MICE Batch Simulation and Analysis

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MICE CM42, 22 June 2015

Physics Block Analysis

Purpose of Exercise

- Evaluate step IV beam line settings.
- Test the scope of potential physics results.
- Prepare analysis in advance of data collection.
- Ensure that machinery for batch simulation exists.

Course of exercise

1. Define settings for simulations.
2. Ensure machinery for simulation is prepared.
   - MAUS
   - CDB
3. Run simulations locally — Ensure settings and software are valid.
4. Run simulations on the grid — Ensure production simulation works.
5. Produce "publication ready" plots from simulation.

Progress with Infrastructure

GRID Readiness (My Opinion)

- Simulation has been tested on the GRID from end to end
  - Have run a number of MAUS test jobs on the grid
  - Included an analysis equivalent to a full data run (but with correlated spills).
- Archival support has not been tested

G4beamline Generation

3π 140 MeV/c	6π 140 MeV/c	10π 140 MeV/c
3π 200 MeV/c	6π 200 MeV/c	10π 200 MeV/c
3π 240 MeV/c	6π 240 MeV/c	10π 240 MeV/c

- Optimization limited to downstream beam-line.
- Have begun simulations of a "beamline library"
  - Motivated by alignment runs and material studies.

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Batch Processing

Circulated Simulation

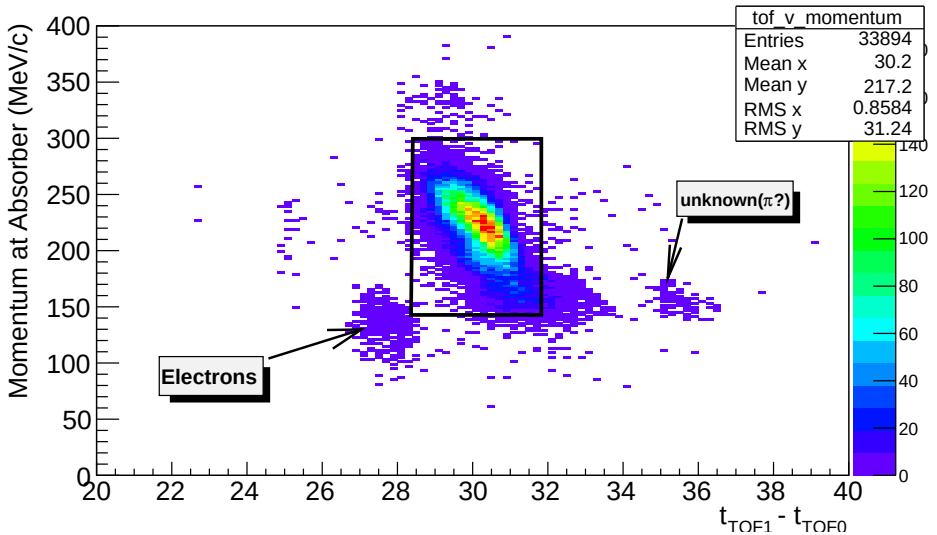
- Have generated and circulated an end to end simulation.
- Lacking an "official" location it was stored on personal webspace
  - has since been removed due to space considerations.
- Used G4beamline simulation with interface 1 m upstream of D2.
- Simulation/reconstruction with v0.9.2

Simulations Generated Since

- All simulations redone with MAUSv0.9.5.
- Improved beam matching to channel.
- Channel fields turned off for MCS studies.

Particle Selection

- Applied a simple trigger selection
  - Choose events that produce a single hit in TOF2
- Attempt a simple selection
  - Time of Flight:
    26 ns$< t_{TOF1} - t_{TOF0} <$42 ns.
  - There must be a single track upstream and downstream
  - Momentum:
    $140 < p_{tot} < 300$ MeV/c
  - Considered a 5σ beam selection



1.4×10^7 particles prior to D2

	TOF1	TOF2	Selected
Field Off	44673	2096	130
Field On	40539	34274	26676
Match 1	49044	30427	22183

Emittance measurements

- Prediction for data obtained from the tracker reconstruction.
- No MC information used (including "corrections").

Match0 6π200 MeV/c Flip

	US	DS
$< x >$[mm]	22.0±0.2	20.3±0.3
$< y >$[mm]	13.8±0.2	6.9±0.2
$< p_x >$[MeV/c]	-14.7±0.2	-5.5±0.2
$< p_y >$[MeV/c]	7.2±0.2	-17.9±0.2
$< p_z >$[MeV/c]	223.1±0.2	208.6±0.2
ϵ_{4D}[mm]	5.23±0.03	6.54±0.04
$\beta(x, y)$[mm]	572±4	440±3
$\alpha(x, y)$	-0.625±0.004	-0.783±0.004

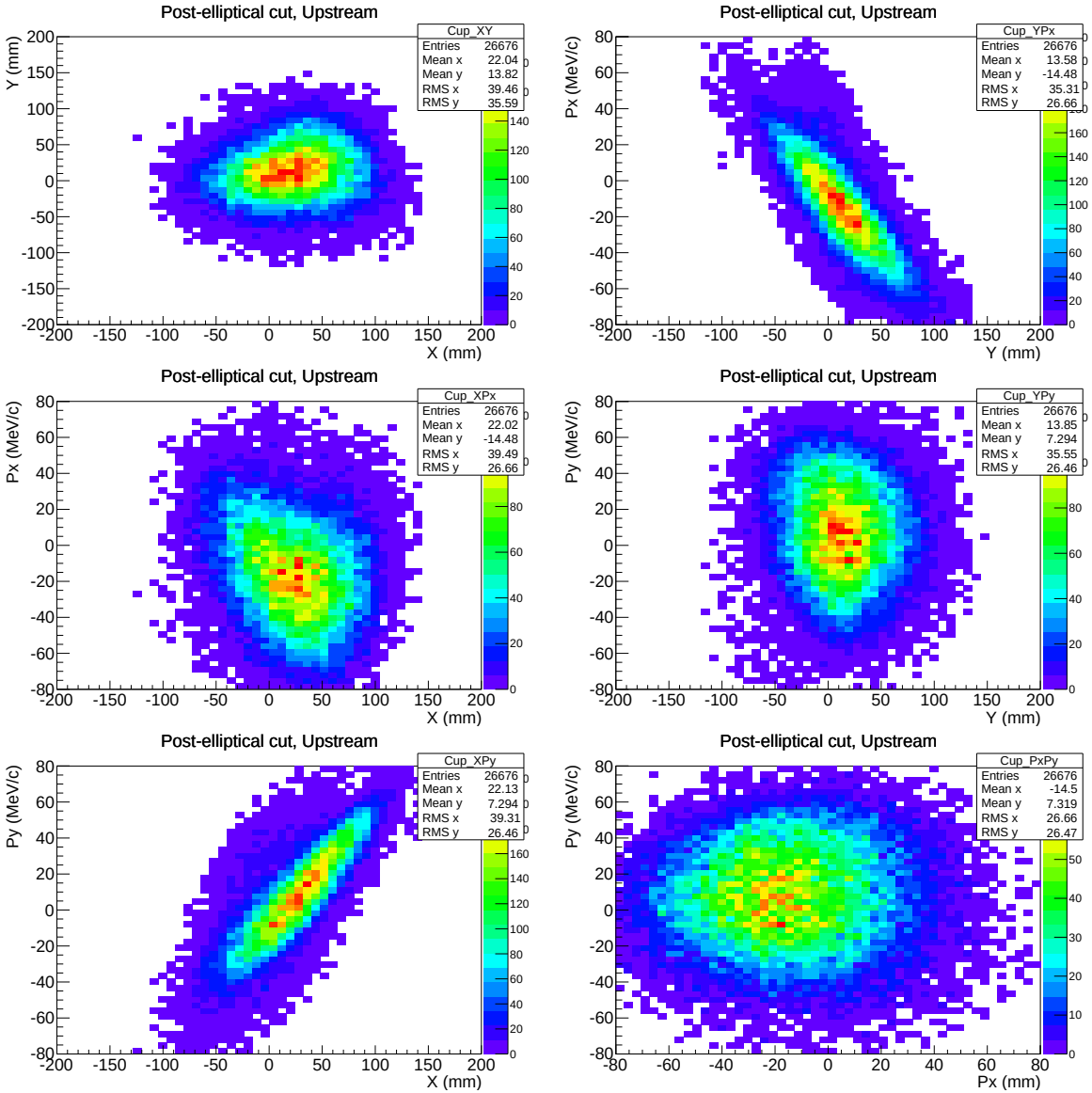
Upstream Covariance Matrix

	x	p_x	y	p_y
x	1557	-271	145	840
p_x		724	-788	4
y			1266	-73
p_y				711

Downstream Covariance Matrix

	x	p_x	y	p_y
x	1671	-191	203	-995
p_x		826	680	43
y			1233	-350
p_y				931

Beam Phase Space at Trackers



- Particles after tracker matching and "PID" selection shown.
- Particle must create a (single) trigger in TOF2.
- Correlation in momentum and position off-axis elements flip with field.
- Explicit demonstration of quad-to-solenoid mis-match.

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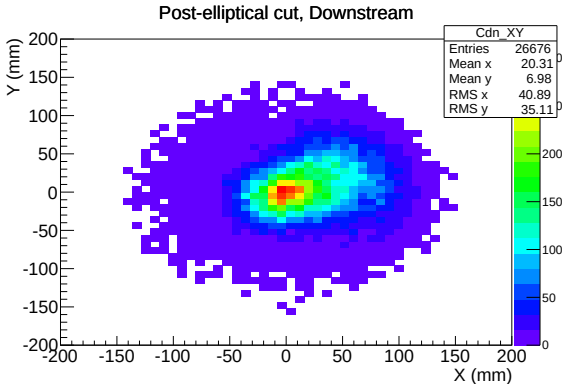

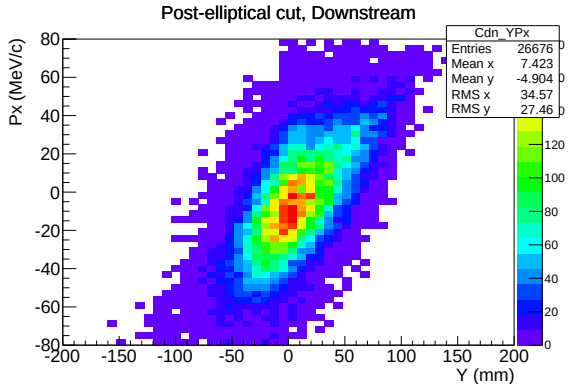

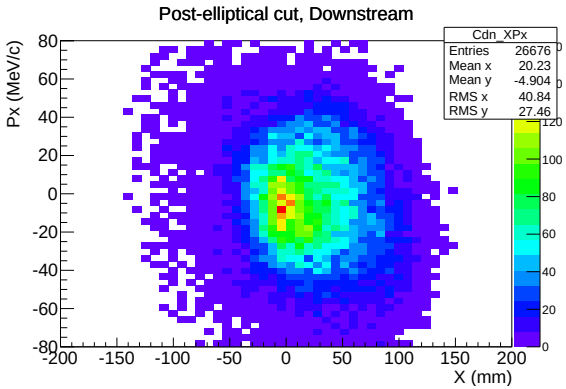

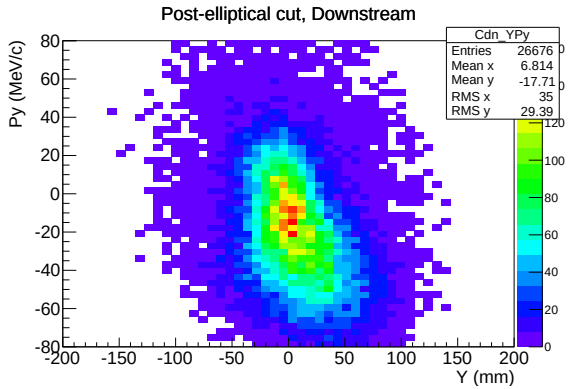

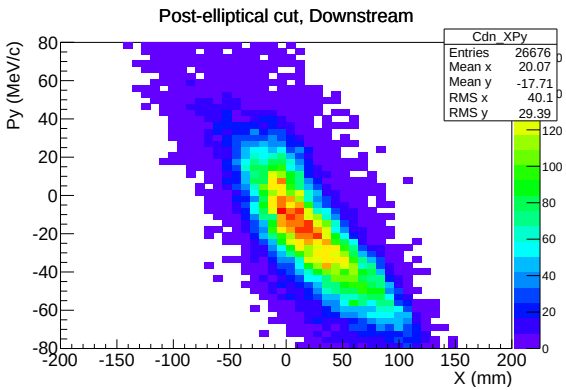

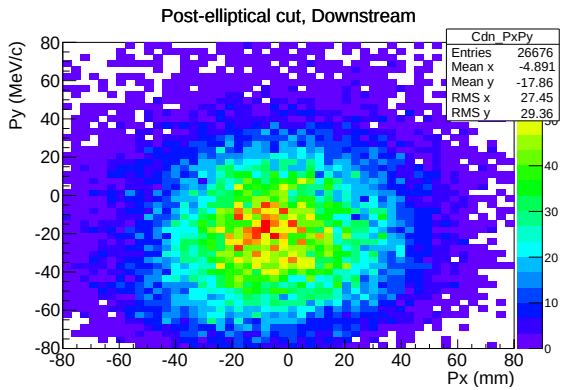

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- Particle must create a (single) trigger in TOF2.
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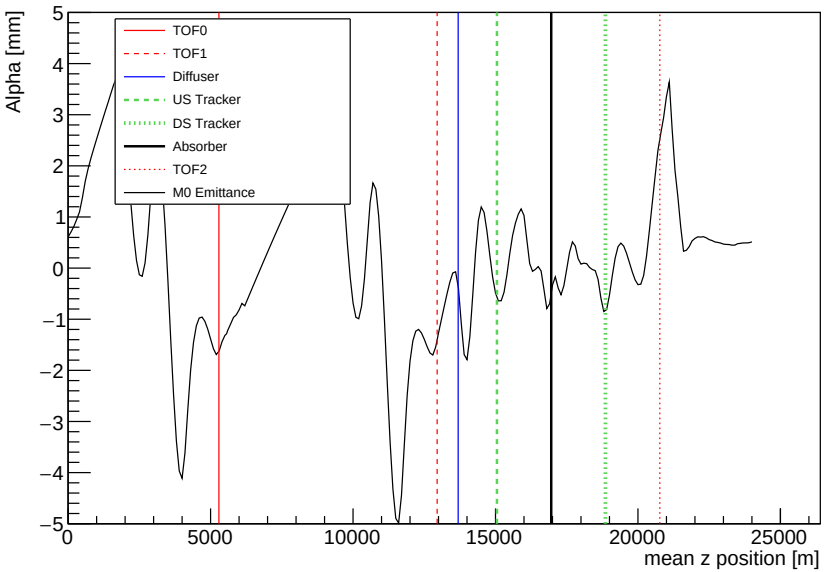
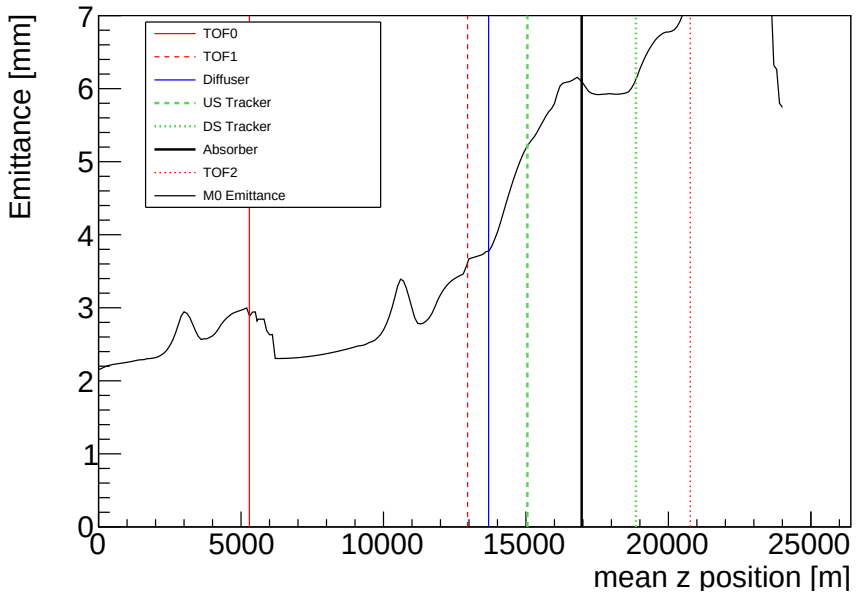
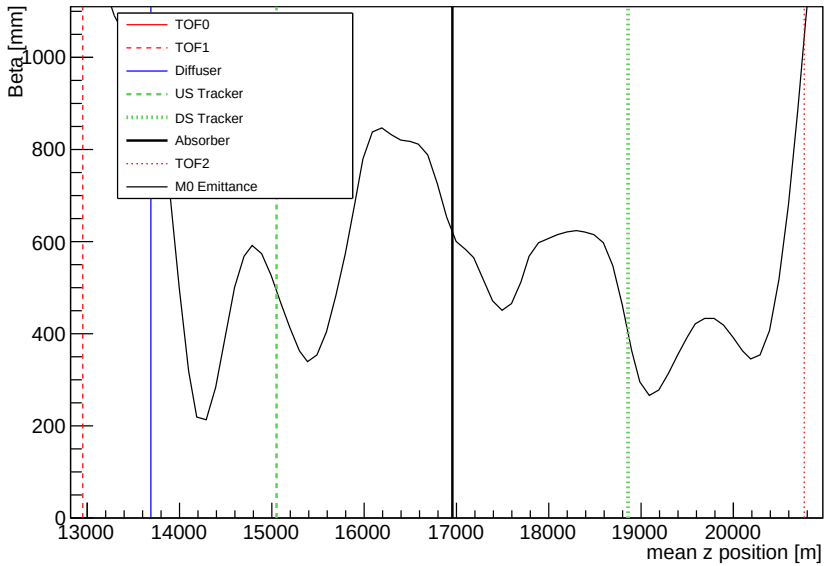
Virtual Plane Analysis

- Track the evolution of the beam through the full beam line.
- Used virtual planes in the simulation every 10 cm.







Approaches to Correcting Mis-match

New beam-line settings

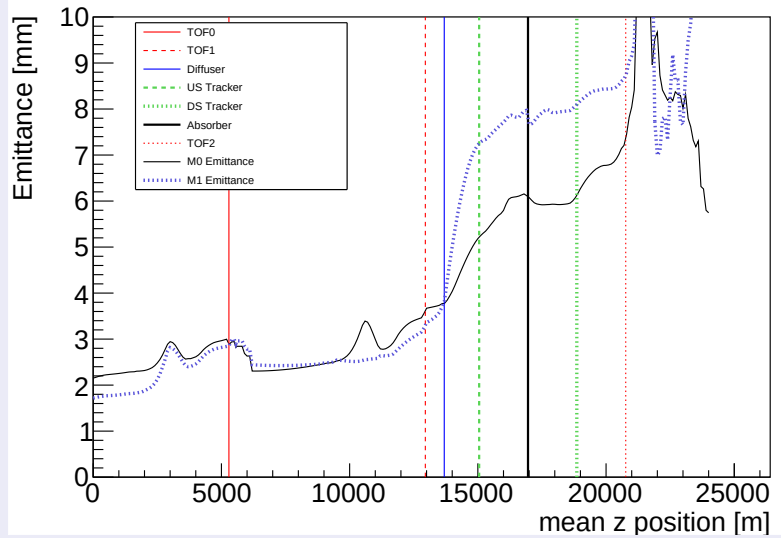
- Being actively followed by Jaroslaw et al.
- Results have been promised but not yet seen.
- Data haas been collected to test one prospective setting.

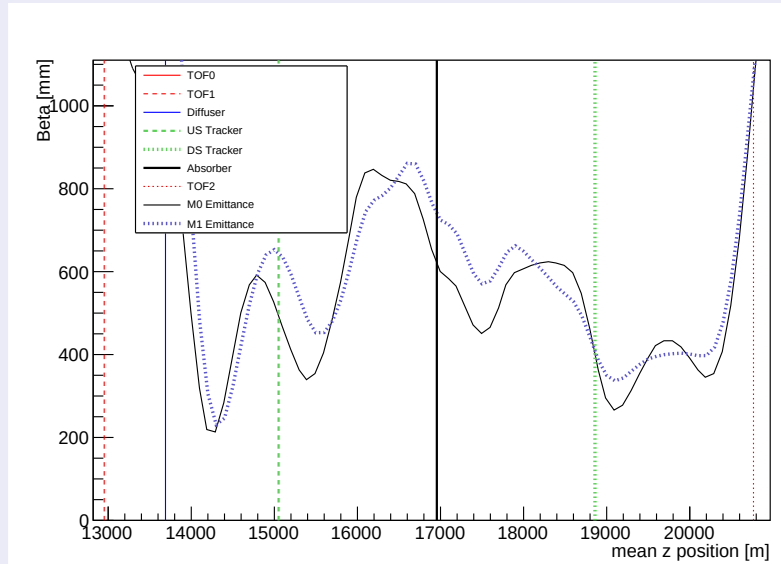
Beam Selection

- "A solenoid beam exists in there, somewhere."
- A particle selection/re-weighting algorithm may select well matched beam manifolds.
- Has been pursued by Chris Rogers with weighting by beam moments or Voronoi tesselation.
- I have attempted elliptical cuts and selection on beam parameters
  - no great improvement observed.

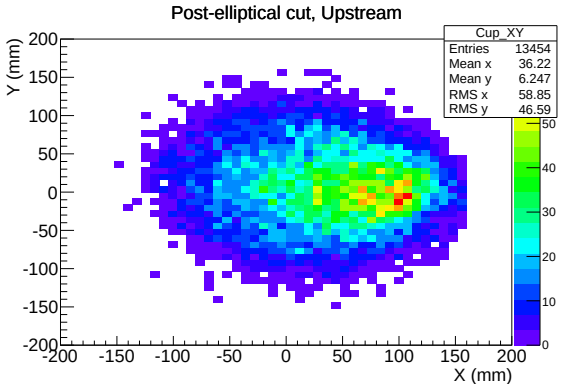
Comparisons with New Beam Settings

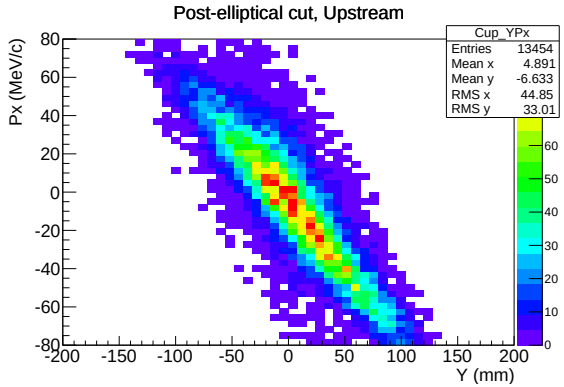
- Jaroslaw has proposed new beam line settings that have been tested (data collected April 26).
- Ran the simulation with G4BL input.
- Compared the emittance and beta functions to evaluate matching.
- Matching appears to be worse.
- Efforts still ongoing.

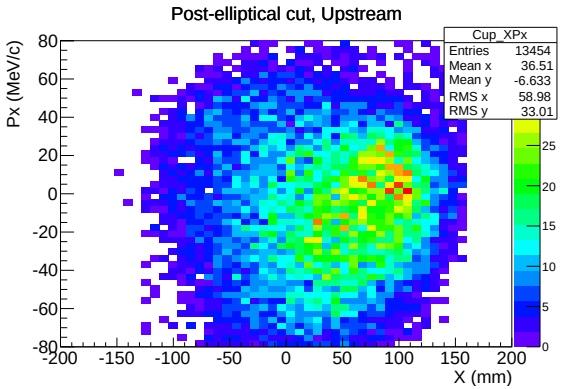


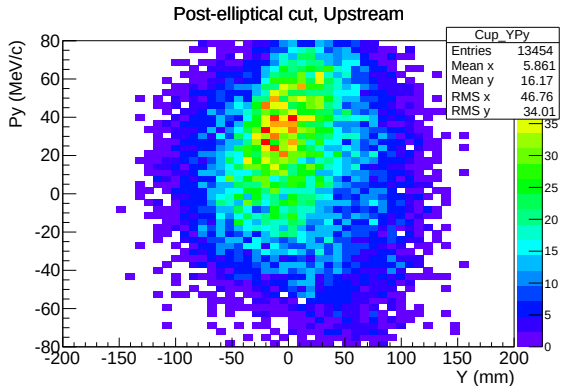


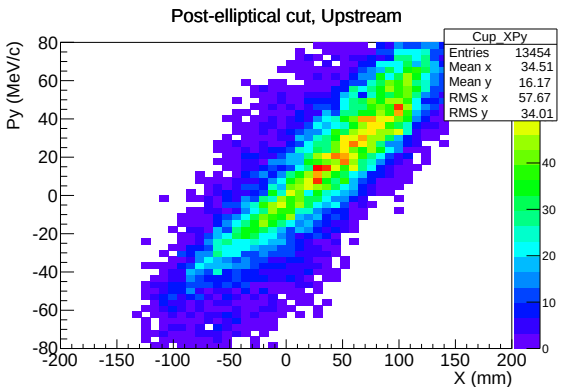
Beam phase space with Match 1 Settings

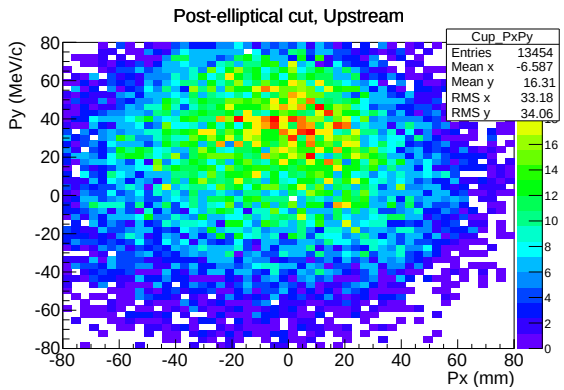












- Particles after tracker matching and "PID" selection shown.
- Beam seems more diffuse than in the M0 settings.
- Explicit demonstration of quad-to-solenoid mis-match.
- Looking forward to new beamline settings

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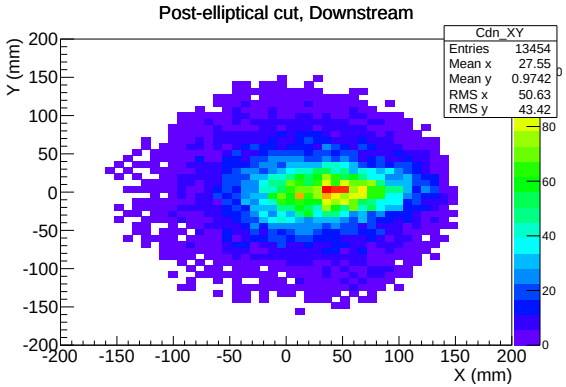

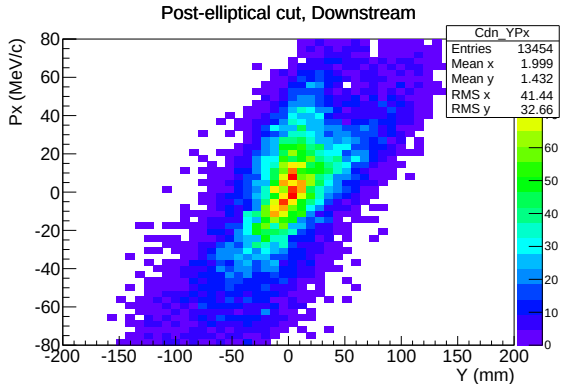

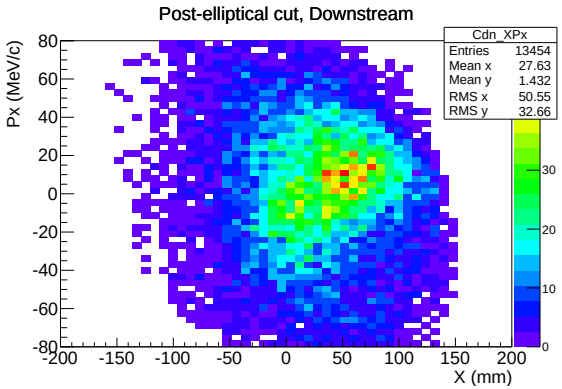

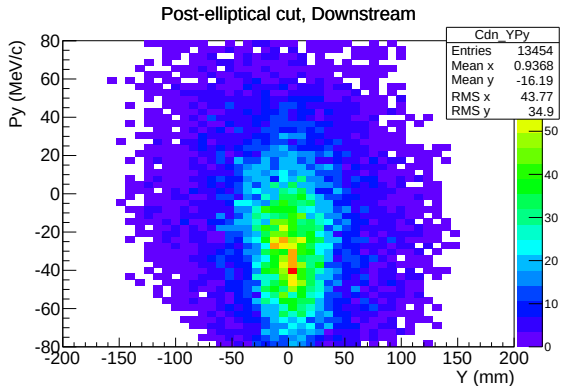

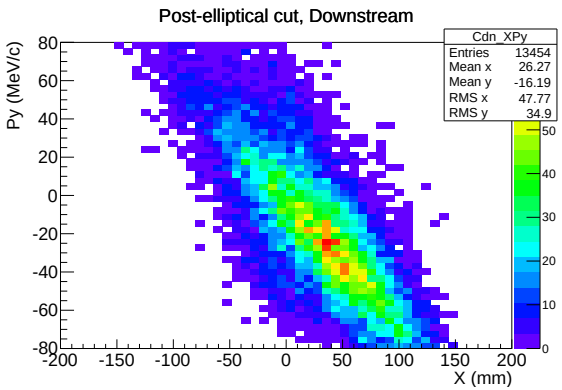

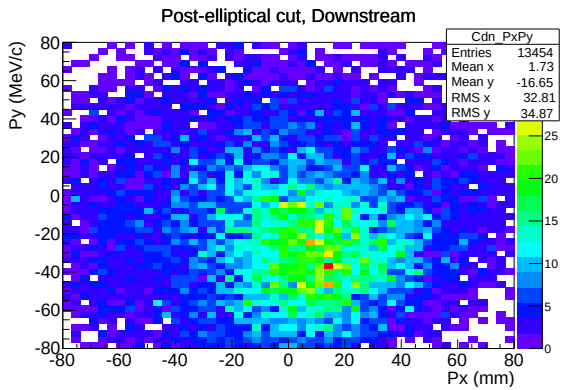

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Simulation Constraints

1.4×10^7 particles prior to D2

	TOF1	TOF2	Selected
Field Off	44673	2096	130
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Match 1	49044	30427	22183

- Existing statistics generated with from 10^{11} simulated POT in G4Beamline.
- Requires $\mathcal{O}(10^4)$ CPU-hr for G4BI simulation.
- NB: MAUS simulation requires 26 min / 10^4 particles.

Storage Considerations

- 1.4×10^7 particles prior to D2 creates $\mathcal{O}(10)$ GB.
  - This includes 2400 virtual planes.
- Selecting only trigger events this drops this to 2 GB.
- Careful consideration of archival information is required.

Options to reduce simulation inefficiencies

Use an analytical approach to generate beam

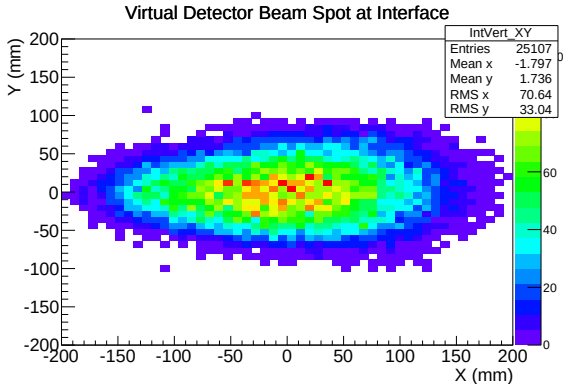
- Will need an accurate beam transport model (how accurate?).
- How does this model include backgrounds?

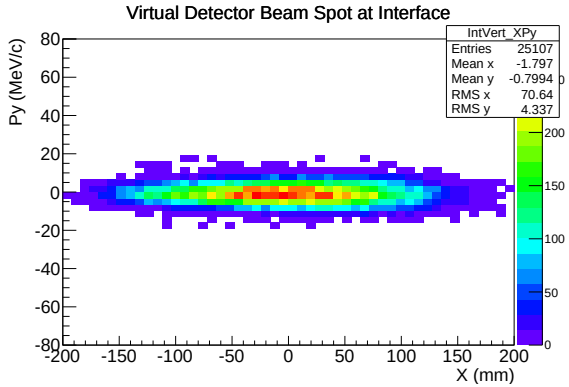
Use a predefined distribution to provide initial conditions

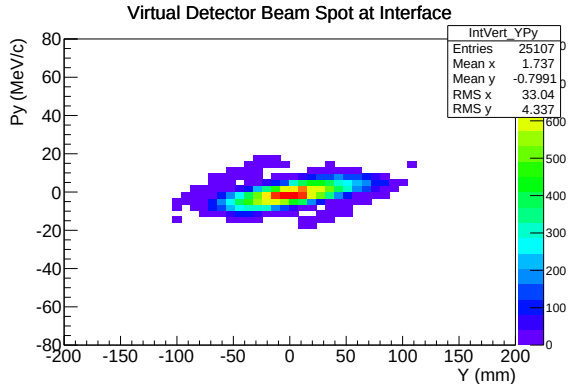
- These distributions have been generated from existing G4Beamline simulations.
- Can select events that survive to the end of the channel (or TOF0, TOF1 etc.)
- How general would be the distribution "library"?

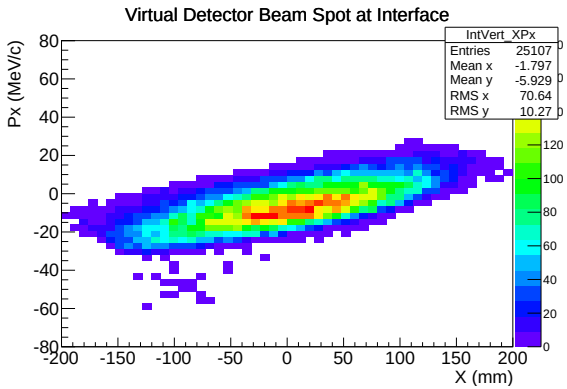
- Can address the second point with existing simulations...

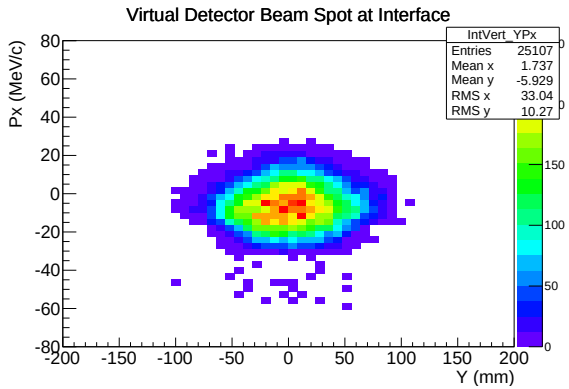
Beam at Interface Plane

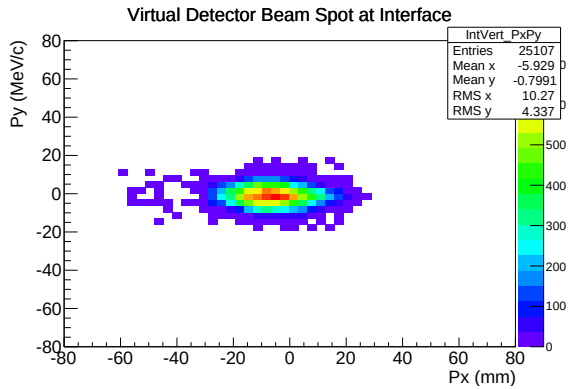


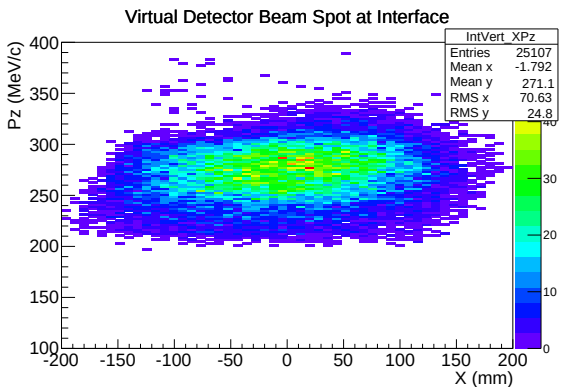


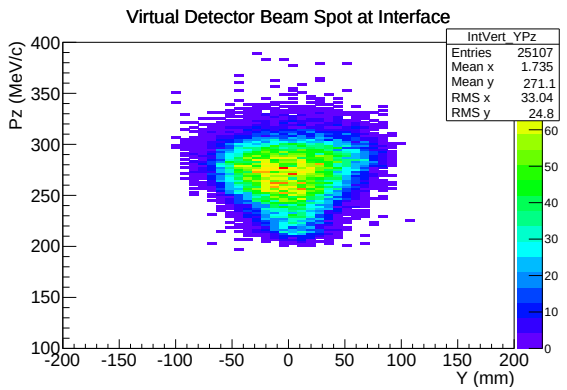


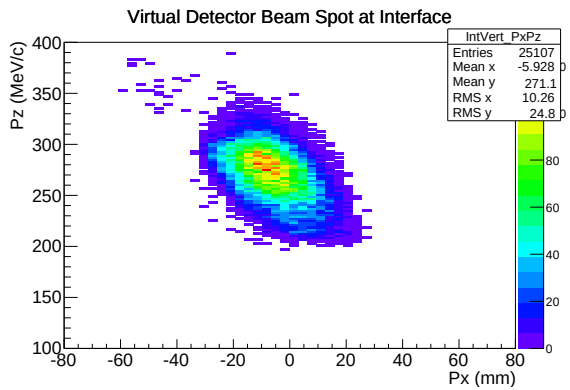






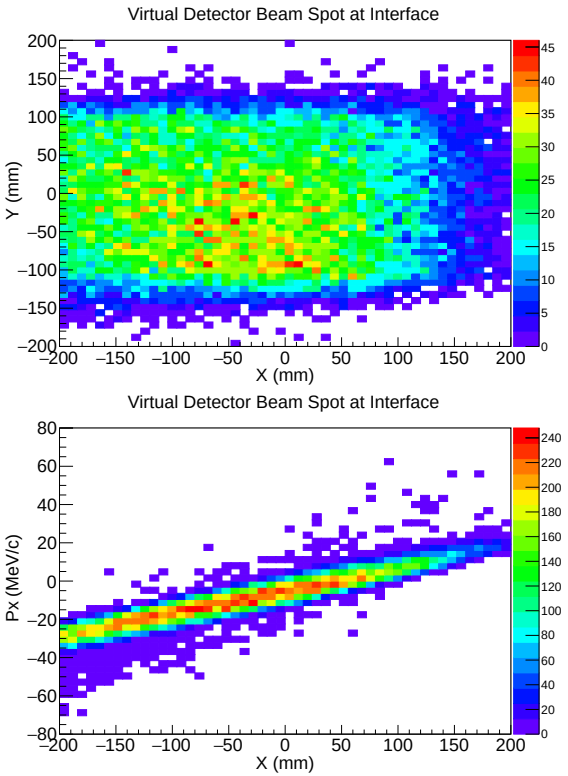


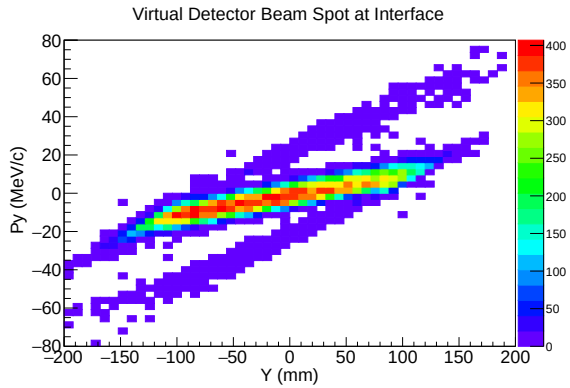




- Consider distribution of selected particles at $z = 1$ m.
- Distributions with no selection at $z = 1$ m.

Beam at Interface Plane





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Conclusions

- After false starts the batch simulation is now going ahead.
  - Running G4Beamline to create settings library.
  - Updated all extant simulations to use MAUSv0.9.5.
- New beam line settings are required.
  - Clear that there is poor beam matching with the M0 settings.
  - First attempt correction attempt did not solve the mis-match.
  - Work is still in progress.
- Infrastructure for simulations on the grid has been exercised in local simulations.
  - Includes CDB interface for cooling channel and simulation settings.
  - Archival framework has not been explicitly tested.
  - Local batch simulations do not have a home.