MICE Descope - Options

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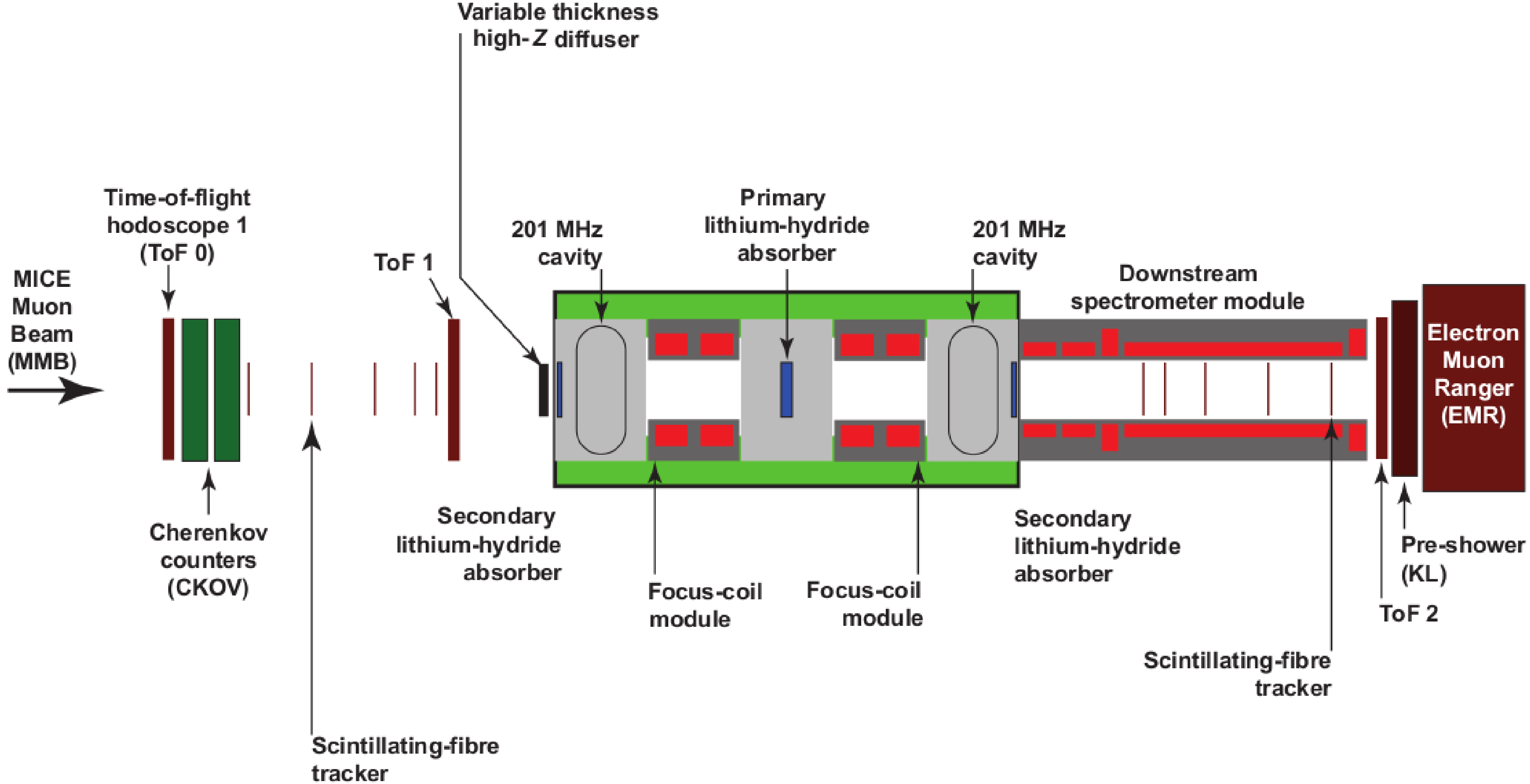
MICE Descope Options

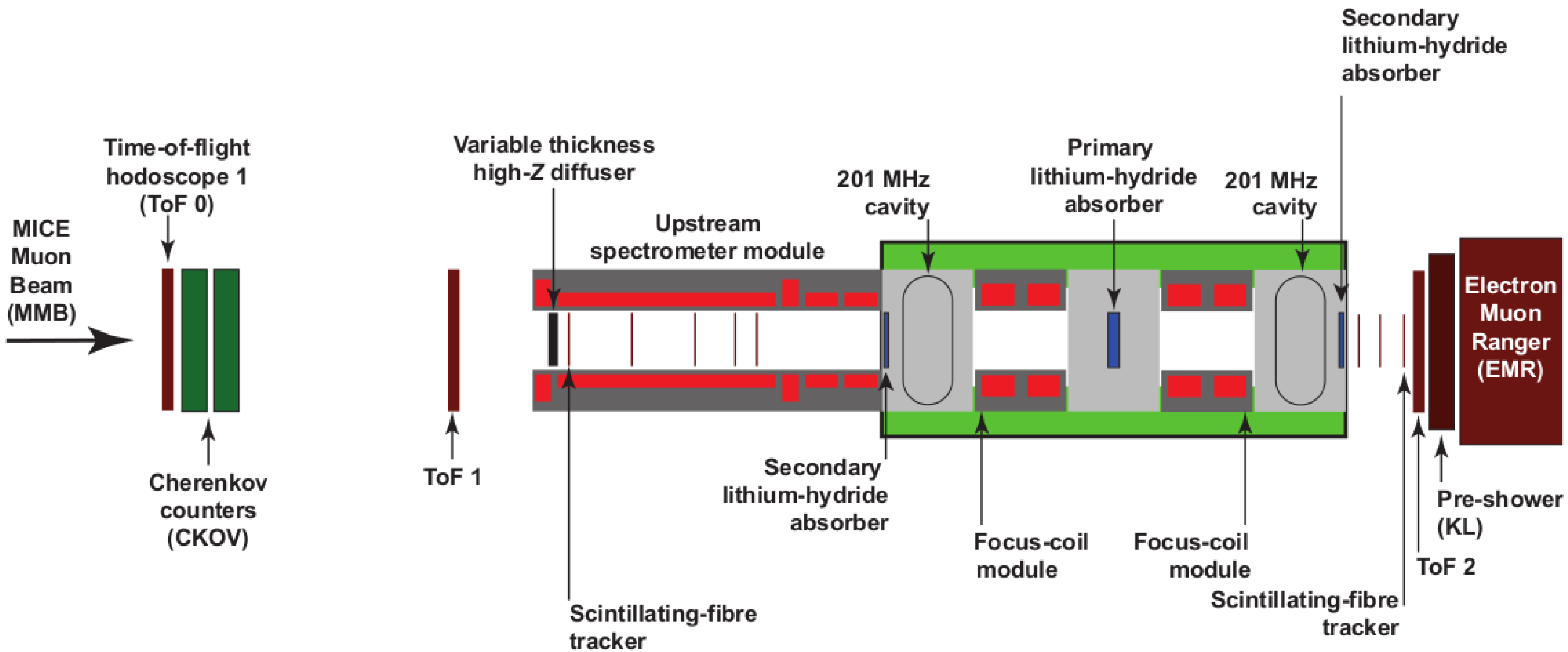
- SS2 in downstream, no SS1
  - Measurement can be a difference measurement, i.e. absorber in vs absorber out
  - Upstream diagnostics for beam sampling or to control systematic due to instability in input beam
- SS2 in upstream, no SS1
  - Tracker straight tracks for x, x', y, y'
  - EMR range for pz
  - TOF12 augments downstream PID and downstream pz
- Use SS1 and SS2
  - Largely ruled out on grounds of risk
  - Should establish existence of viable optics
- In all cases, likely we only have 1 RF power source
  - $V \rightarrow V/\sqrt{2}$

SS2 in downstream



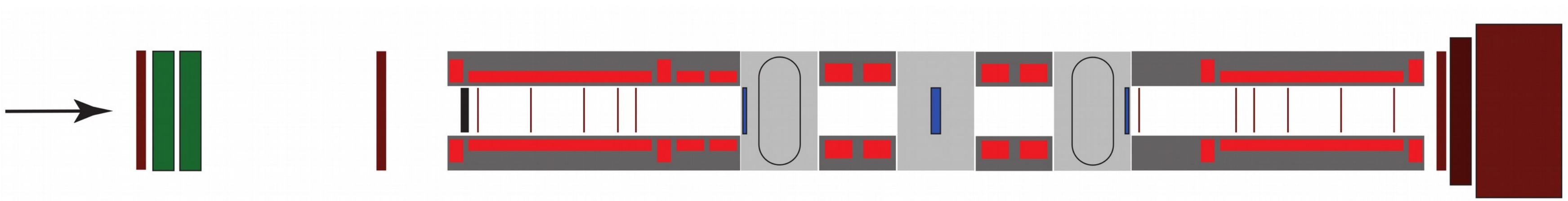
- Questions
  - Can we find a viable optics to match to FCU?
  - Can we reconstruct well enough in the Quads+diffuser OR do a difference (absorber in vs out) measurement?

SS2 in upstream



- Questions
  - Can we get sufficient downstream detector performance?
  - Does the beam scrape too much in TKD?

SS2 in upstream

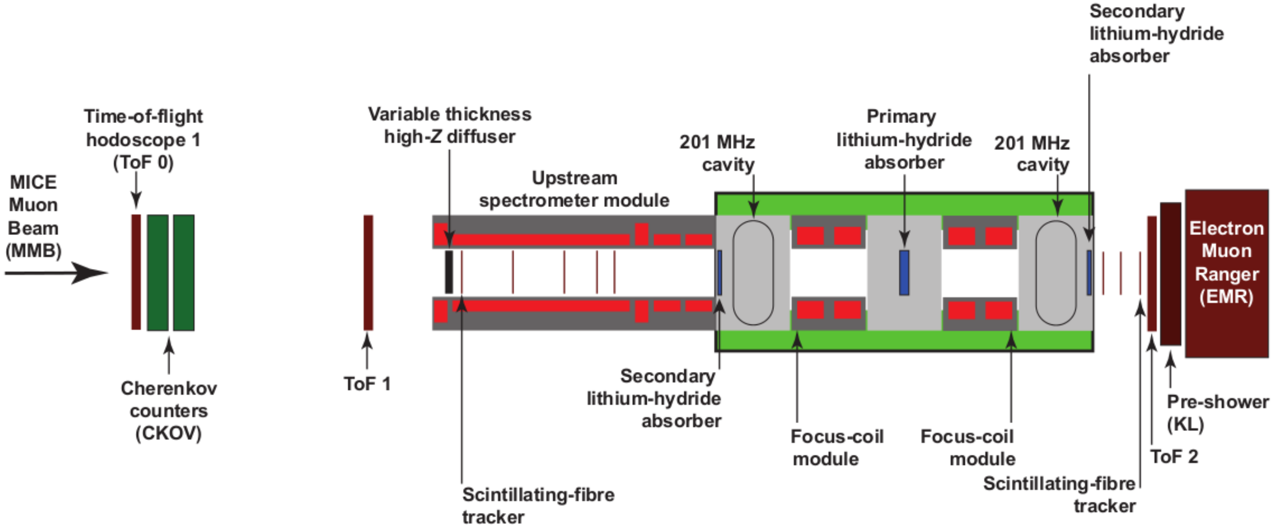


- Questions
  - Can we get a reasonable optics?
  - Can we rotate SS1 and improve the situation?
  - Is the risk of further issues with SS1 too great?
  - See talk by Jaroslaw

Timescales

- Fall out from UK C2C 4th May
- Would like to see some convergence by ~ 13th May
- Need to have main physics inputs ~ 20th May
- Decision point is 27th May ←

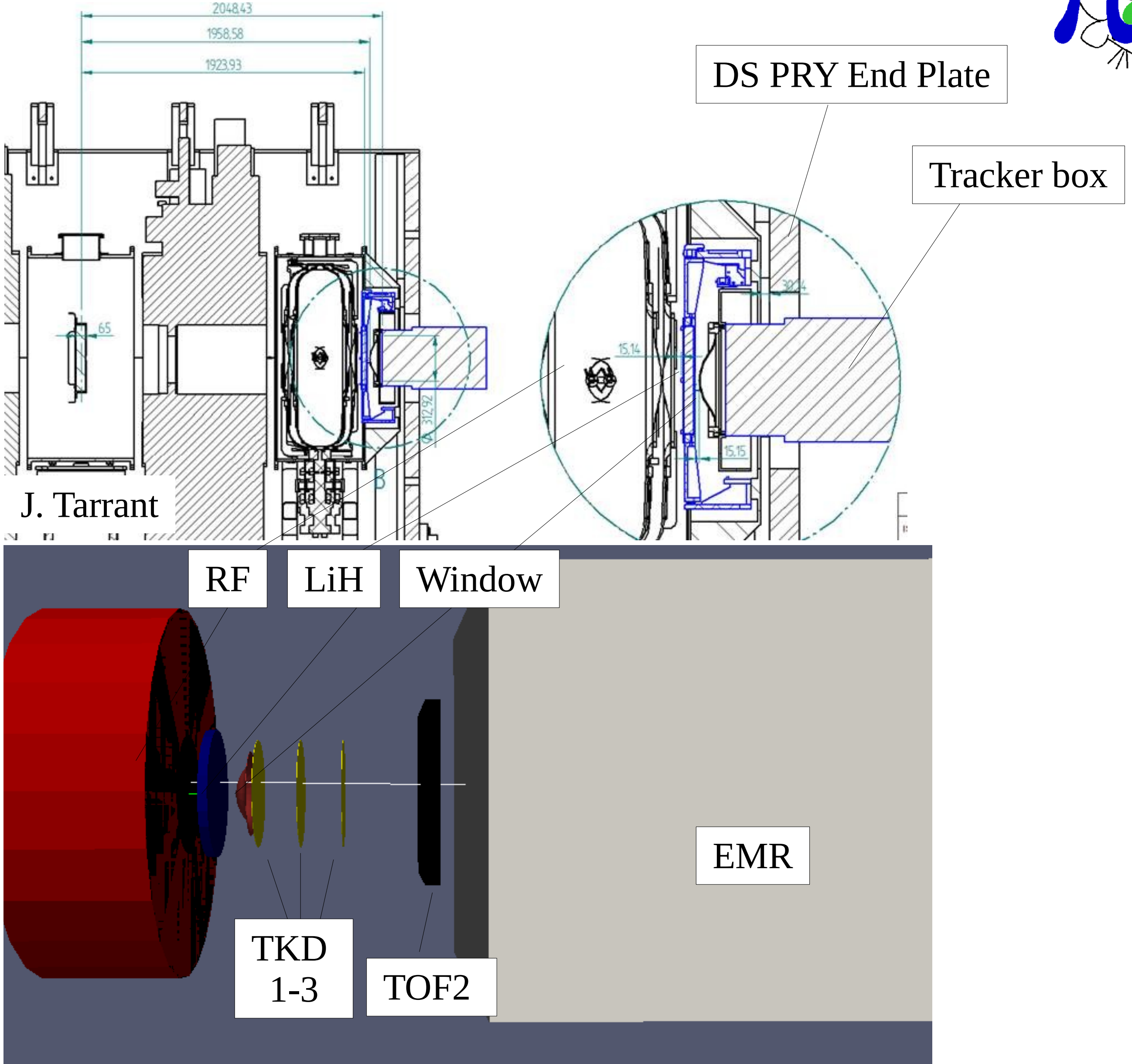
SS2 Upstream Option



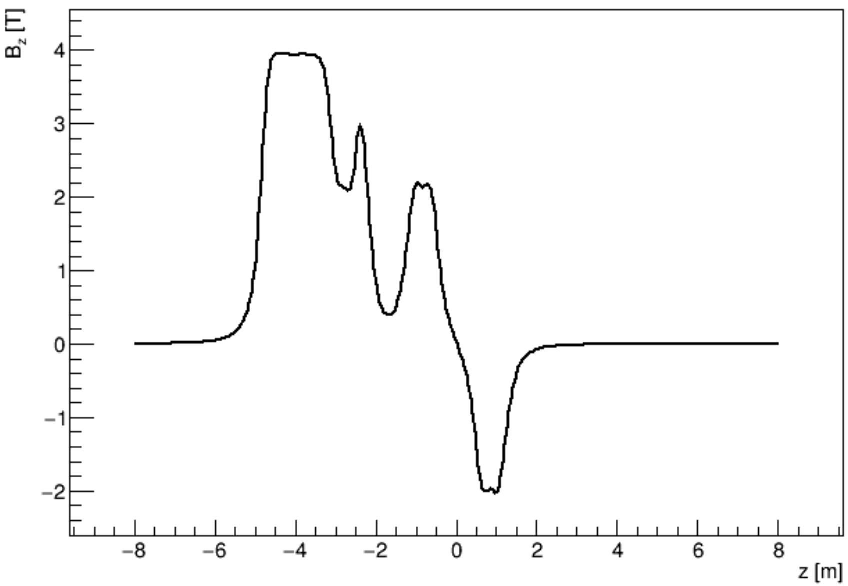
Revised Detector Configuration

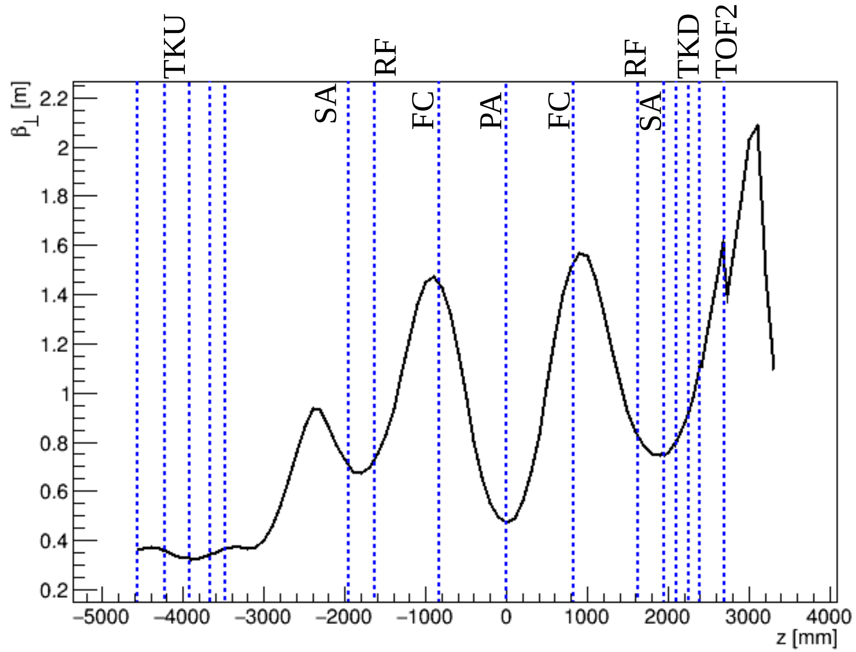
- Use TKD to measure x, x', y, y'
- Use EMR to measure range => momentum
- Combined fit between EMR, TOF2 and TKD to get phase space at downstream end
  - Focus in this talk on position and momentum resolutions
- 3 stations in TKD
  - 2 stations to make a straight track, 3^{rd} station for redundancy/noise rejection
- KL makes energy straggling => problem for momentum extrapolation
  - KL can be included for “better PID” runs
  - KL can be excluded for “better momentum resolution” runs
  - Simulations here do not include KL

Downstream detectors



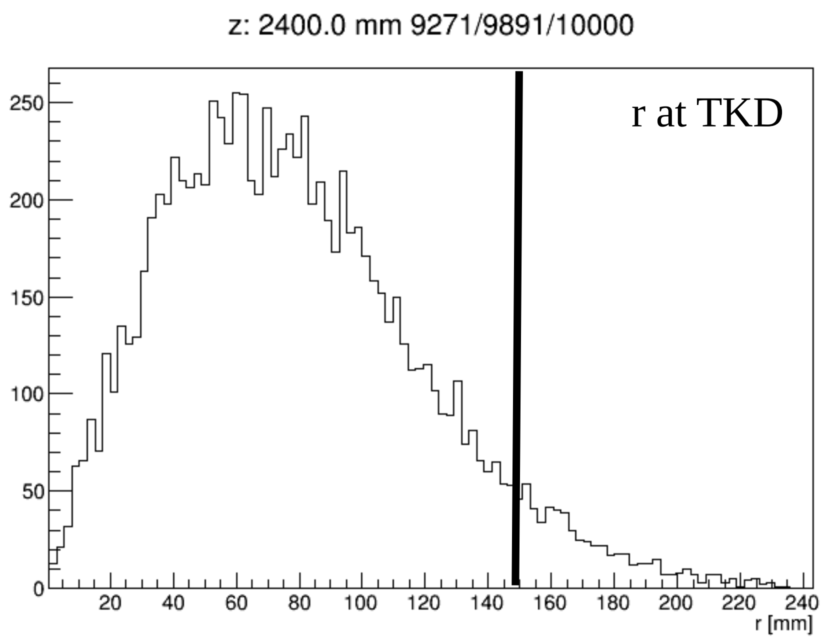
Optics

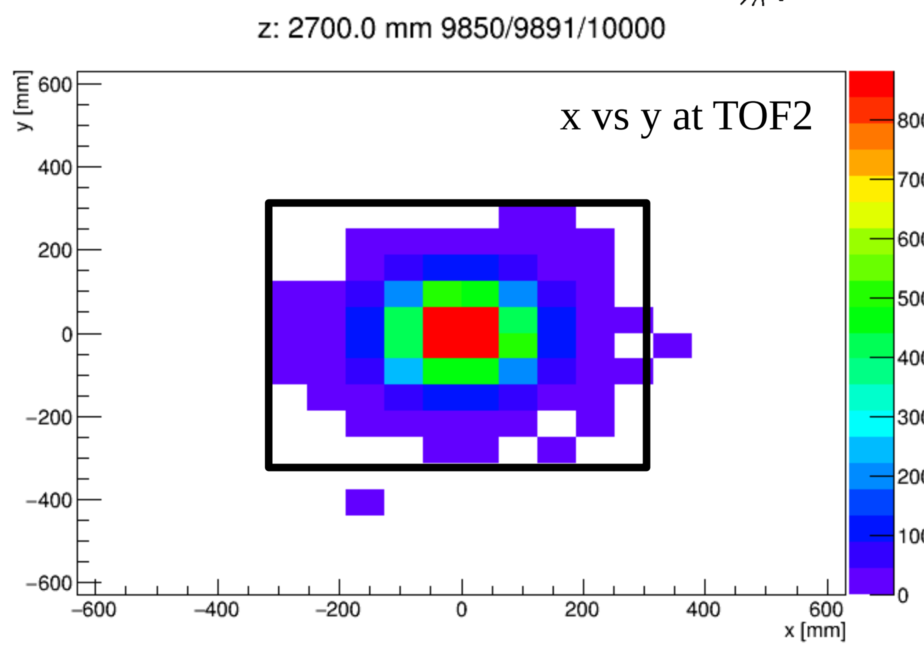




- Using modified version of 200 MeV/c Demo lattice
  - Remove SSD, keep currents/etc same

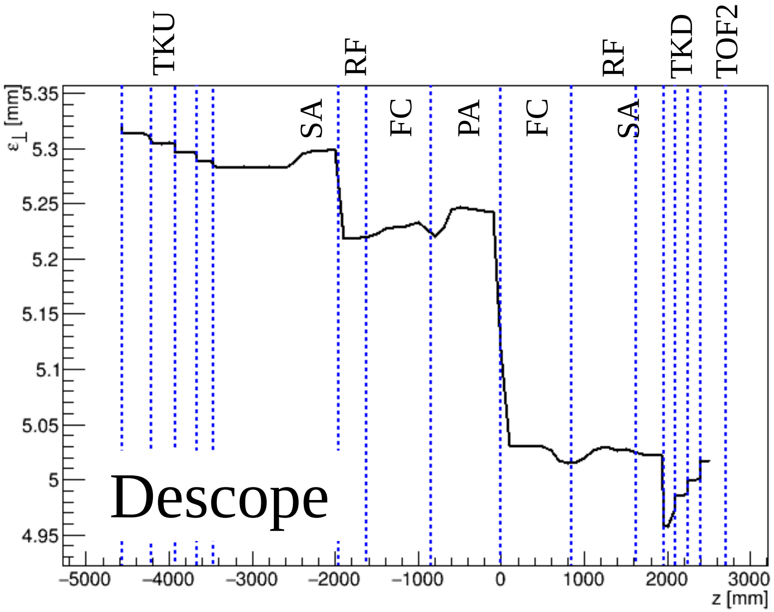
Optics

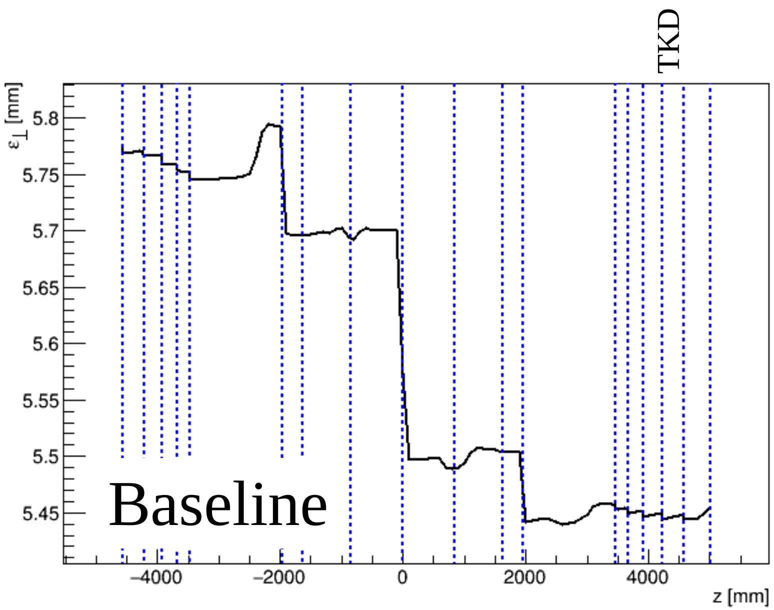




- Radial distribution at TKD station 3 for 6 mm emittance beam
  - 99 % of beam is transported to TKD
  - 93 % of beam is transported through TKD radial cut
- TKD becomes the limiting aperture

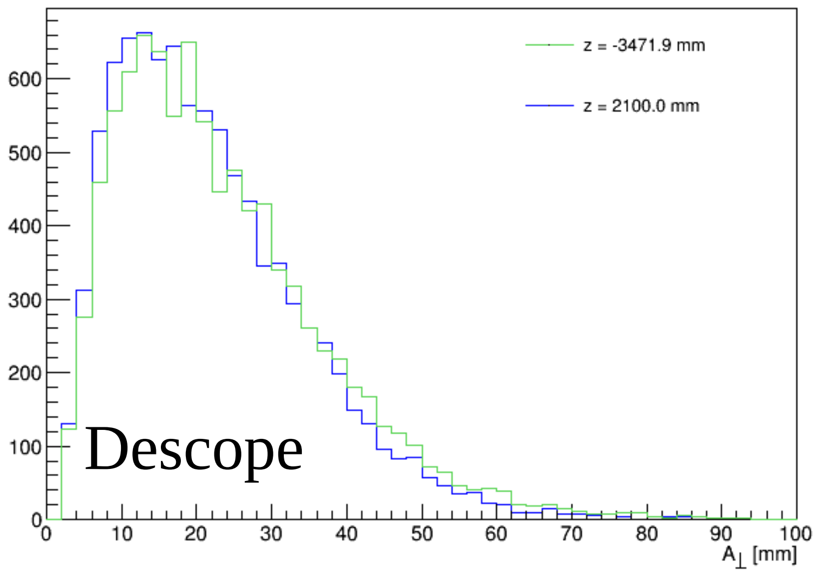
Emittance Reduction

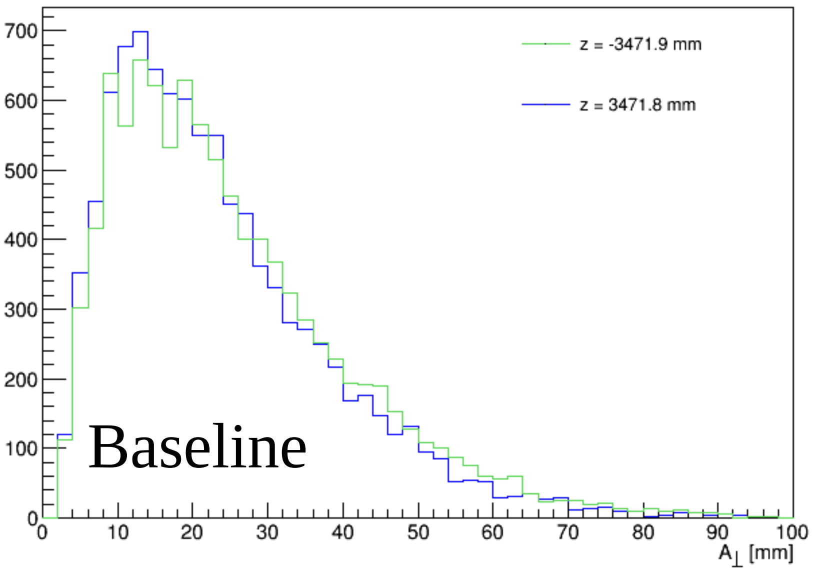




- See expected emittance reduction
- Transmission in descope – 93 %
- Transmission in baseline – 98 %
- Nb this is for initial beam emittance 6 mm nominal

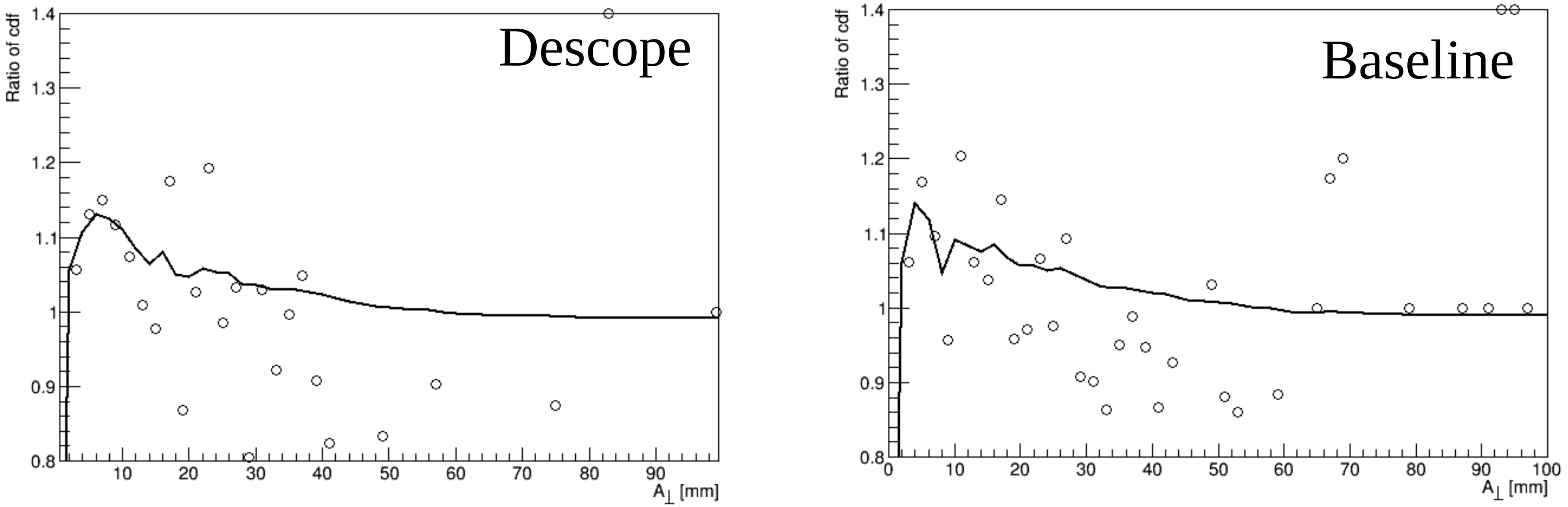
Amplitude change





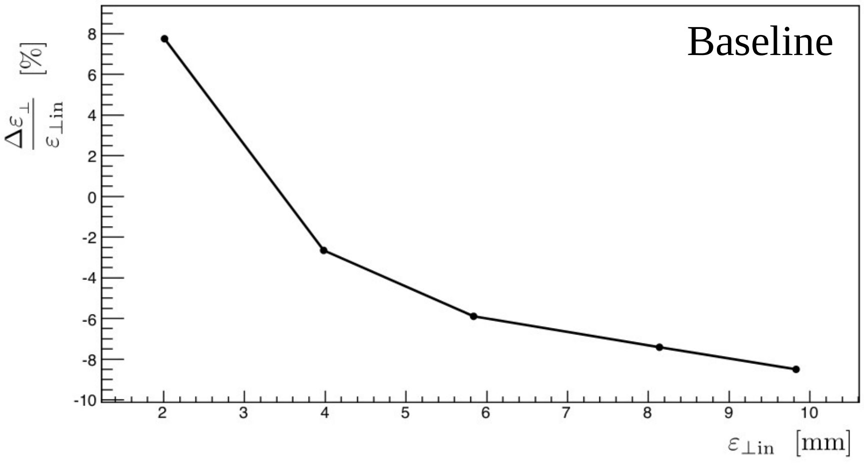
- Number of muons in each amplitude bin
  - Green – upstream
  - Blue - downstream

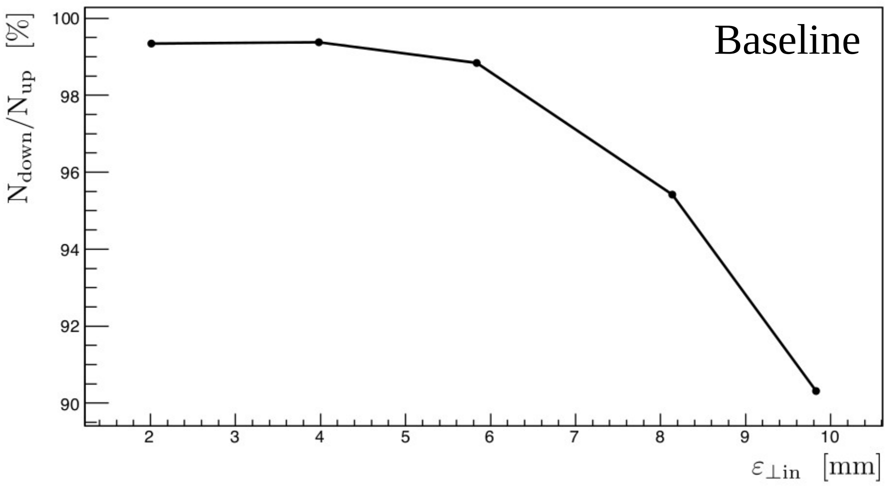
Ratio



- Histogram
  - Consider the number of muons in each amplitude bin, n
  - Histogram is n(downstream)/n(upstream)
- Line
  - Consider the number of muons with amplitude <= bin edge, N
  - Line is N(downstream)/N(upstream)

Cooling Performance





Descope:

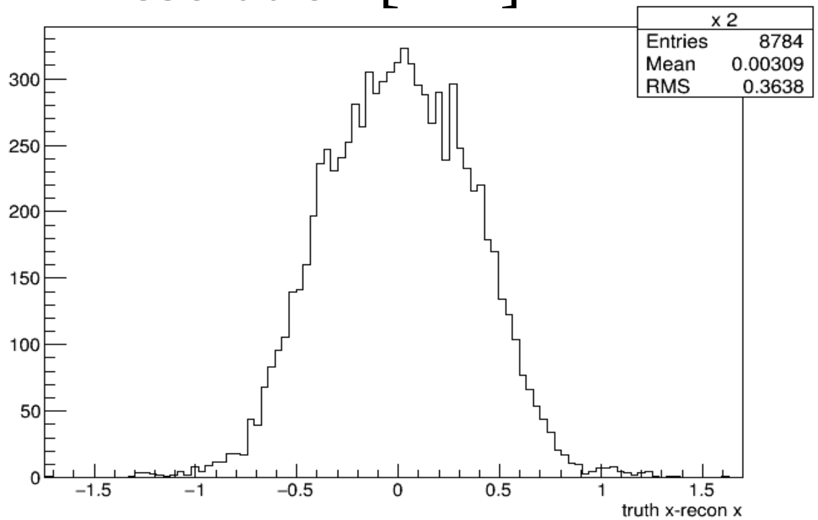
Nominal emittance [mm]	Input emittance [mm]	Output emittance [mm]	Emittance Change [%]	Transmission [%]
2.00	2.00	2.18	8.44	100.00
3.00	2.94	2.98	1.29	98.93
6.00	5.28	4.98	-6.23	92.66
10.00	7.34	6.65	-10.30	79.03

Combined fit - algorithm

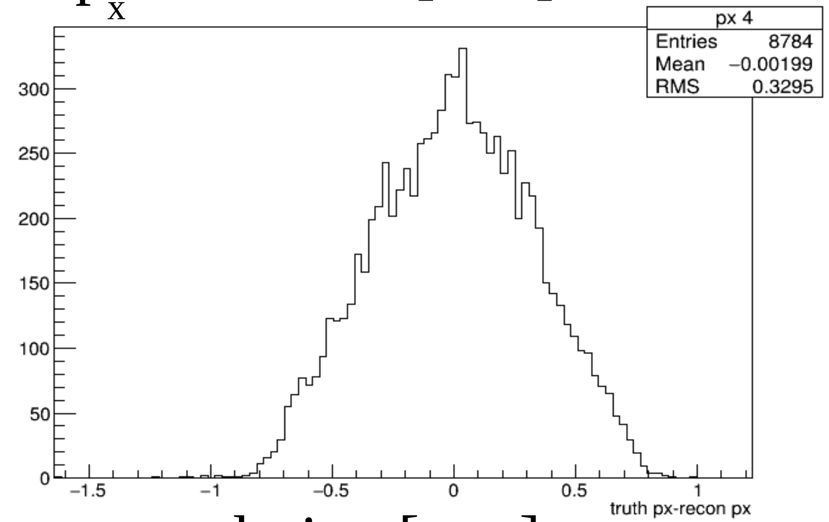
- Use x, y from TKD station 1
- Use x', y' calculated from TKD station 1 and station 2
- Extrapolate EMR track (incl x', y', x, y at EMR) back to tracker
  - Use Bethe Bloch formula to “undo” energy loss in TOF, air
  - Step size 1 mm
  - Use extrapolated total momentum to scale x', y' and deduce pz
- Do not model: cross-talk in EMR, RF-induced backgrounds
  - Not sure about tracker efficiency model (default tracker recon)
- Plots that follow are for 6 mm emittance, 200 MeV/c beam shown in earlier slides
  - Nb: expect worse performance for low pz

Combined fit - resolution

x resolution [mm]

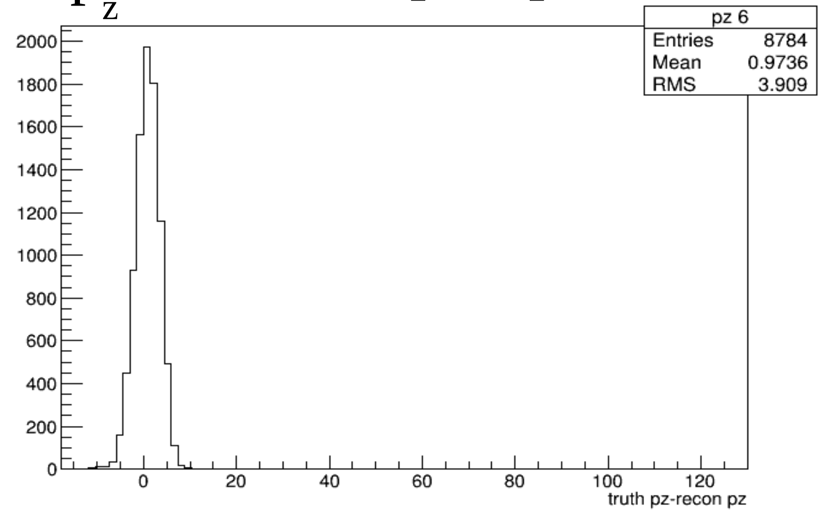


p_x resolution [mm]



- Reject tracker noise
  - 5 standard deviation cut on x, y, p_x, p_y
  - 1 % of events
- Reject events which do not have 3 scifi space points and 1 emr track
  - 5 % of events

p_z resolution [mm]



Recon Performance

True Emittance [mm]	Recon Emittance [mm]	Bias [%]
2.18	2.22	1.73
3.02	3.05	1.29
5.12	5.17	0.86
6.94	6.99	0.78

- Bias is significant
  - Old specification was for 1 % bias on 10 % emittance reduction
  - i.e. 0.1 % bias on emittance
  - Compare with TKU bias ~ 0.2 % (MICE note 122)
- Bias is dominated by x' resolution
  - We can measure x' resolution
    - E.g. compare x' from station 1-2 with x' from station 2-3 and assume stations are identical
  - Bringing the bias to < 0.1 % requires measurement of px resolution at few % level
- Emittance change signal is still significantly greater than bias

Biases and Errors

	Magnitude	Mitigation
EMR Material Budget	0.4 MeV/c p	Use TOF12 to cross-check p reconstruction
TOF2 Material Budget	0.15 MeV/c p	Use TOF12 to cross-check p reconstruction
Reconstruction Bias	~1 % emittance	Measure x' resolution in tracker stations
Detector Efficiency	?	Cross-check with EMR/TOF2
RF Noise	?	Noise rejection from EMR/TOF2
FCD fringe field	?	Install hall probes on TKD
Position Alignment	100 microns?	TKD directly accessible for survey
Pitch/Yaw	0.3 mrad?	TKD directly accessible for survey
Roll	1 mrad?	TKD directly accessible for survey

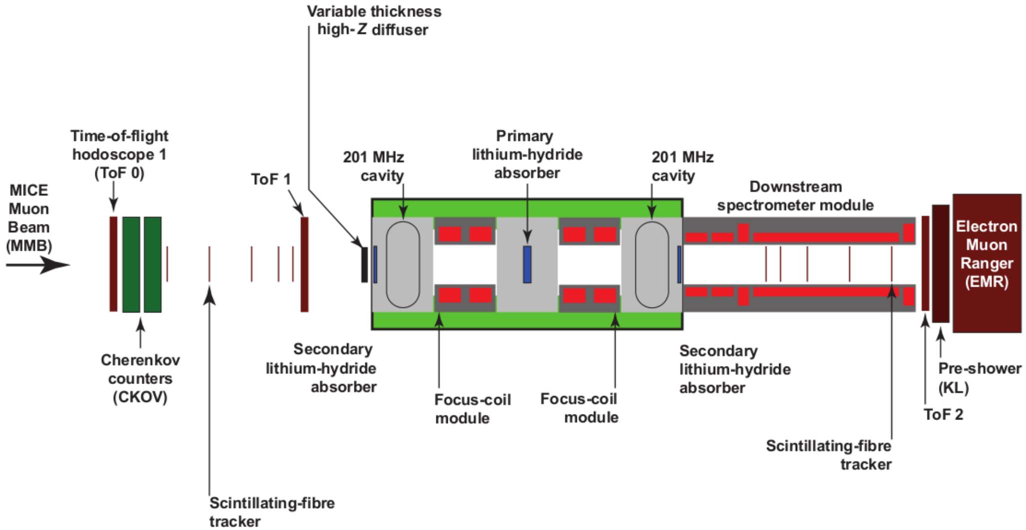
Practical Matters

- Reasonable confidence from Jason and Geoff that this can be built
  - 150 mm tracker spacing may be a bit tight for light guides
- Some things become easier
  - TKD is in air and independent from RFD support/vacuum
    - No Helium
    - Much easier access for e.g. maintenance, alignment
  - RFD may be accessed by sliding detector assemblies and PRY end plate downstream along the beamline
  - Downstream radiation shutter is outside the PRY
    - Slide detector assemblies away to install
- Slight snag with RFD power couplers
  - Interferes with PRY leg attachment (but not legs themselves)

SS2 Upstream - Conclusions

- Cooling channel emittance reduction is unchanged
- Cooling channel transmission/acceptance is somewhat reduced
- Detector resolution is somewhat worse
  - Possible to measure/remove the bias
- The experimental measurement still appears very promising

SS2 Downstream Option



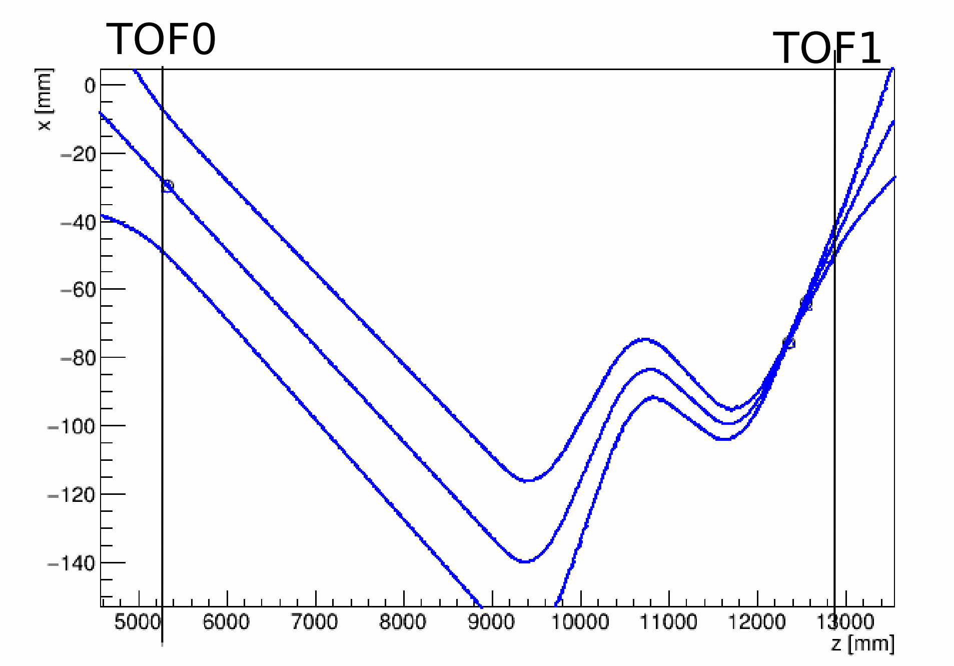
SS2 Downstream

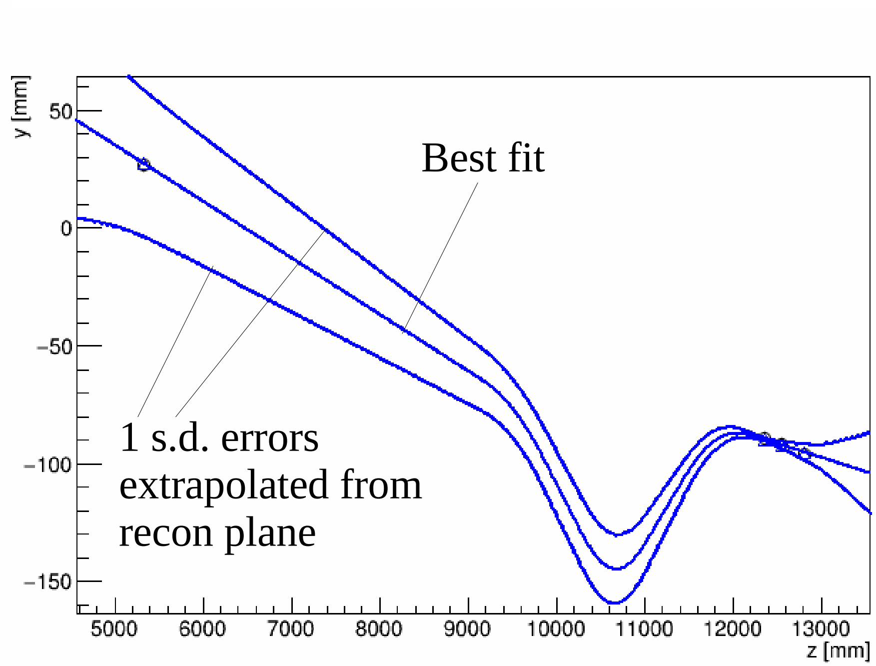
- With SS2 in downstream position – difference measurement
  - Measure emittance downstream with absorber in
  - Measure emittance downstream with absorber out
  - Look at the difference
  - Need to demonstrate match into FCU; possibly with help of beam selection from upstream detector system
- With SS2 in downstream position – direct measurement
  - Use additional tracker stations around the upstream region
  - Need to demonstrate sufficient resolution despite material (e.g. TOFs and diffuser)

Detector Model and Reconstruction

- Tracker stations placed in air
  - Stations as described as in MAUS geometry
  - Virtual planes at each station
  - x, y smeared by tracker resolution (500 um)
  - Time smeared by TOF resolution (70 ps)
  - Propagate errors & fit x, y, t
  - Energy loss & scattering in material accounted for
  - Require |x,y| < 150 mm at tracker stations
- Code:
  - From Rogers: GlobalErrorTracking & Minuit-fitter
- 3-200 G4BL input
  - Takes a long time to track & fit
  - Minuit takes ~ several hundred iterations to converge

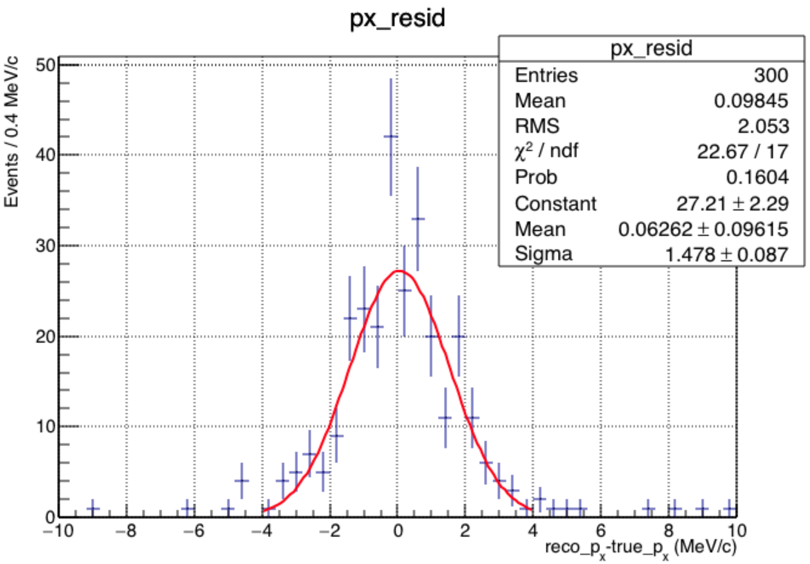
Sample TOF0-TOF1 Fit

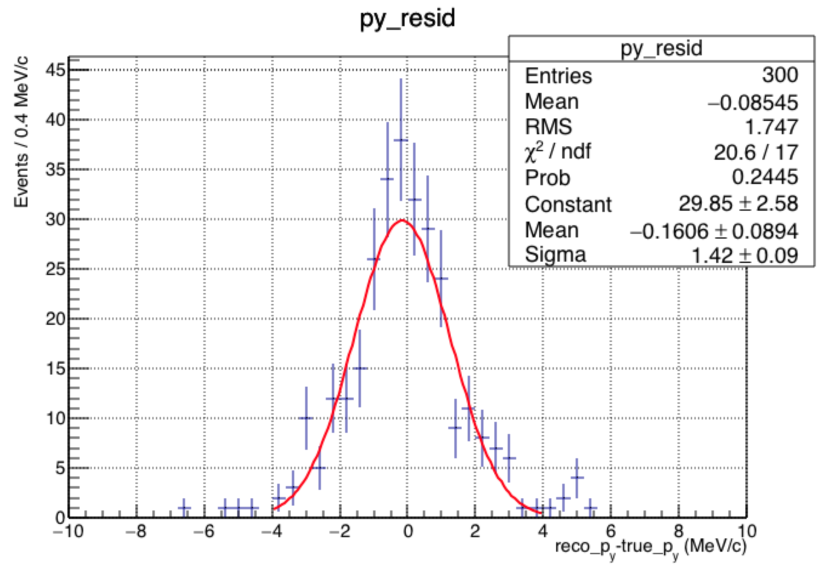




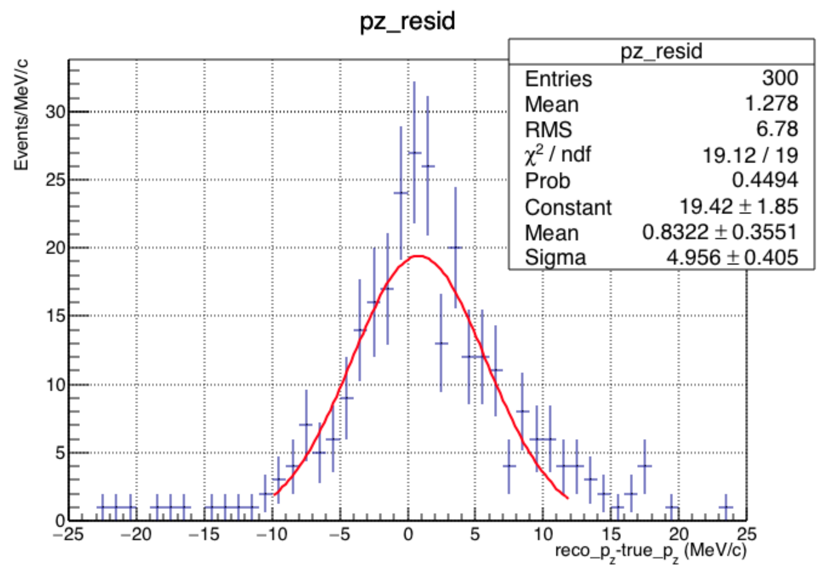
- 3 stations near TOF1
- 1 station near TOF0
  - Clearance between TOF0 & Ckov is tight ~15cm – barely fits a tracker station

Resolutions



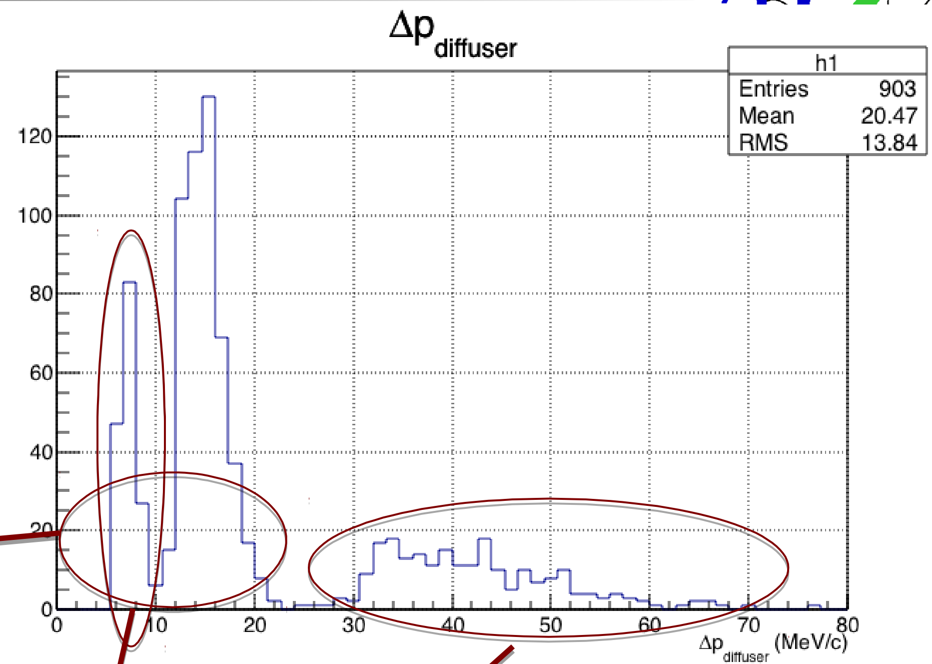


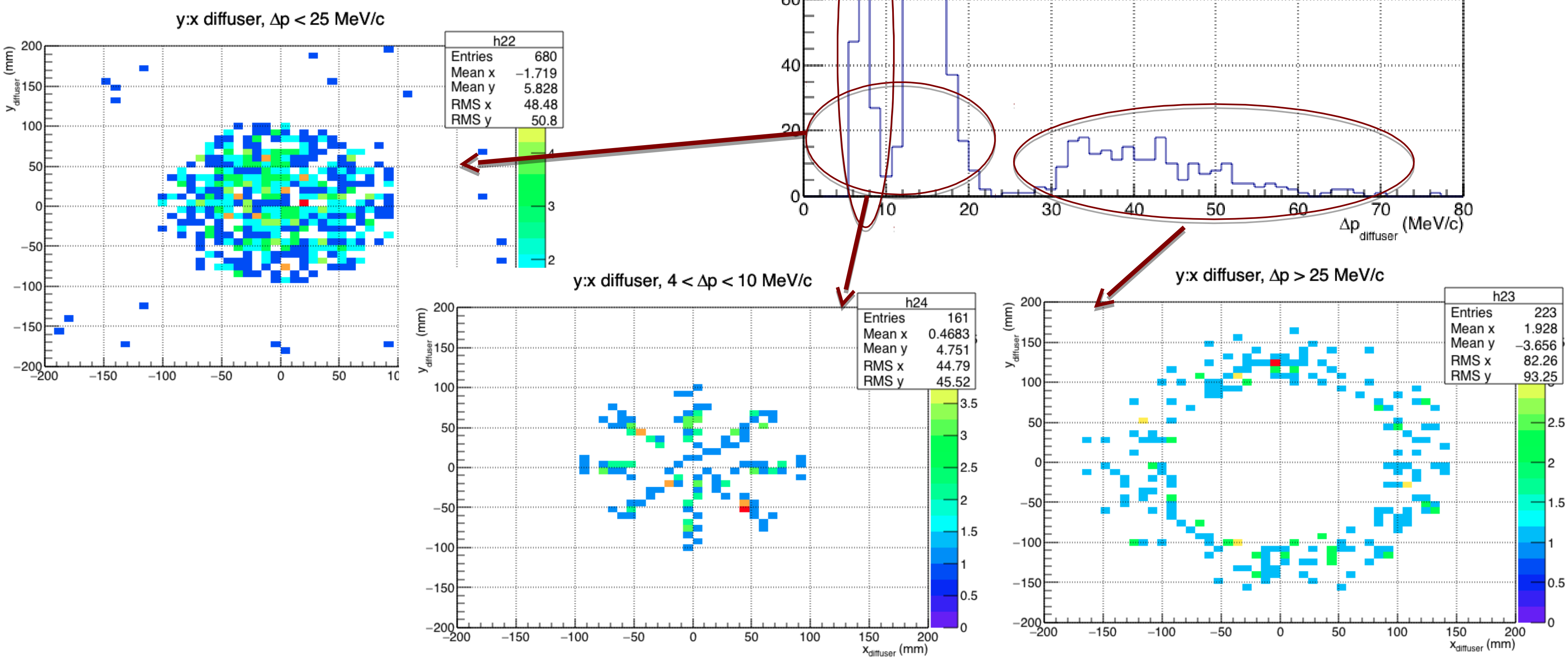
- Pz resolution ~ 5 MeV/c
- px, py ~ 1.5 MeV/c



Energy straggling in diffuser

- 2.8mm W iris closed ~ 0.8 X0
- All other irises stowed (open)
- Standard diffuser may not be suitable for this arrangement

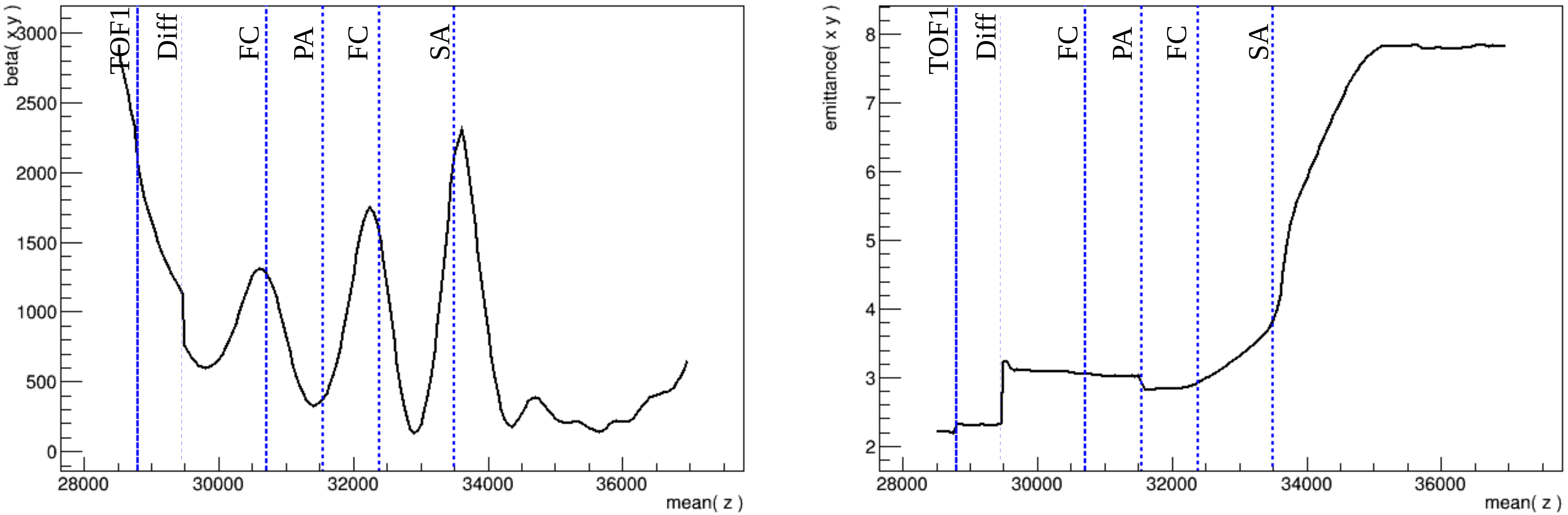




Other checks

- Tried Mark Rayner's transfer-matrix-based reconstruction
  - Modified to include momentum loss estimate due to ckov
  - Pz biased by ~ 5 MeV/c, not explored further
- Tried adding a tracker station between Q7 and Q8
  - No real improvement in resolution for default quad settings
- Checked that downstream tracker reconstruction was not affected by upstream issues

Matching into FCU



- Matching done using G4BL deck
  - Full simulation from the target
  - Includes descoped MICE channel
- Optical beta function match looks okay
  - But significant emittance growth
  - Issue with momentum spread/chromatic aberrations?
  - Under investigation

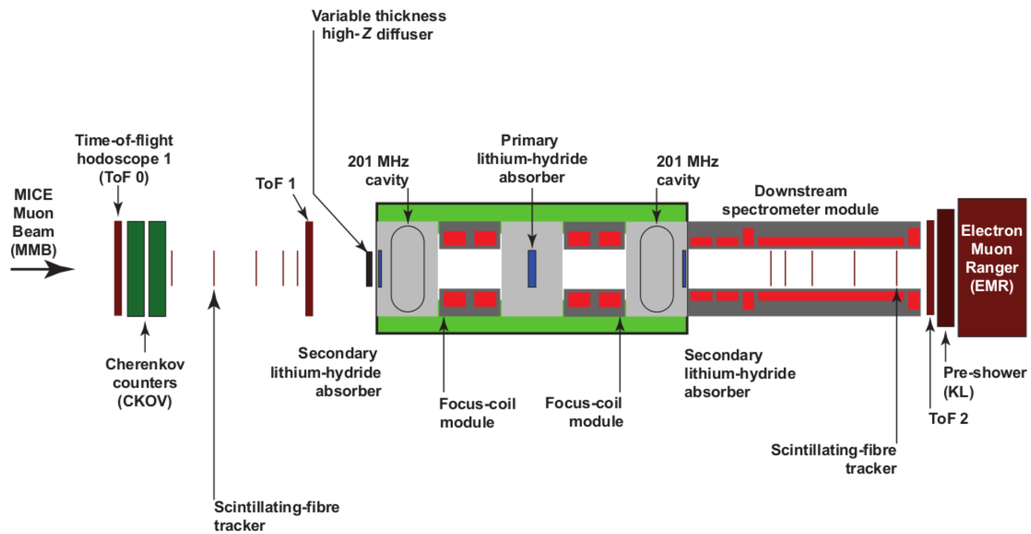
Comments (1)

- Engineering and layout:
  - Tracker stations require at least 150 mm clearance according to Geoff Barber
  - Clearance between TOF0 and Ckov is very tight (142 cm), will require moving TOF0/Ckov to fit a tracker station in
  - Placing a tracker station between Q7-Q8 assumes there's no field in that region. This needs to be measured/verified in the Hall with Q789 turned on
- Tracker infrastructure:
  - Having stations spaced far apart makes it tricky servicing them with the same cryo
  - 1 Plane at Q7-Q8, 2 planes at TOF1 can be serviced by a cryo
  - TOF0 which is behind the wall will need a separate cryo

Comments (2)

- Diffuser:
  - Diffuser position: Have assumed diffuser is placed just upstream of the first secondary absorber
  - Matching optics may dictate that it be moved slightly
  - Having 2 tracker stations downstream of the diffuser – if they can be accommodated -- will (should) help with reconstruction – study not complete
- Statistics:
  - For a difference measurement statistical requirements are greater by factor 10
  - Statistical errors arise from sampling the beam distribution
  - (In upstream vs downstream measurement, statistical errors arise from sampling the scattering distribution only)
  - MICE Note 268
  - What about statistics required for systematics reduction?

Conclusions



Conclusions

- SS2 in upstream position
  - Can we get sufficient downstream detector performance?
    - Yes; the detector resolution is somewhat worse, but still manageable
  - Does the beam scrape too much in TKD?
    - TKD becomes the limiting aperture; the transmission is worse, but a clear emittance reduction signal is visible
- SS2 in downstream position
  - Can we find a viable optics to match to FCU?
    - Not yet, but it looks promising
  - Can we reconstruct well enough in the Quads+diffuser OR do a difference (absorber in vs out) measurement?
    - A difference measurement is viable assuming we can match to FCU
    - Need to understand better the effects of the diffuser on resolutions