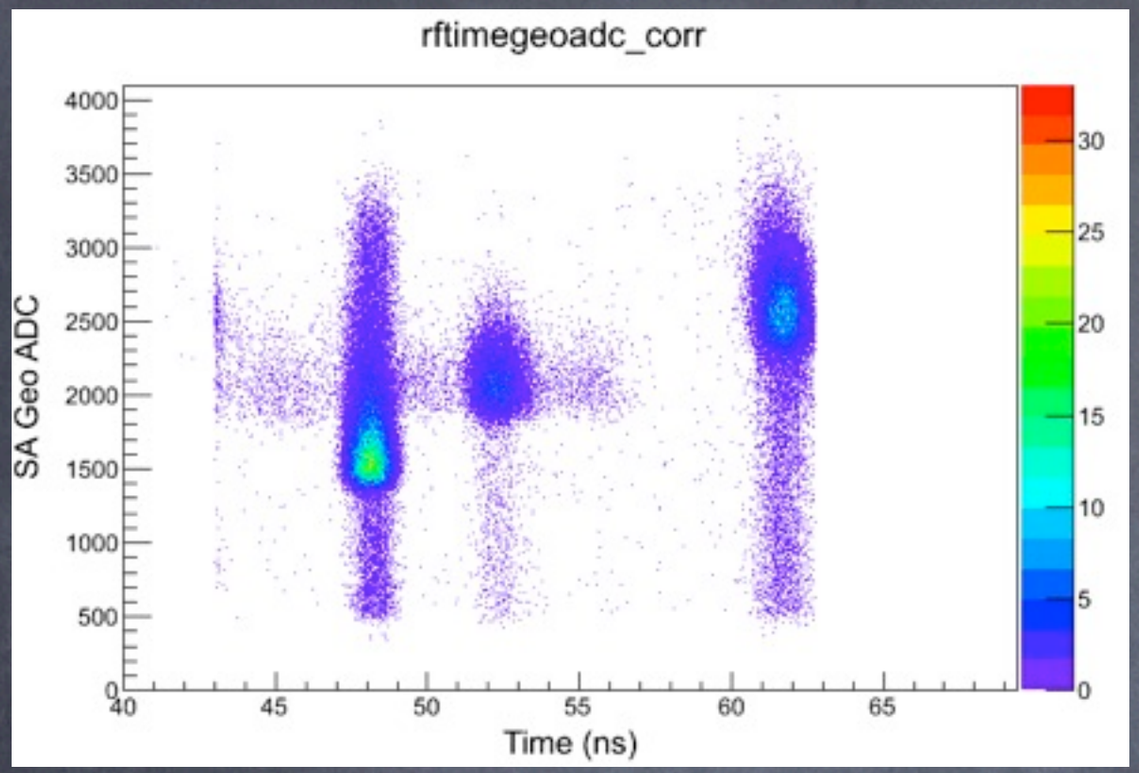
Shape of pion tail from extended scintillator capturing decay muons.

πM1 Channel - Particle Fractions





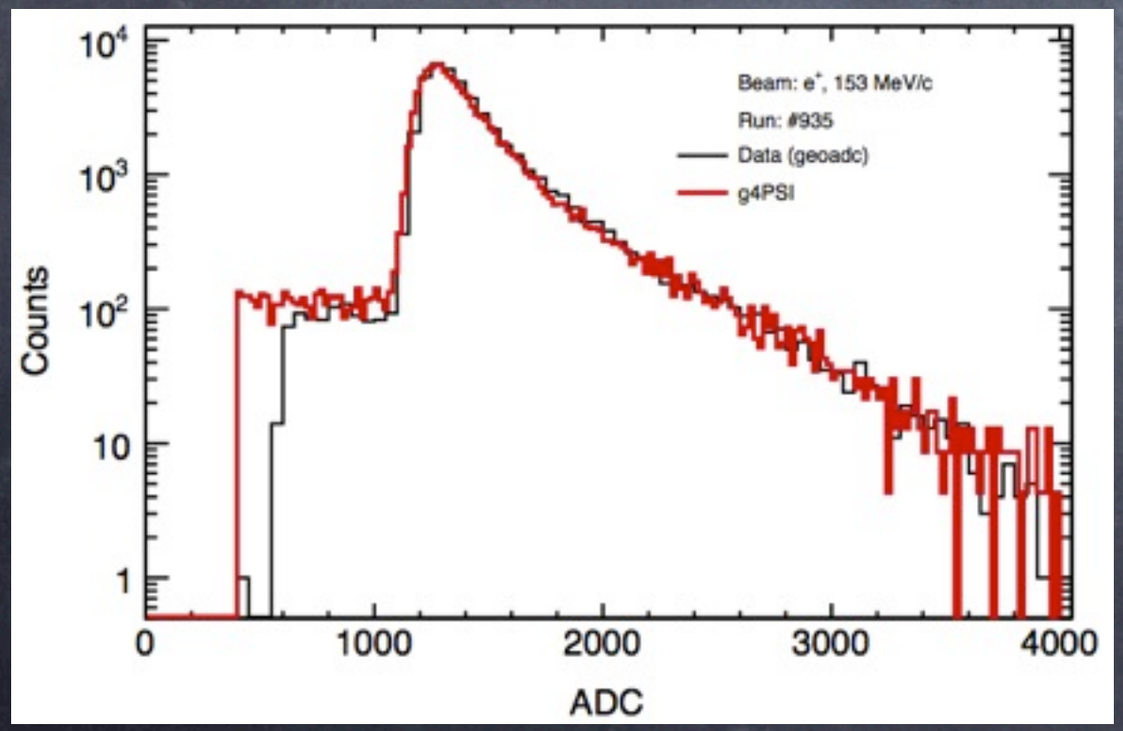
Sample of 2013 Test Run Results

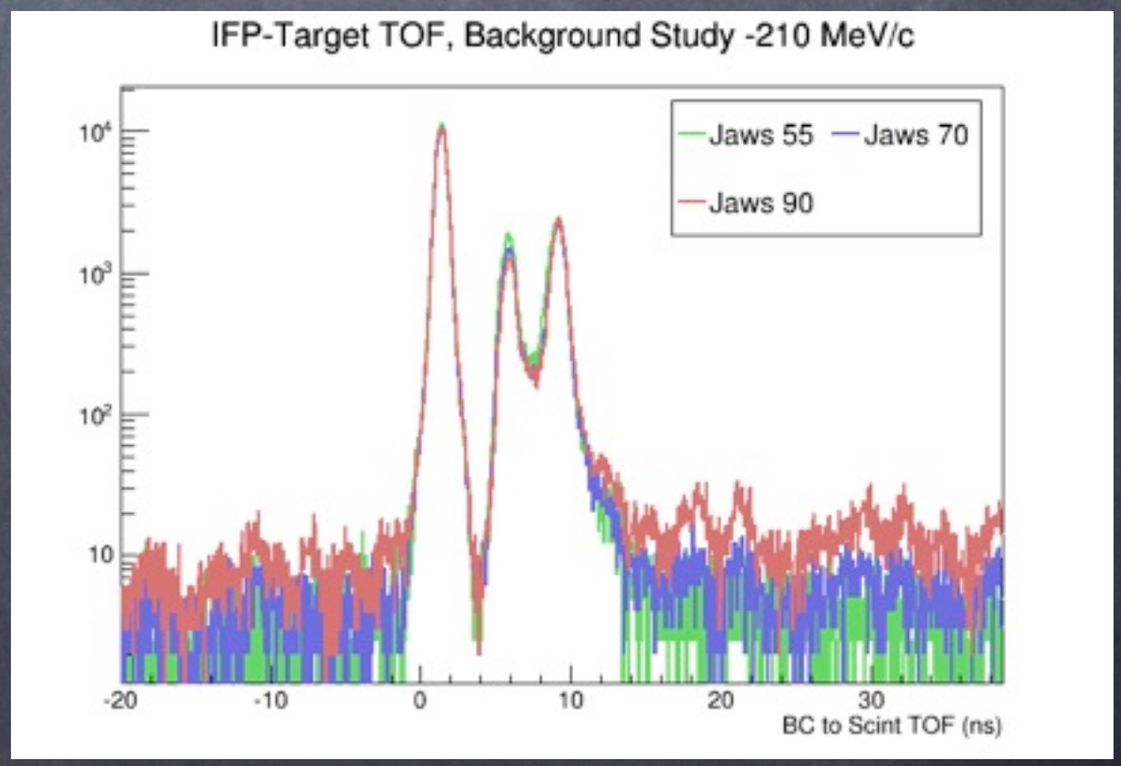


Pulse charge vs RF time shows e, μ, π.

Scintillator pulse charge data vs. simulation.

TOF from IFP to target.

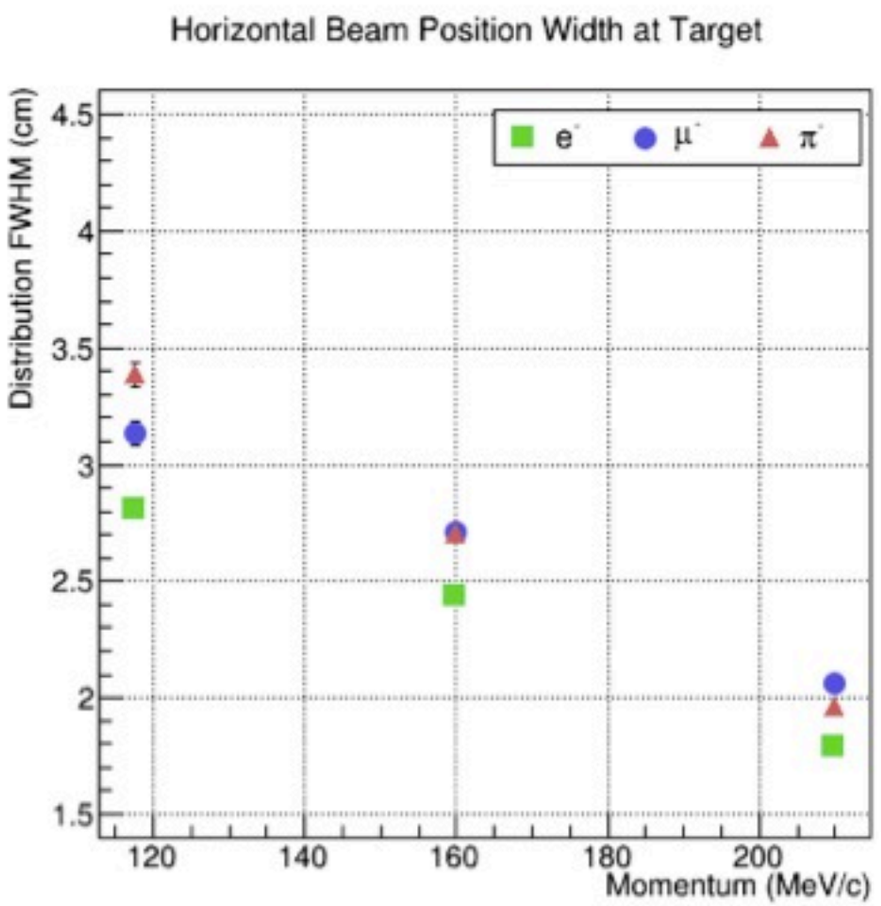


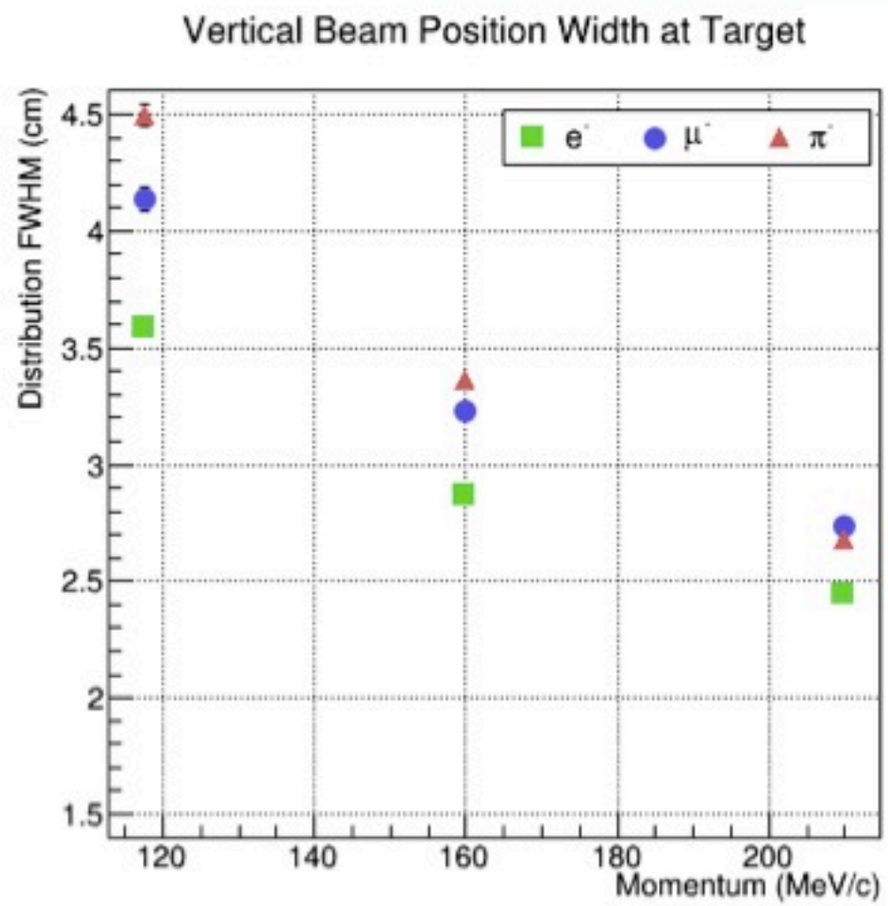


Beam Spot

Beam Position Width projected at Target:

Note: No detector at IFP





At -117.5 MeV/c: 3.5 cm x 4.5 cm FWHM

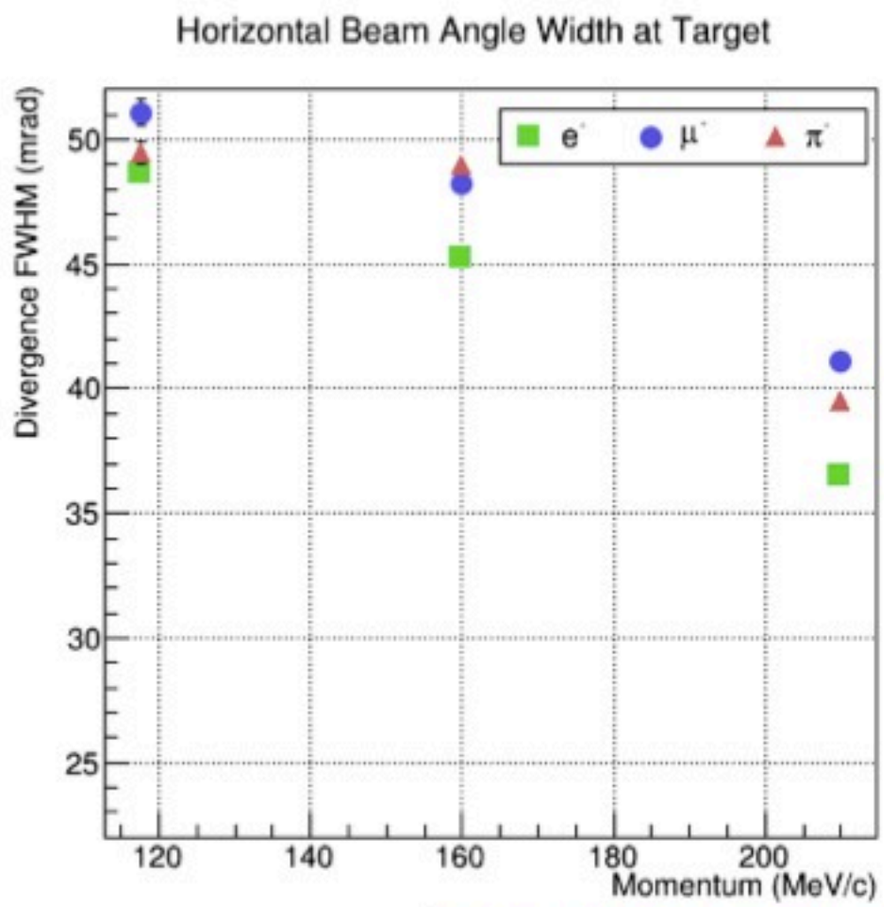
- width larger at lower momentum, wider in vertical
- most spread by PID at lower momentum
- pion's broadest for 117, then muons
- muon's and pion's ~same for 160, 210

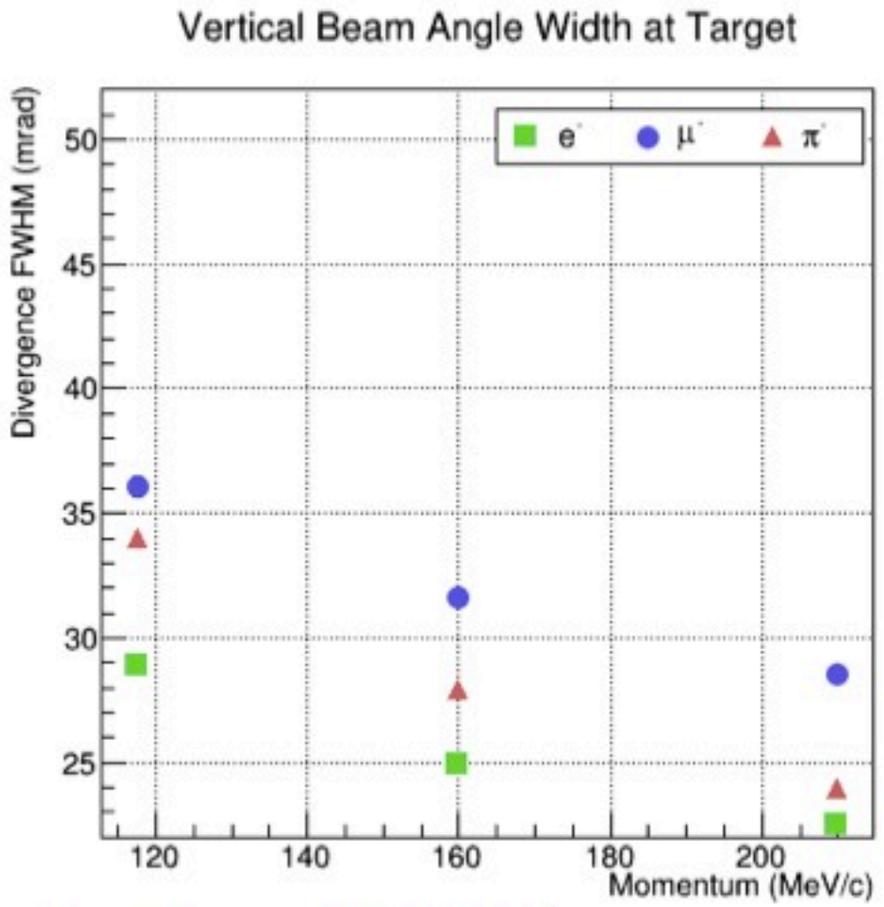
Beam spot is about same size for all particles.

Beam Spot

Beam Divergence:

Note: No detector at IFP





At -117.5 MeV/c: 50 mrad x 35 mrad FWHM

- divergence larger at lower p, larger for horizontal
- more spread with PID for vertical
- muon's largest spread, then pi, then e

Beam spot is about same size for all particles.

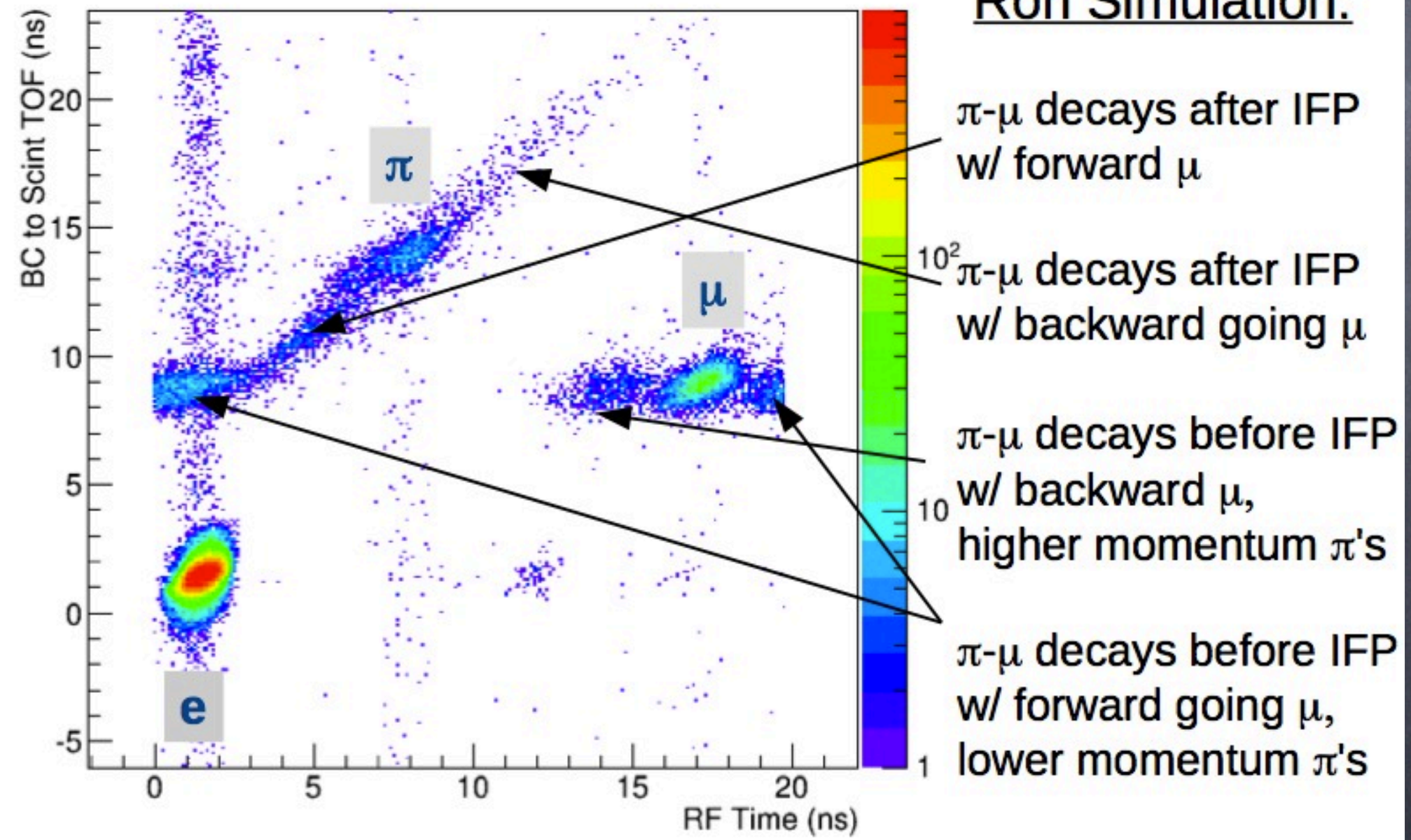
Beam Backgrounds

Katherine Myers analysis

-160 MeV/c

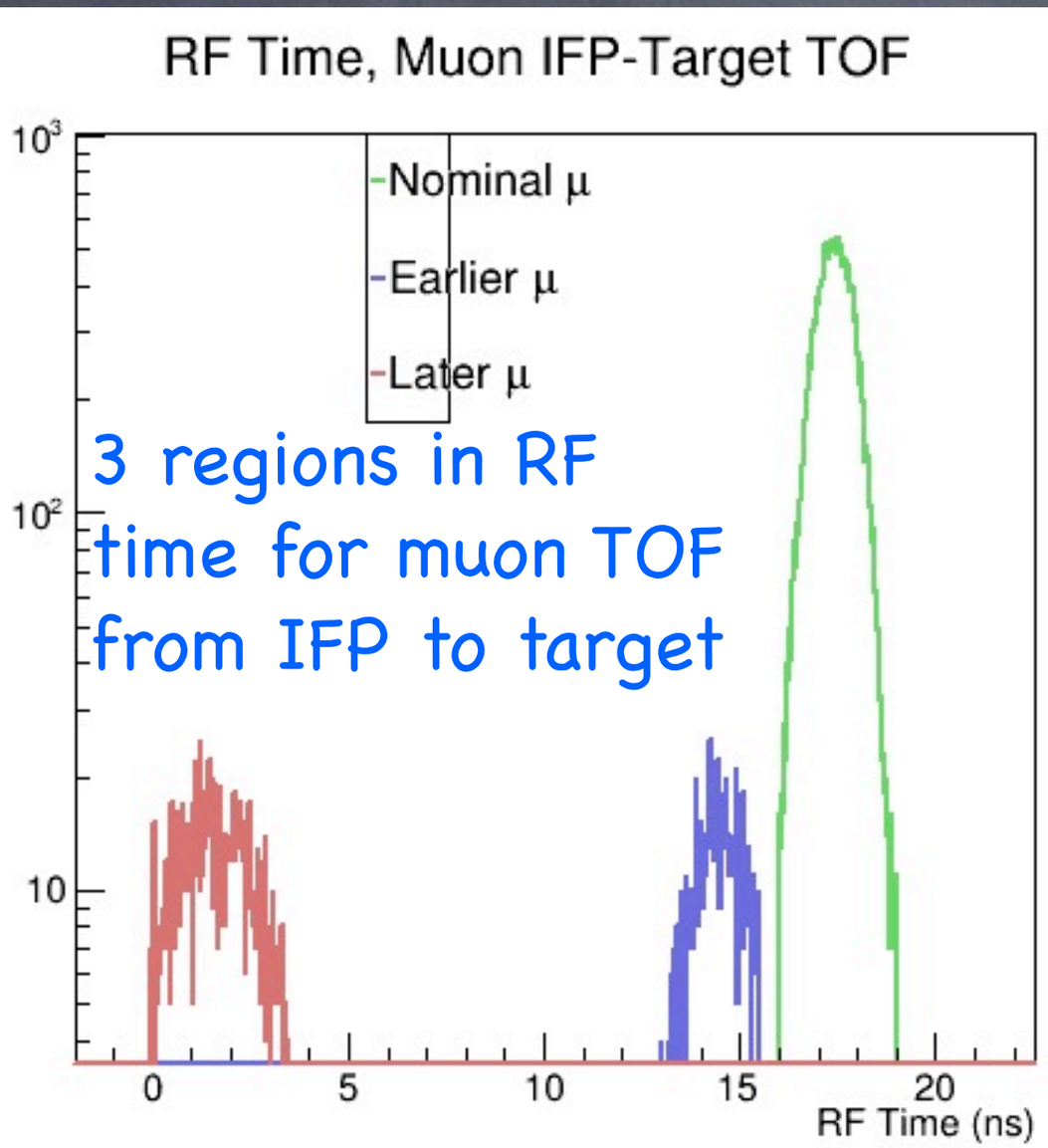
Jaws 55
~ closed

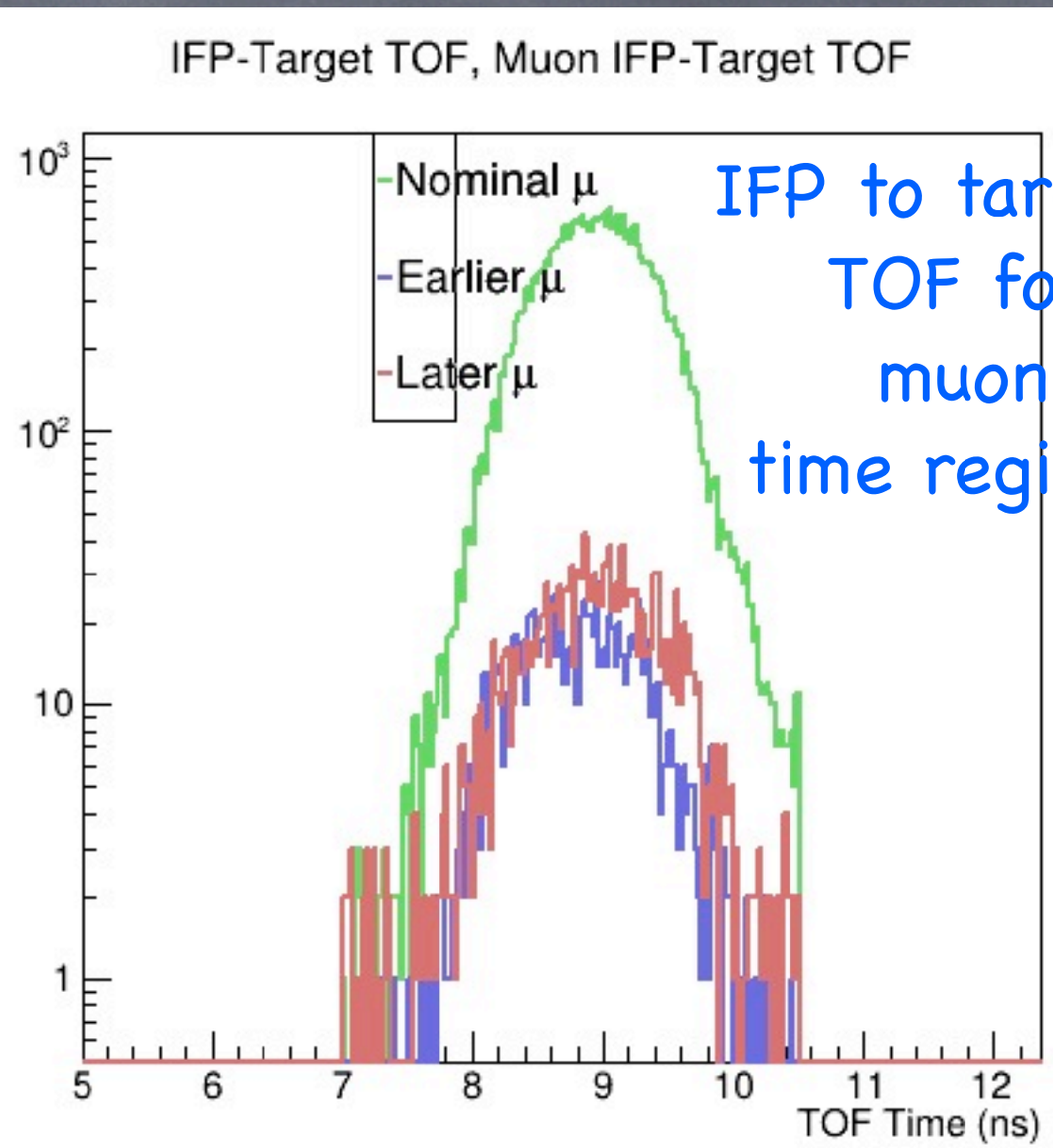
IFP-Targ TOF vs. RF Time



Beam Backgrounds 2

Katherine Myers analysis 161 MeV/c

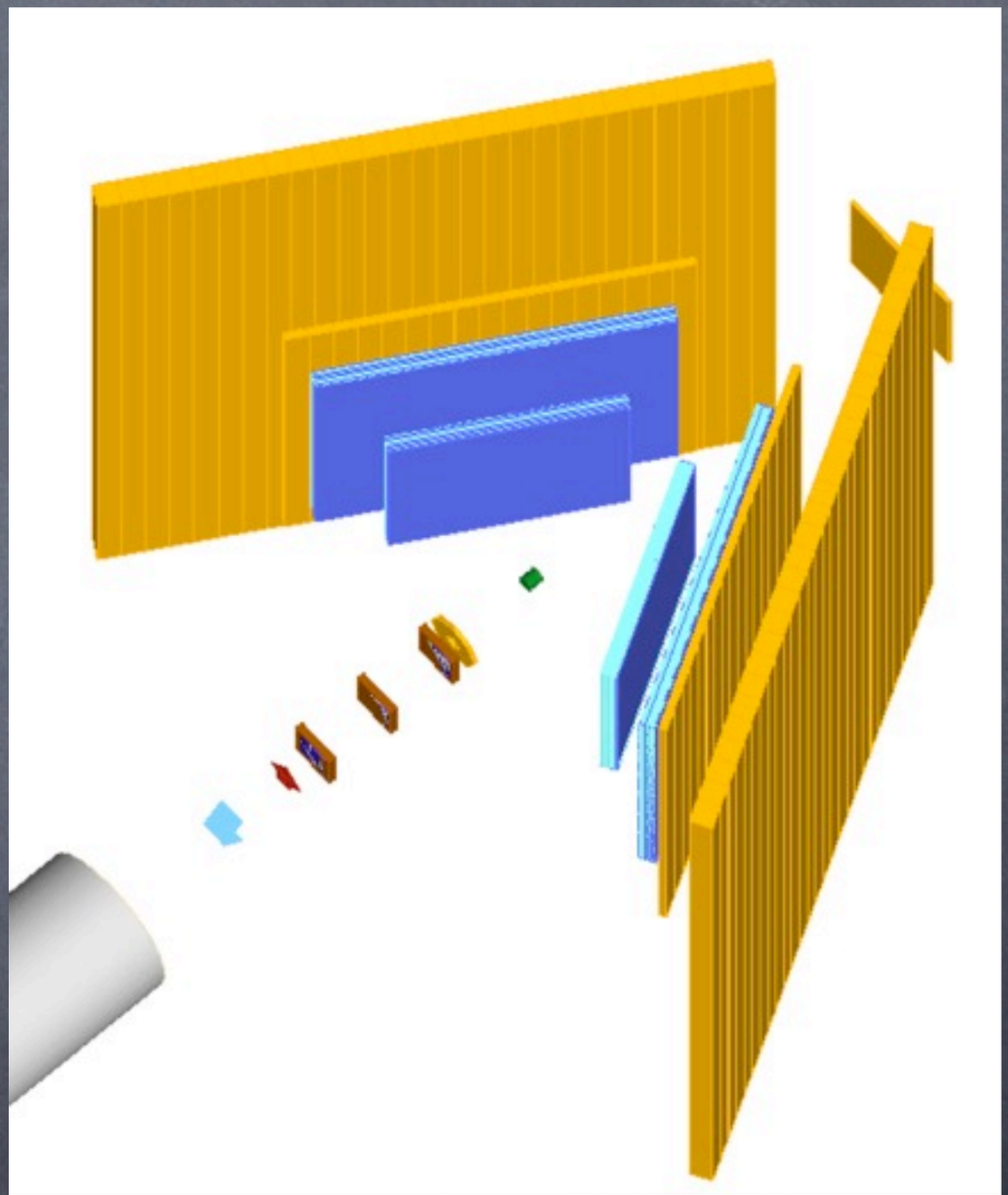




Muon peak width 430 ps, vs 480-490 ps for "tails". Early tail ≈ 140 ps earlier in TOF, corresponding to 1.5 MeV/c in momentum.

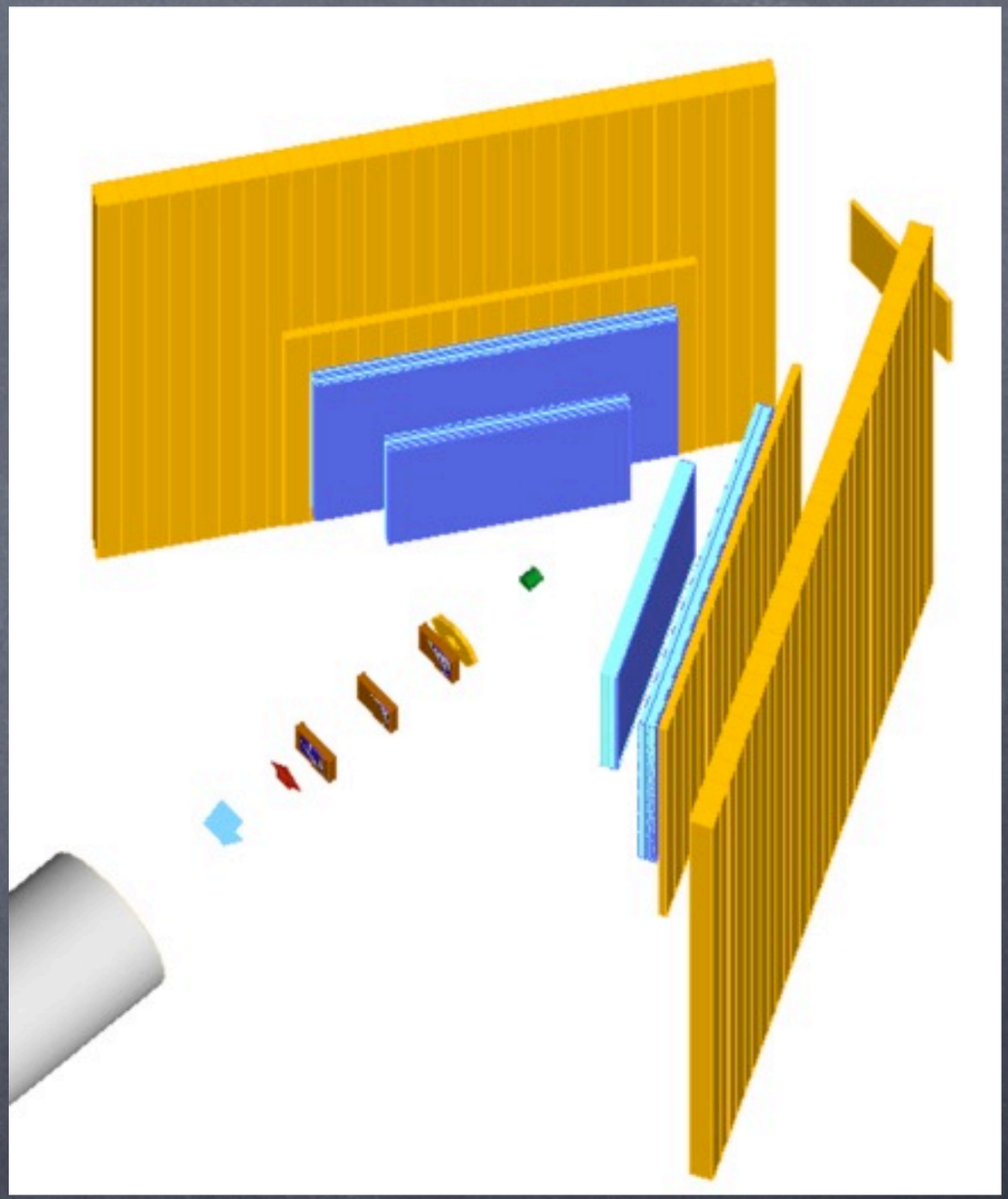
General Plan Unchanged

- PSI πM1 channel
- ≈115, 153, 210 MeV/c mixed beams of $e^{\pm}$, $\mu^{\pm}$ and $\pi^{\pm}$
- $\theta \approx 20^{\circ} - 100^{\circ}$
- $Q^2 \approx 0.002 - 0.07$ GeV^2
- Collimate to 5 MHz total flux, ≈2-15% μ's, 10-98% e's, 0-80% π's
- Beam monitored with ``quartz'' Cerenkov, SciFi, GEMs, beam monitor scintillators
- Scattered particles detected with wire chambers and scintillators



What is Different?

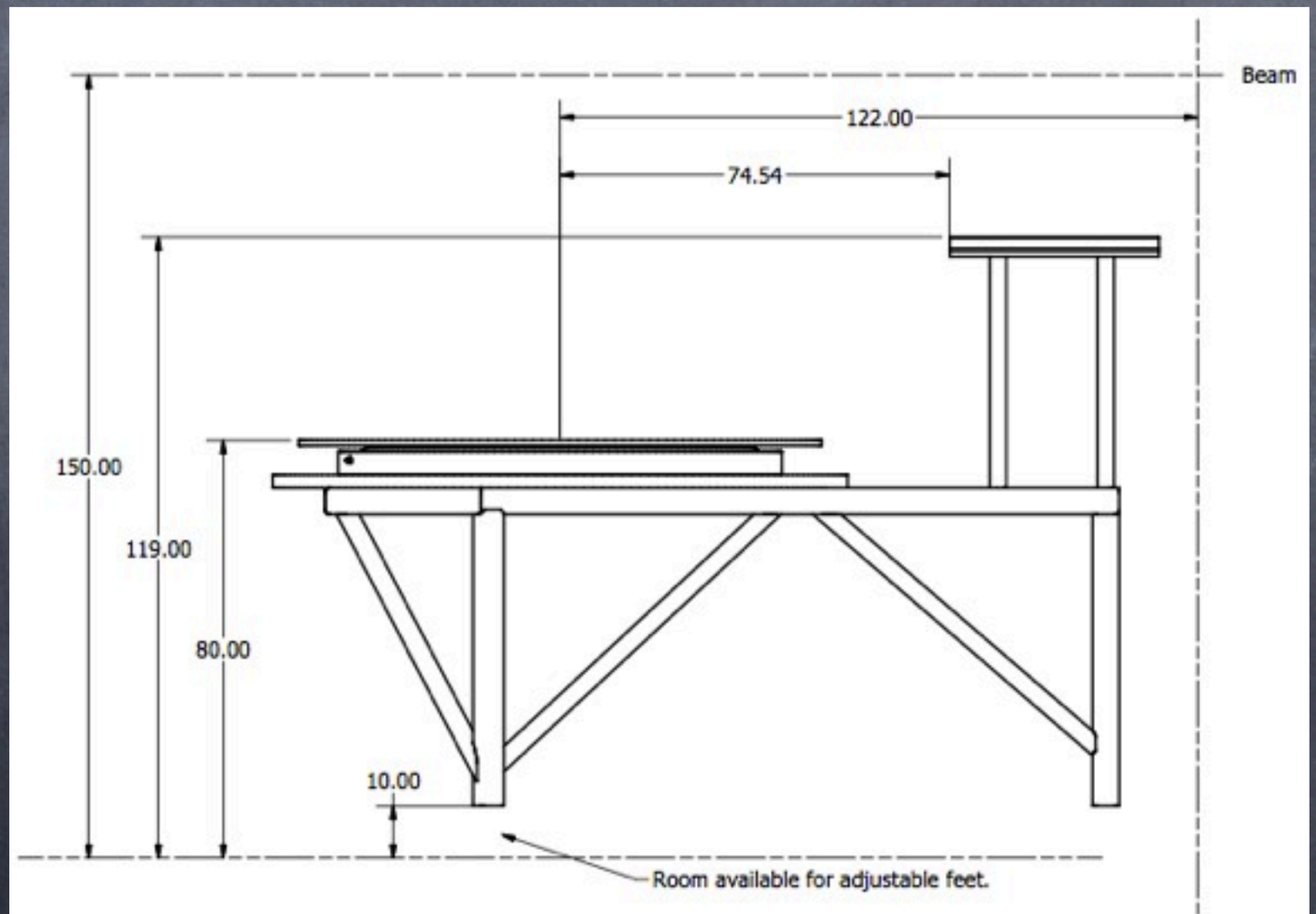
- Collimating at IFP rather than using FS11 jaws.
- IFP detector will be Cerenkov, rather than SciFi.
- Cerenkov material likely sapphire rather than quartz.
- Veto scintillator added after GEMs, no shielding planned.
- Chamber responsibility moved from MIT to Hebrew, now planning on "PANDA" straw chambers.
- Target to be done at GW.
- TDC readout, scalers, and trigger all moved into TRB3 hardware.



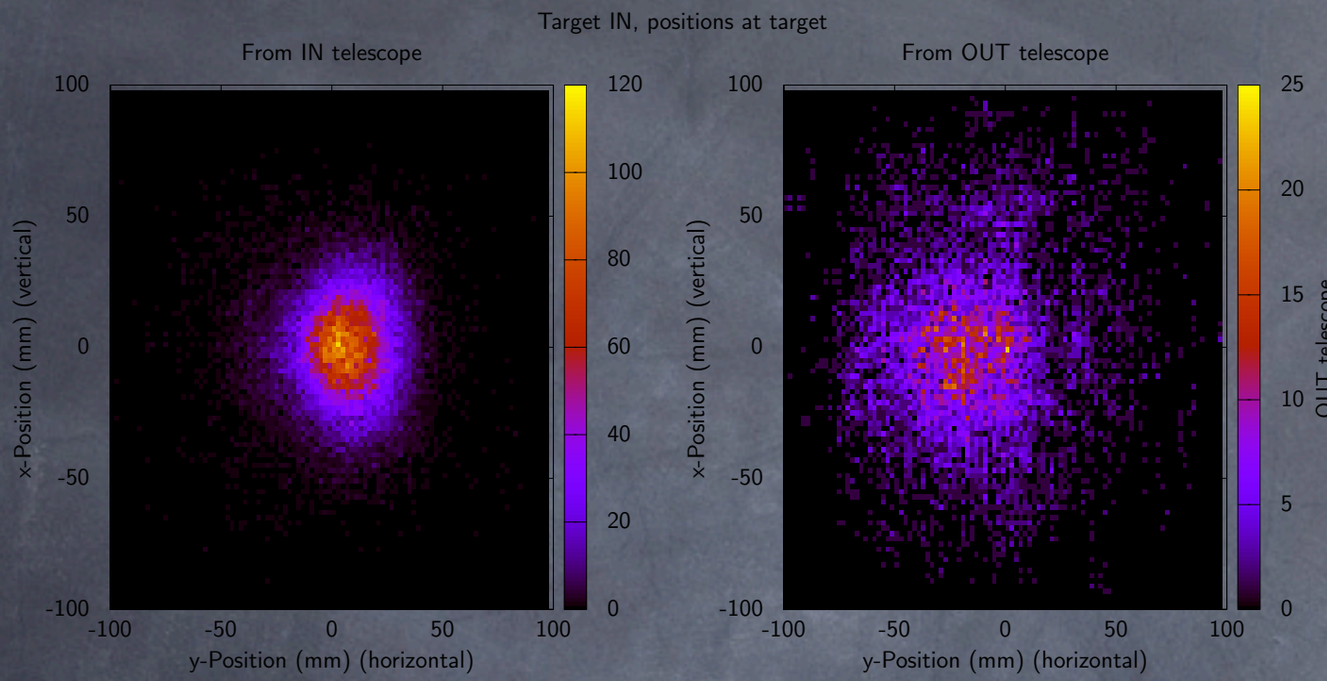
Design Effort

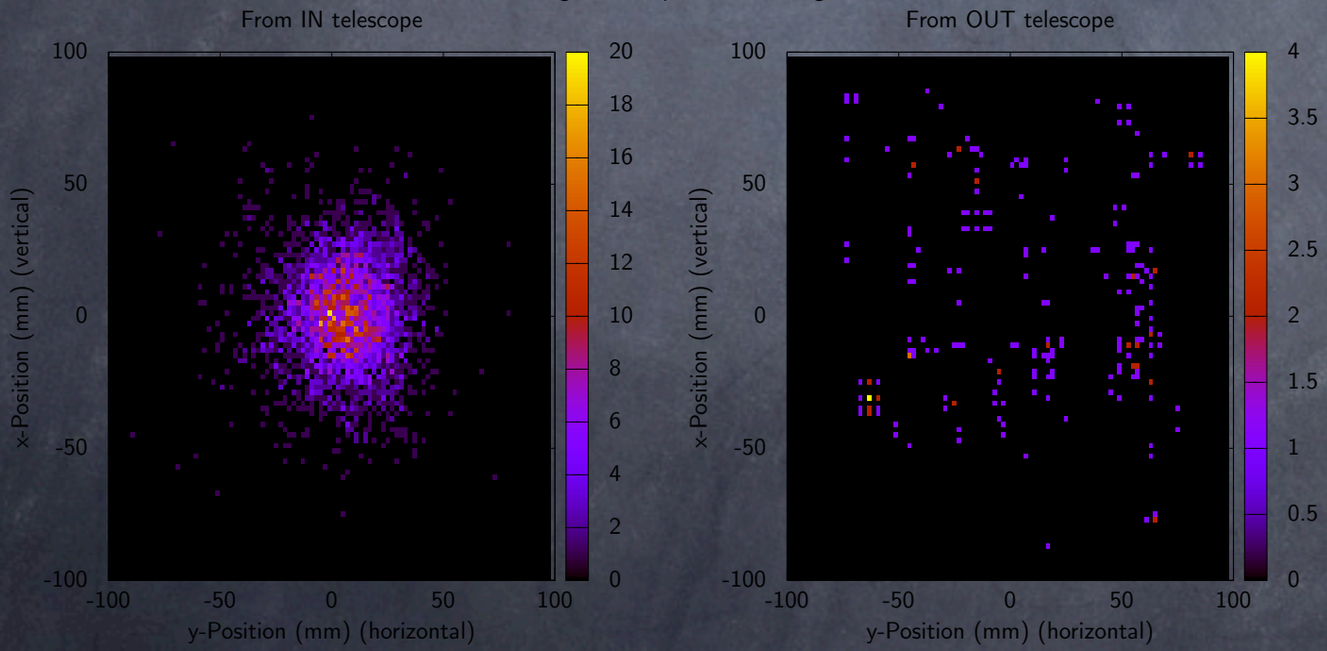
As part of the funding proposal process, we have been doing detailed cost estimates for building detectors, and have started on integration efforts.

We've worried about electronics connections already, and have started to worry about physical placement of components - frames - as these are a relatively large uncertainty in the project.



Fall 2013 Scattering Test





Projections on intersecting transverse planes.

What's happened in the past year?

January: prepared progress report for PSI PAC.

January: held collaboration meeting in DC - when we had earlier expected we might have a funding review. Reviewed current status and designs, analysis of December data, talked with NSF + DOE.

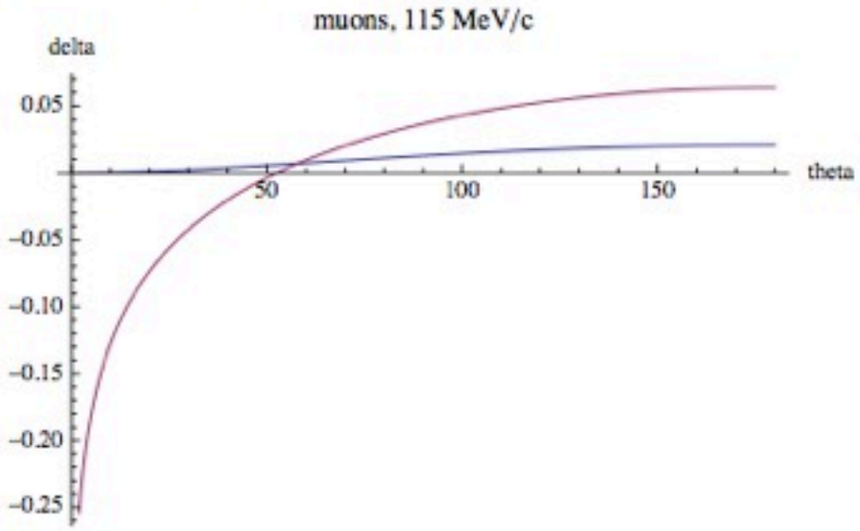
January: Worked on WBS / project management for NSF

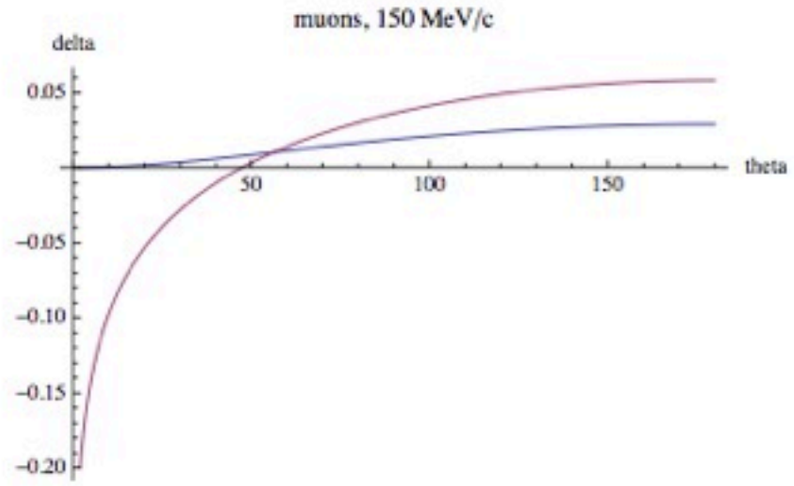
January: worked on TDR upgrade but did not finish

This week: talks, tests in πM1 (Photek, MESYTEC QDC, readout times, TRB3), GEM to Hampton, scintillator to Mainz

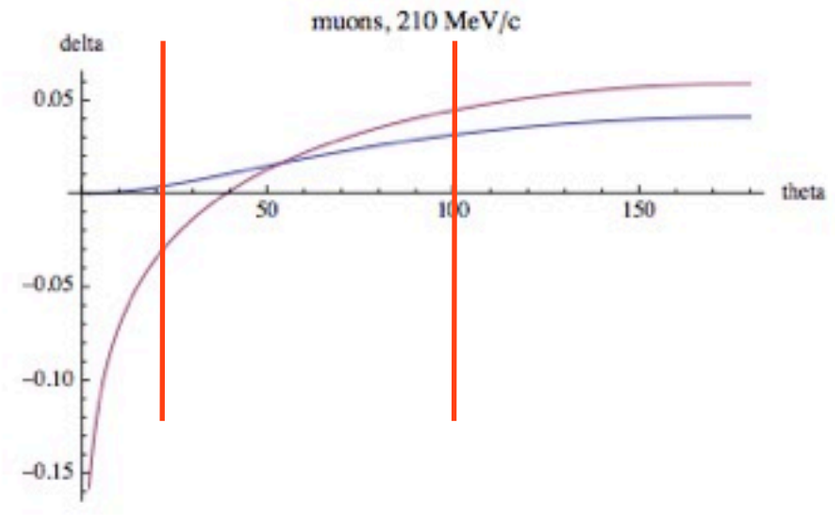
Radiative Corrections - A Afanasev

- Mass effects for muons are essential; ultra-relativistic expressions (purple) no longer valid. Exact calcs (blue). Show brem correction vs lab scattering angle





Muon brem corrections are < 3%.
Uncertainties ≈ 10% of correction.



THE GEORGE WASHINGTON UNIVERSITY
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Andrei Afanasev, MUSE Collab Meeting, Jan 7-8, 2014, GWU

What are we thinking of for the next few months?

February: turn in project management documents to NSF

February: ``finish'' TDR upgrade

February: start G4beamline?

March: funding review, assuming positive result...

July: Start POs for construction

2014 Tests?

Still thinking about 2013 results

Request (tentatively) 7 - 10 days about start of August and 3 weeks in December for

more beam line studies

test Tel Aviv prototype

put Photek Cerenkov in beam

test GEM readout upgrades

...

Thank you