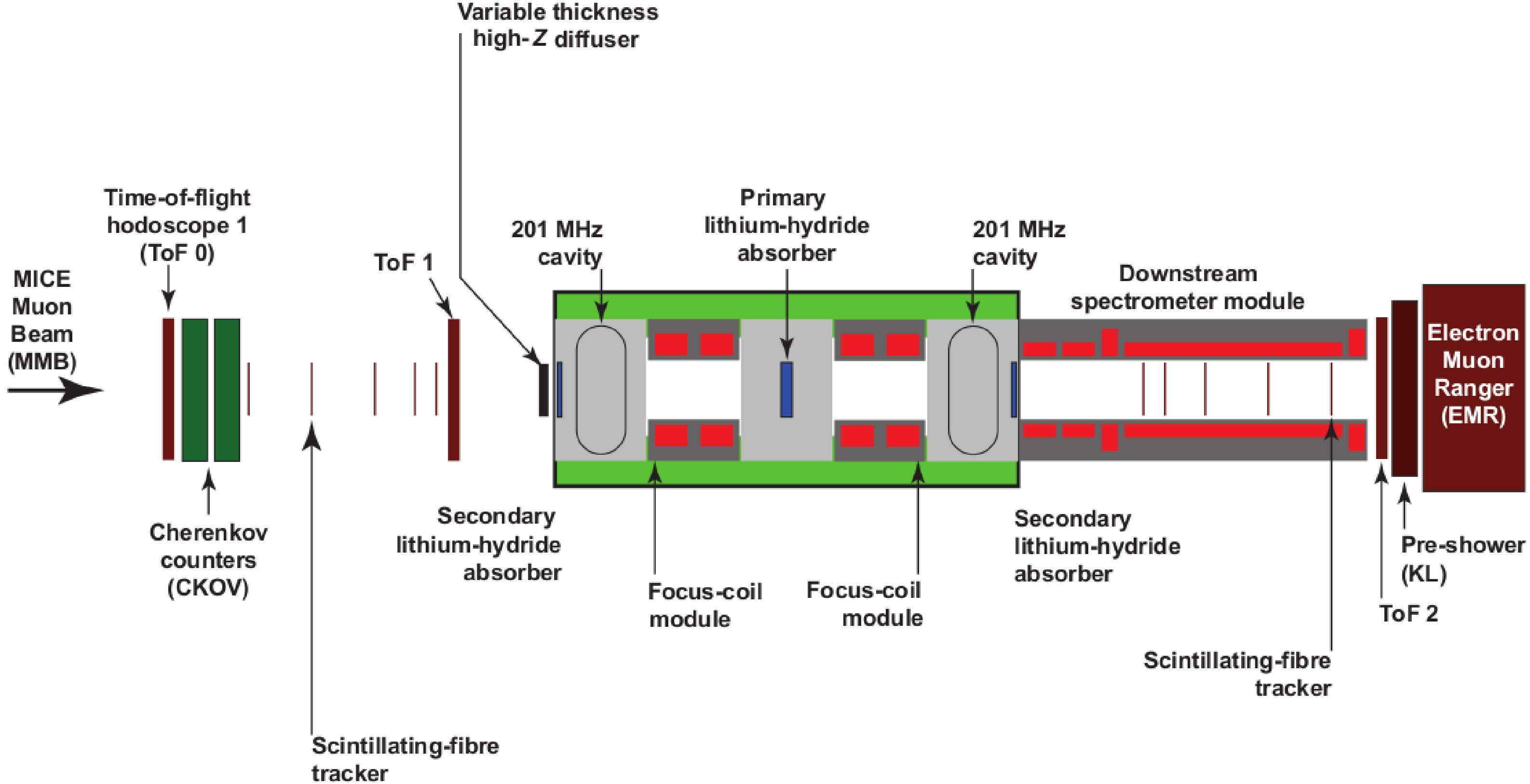
# MICE Descope - Options

C.T.  Rogers, D. Rajaram, P. Franchini, F. Drielsma, J. Tarrant, ...

# MICE Descope Options

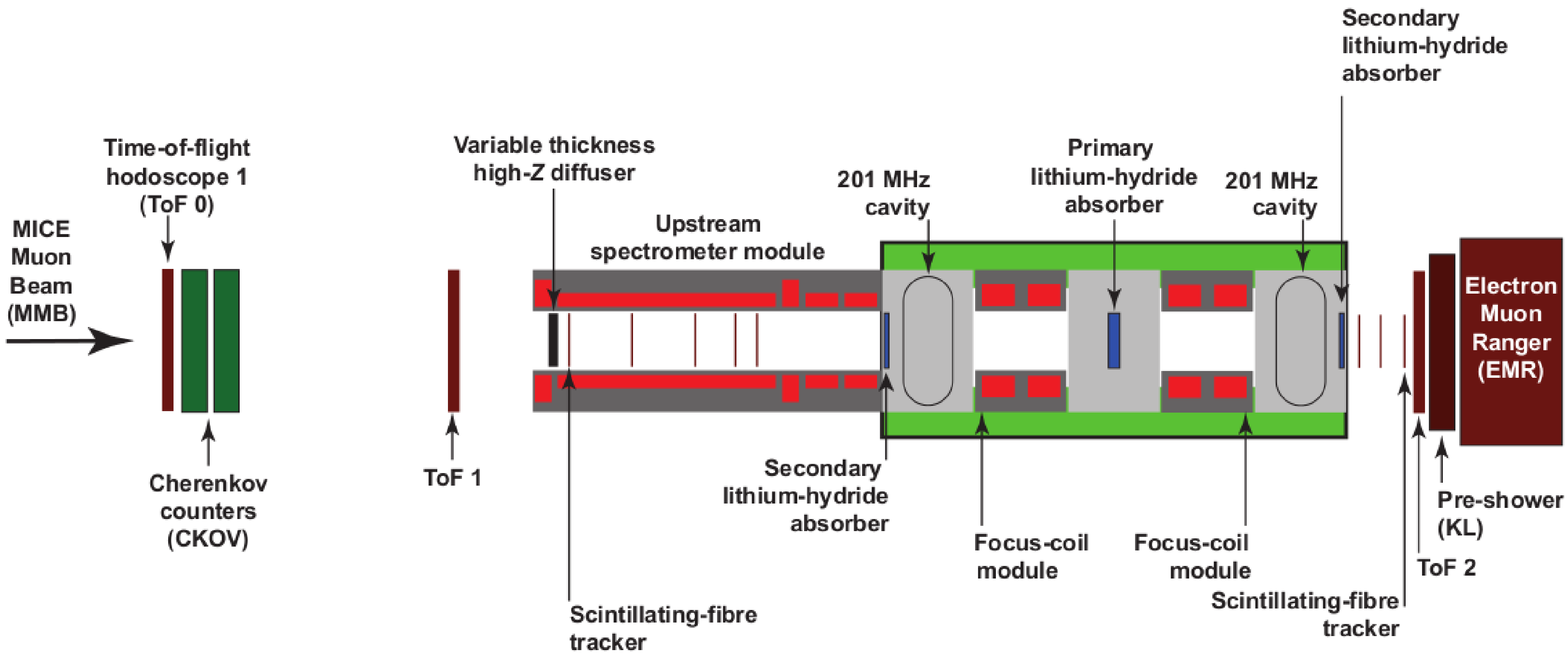
- SS2 in downstream, no SS1
  - Measurement can be a difference measurement, i.e. absorber in vs absorber out
  - Upstream diagnostics for beam sampling or to control systematic due to instability in input beam
- SS2 in upstream, no SS1
  - Tracker straight tracks for x, x', y, y'
  - EMR range for pz
  - 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 → V/sqrt(2)

# SS2 in downstream



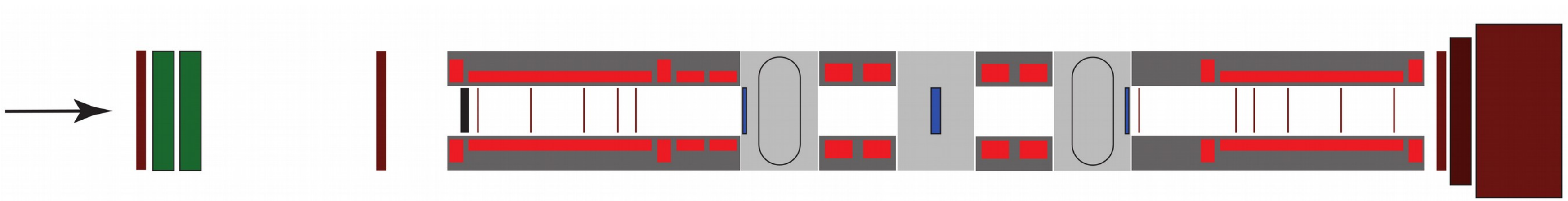

- Questions
  - Can we find a viable optics to match to FCU?
  - Can we reconstruct well enough in the Quads+diffuser OR do a difference (absorber in vs out) measurement?

# SS2 in upstream




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

# SS2 in upstream

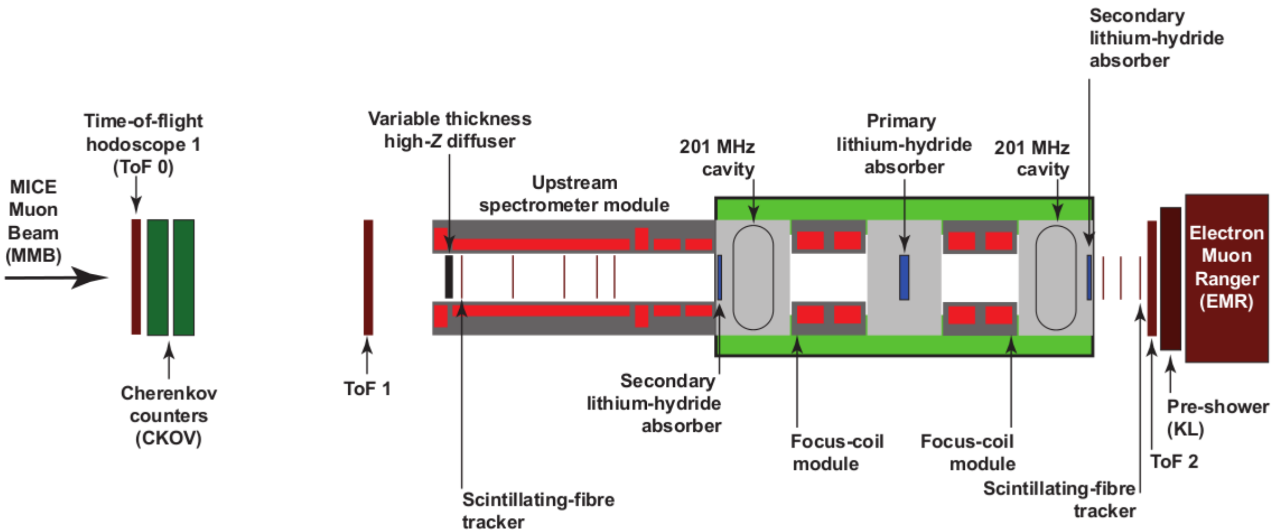


- Questions
  - Can we get a reasonable optics?
  - Can we rotate SS1 and improve the situation?
  - Is the risk of further issues with SS1 too great?
  - See talk by Jaroslaw

# Optioneering

- Tracker upstream
  - Fabrication is complicated; many tracker pieces in many locations; cabling to two available cryostats challenging
  - Reconstruction in upstream region is difficult; quads are not well-characterised
  - Match to FCU is tricky
  - Upstream reconstruction, through diffuser, leaves large uncertainty in energy straggling
  - Stability of upstream beamline has not been proven
- SSD turned around
  - Still rely on potentially unstable magnet
  - Concern for mechanical stability/force between FC and SSD
  - Poor transmission to downstream PID detectors
- Adopted “tracker downstream” option as baseline

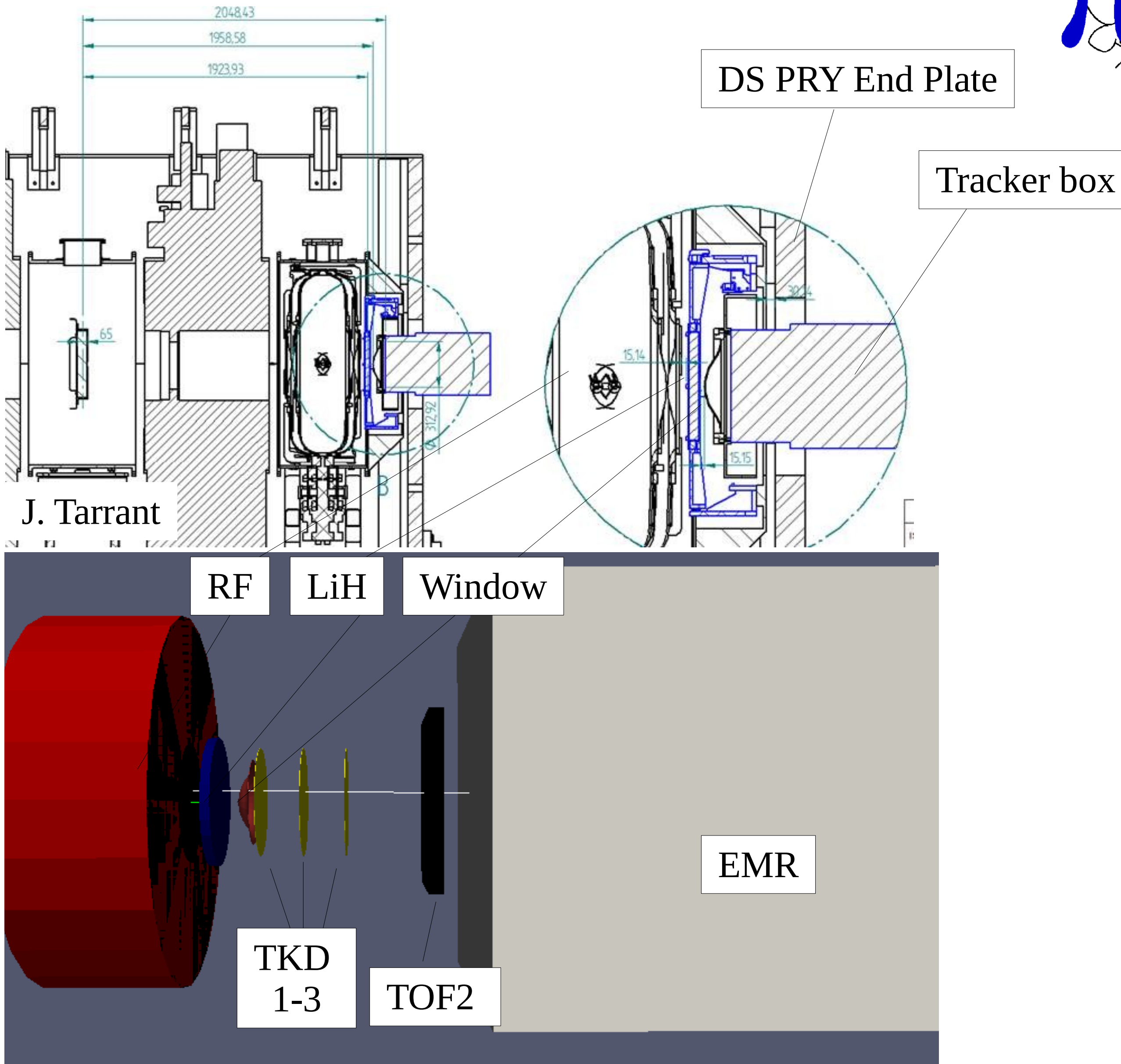
# SS2 Upstream Option



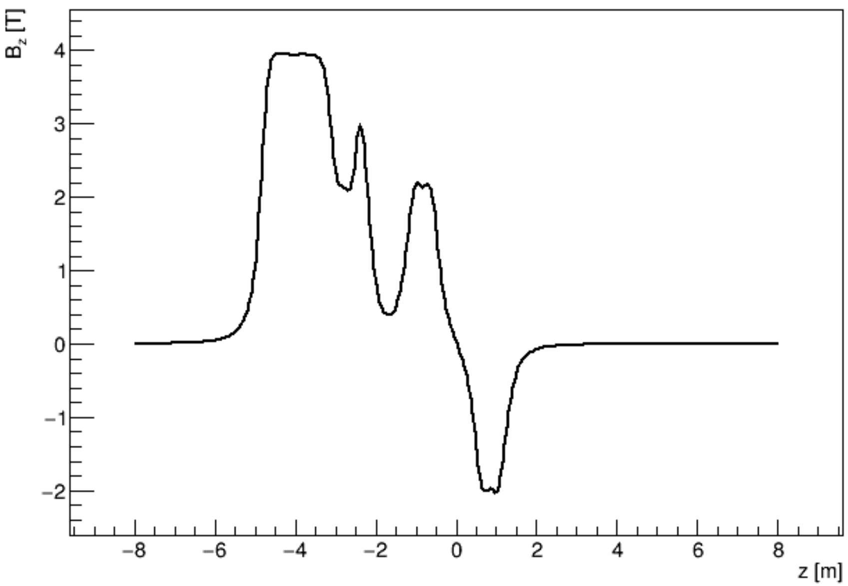
# Revised Detector Configuration

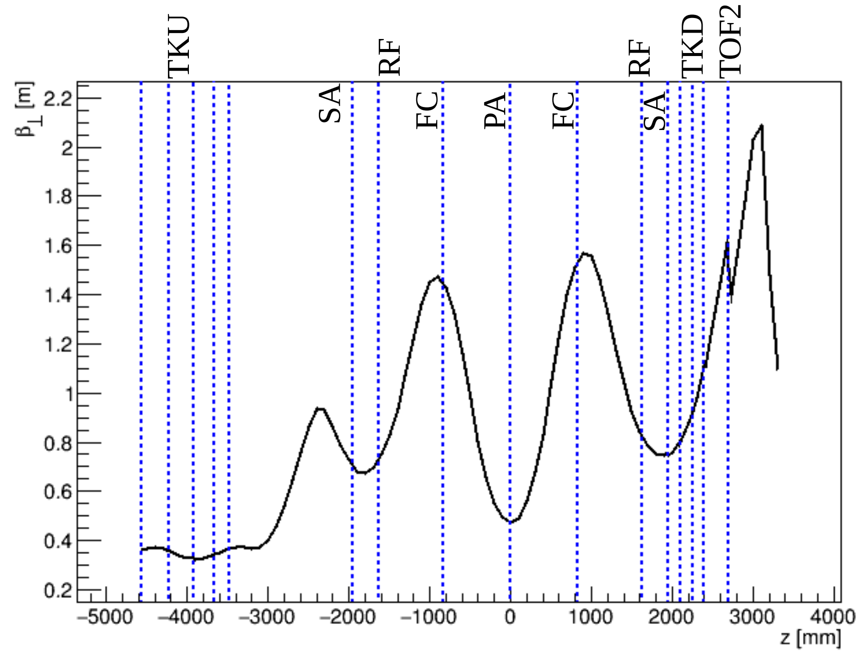
- Use TKD to measure x, x', y, y'
- Use EMR to measure range => momentum
- Combined fit between EMR, TOF2 and TKD to get phase space at downstream end
  - Focus in this talk on position and momentum resolutions
- 3 stations in TKD
  - 2 stations to make a straight track, $3^{rd}$ station for redundancy/noise 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



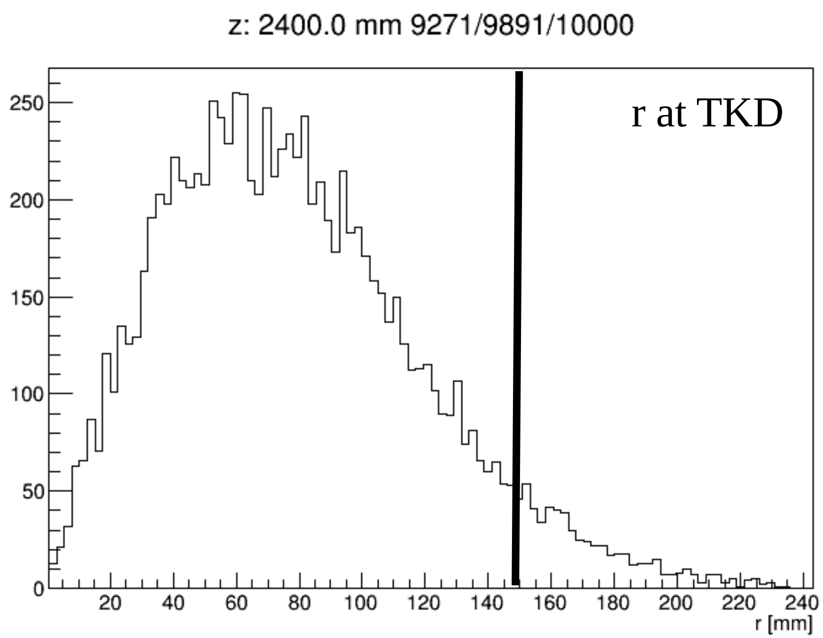
# Optics

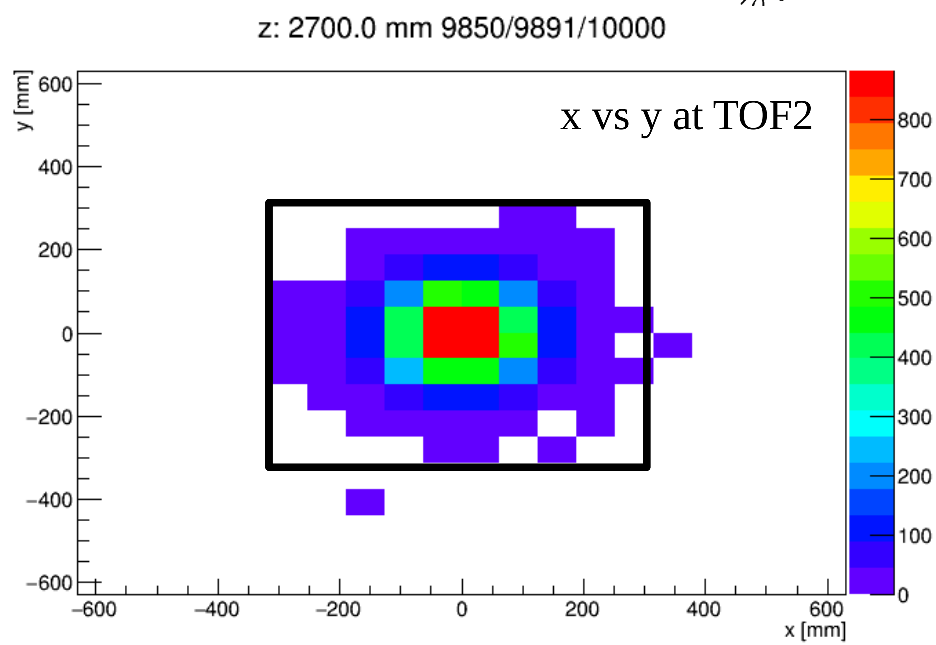



- Using modified version of 200 MeV/c Demo lattice
  - Remove SSD, keep currents/etc same

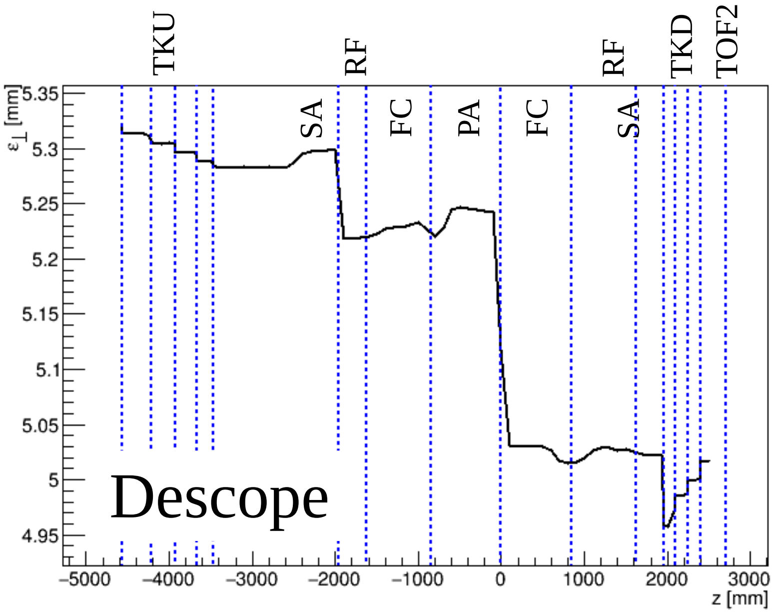
# Optics

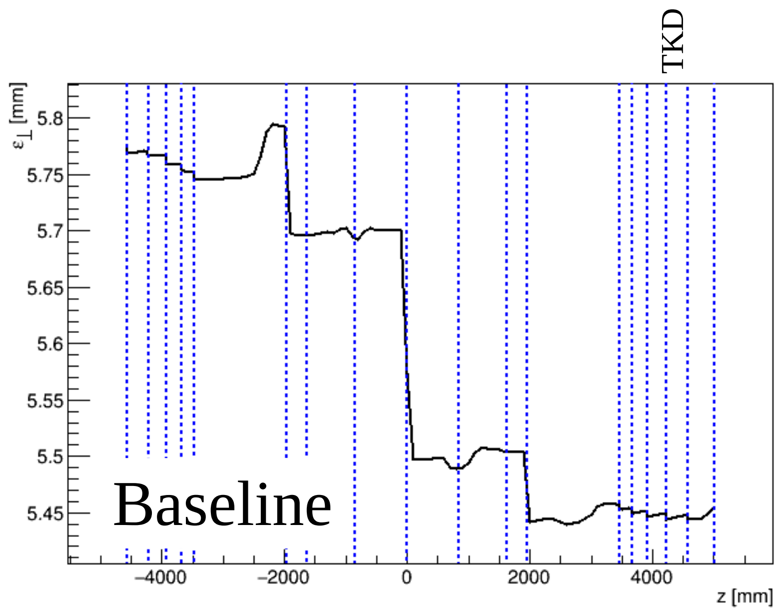



- Radial distribution at TKD station 3 for 6 mm emittance beam
  - 99 % of beam is transported to TKD
  - 93 % of beam is transported through TKD radial cut
- TKD becomes the limiting aperture

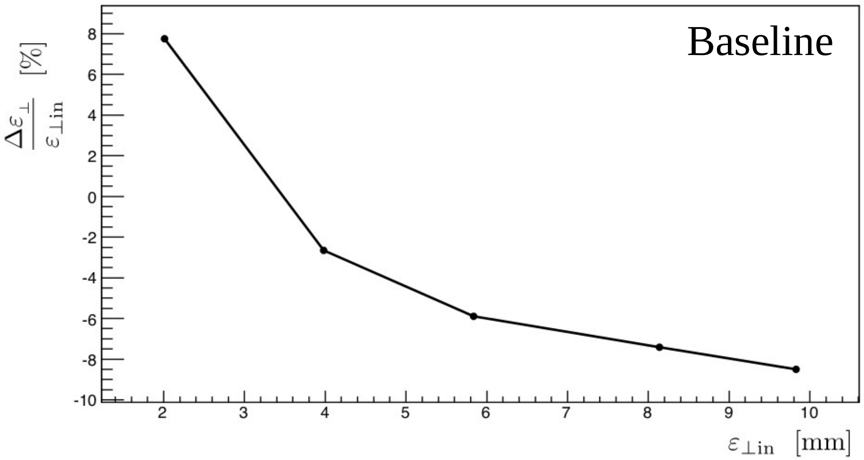
# Emittance Reduction

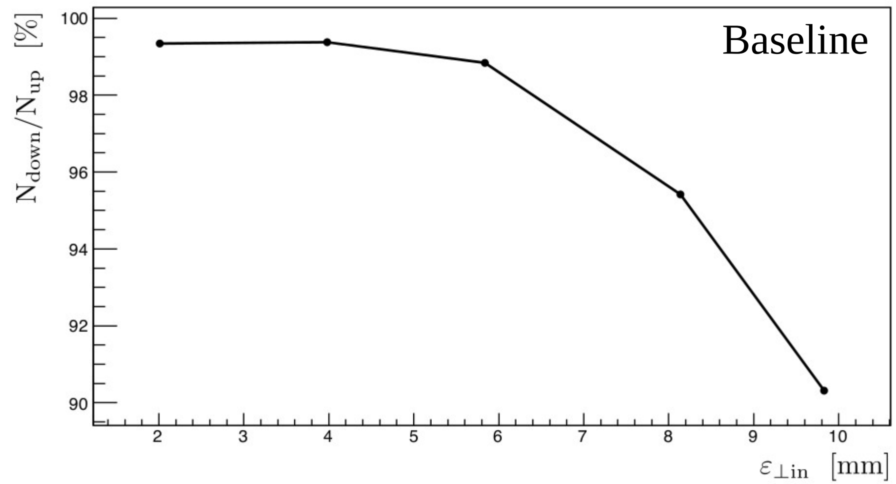



- See expected emittance reduction
- Transmission in descope – 93 %
- Transmission in baseline – 98 %
- Nb this is for initial beam emittance 6 mm nominal

# Cooling Performance




Descope:

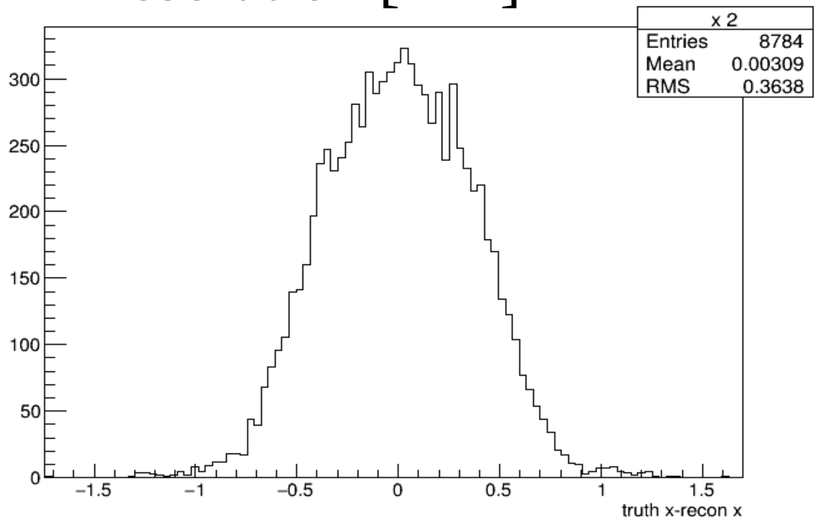
| Nominal emittance [mm] | Input emittance [mm] | Output emittance [mm] | Emittance Change [%] | Transmission [%] |
|---|---|---|---|---|
| 2.00 | 2.00 | 2.18 | 8.44 | 100.00 |
| 3.00 | 2.94 | 2.98 | 1.29 | 98.93 |
| 6.00 | 5.28 | 4.98 | -6.23 | 92.66 |
| 10.00 | 7.34 | 6.65 | -10.30 | 79.03 |

# Combined fit - algorithm

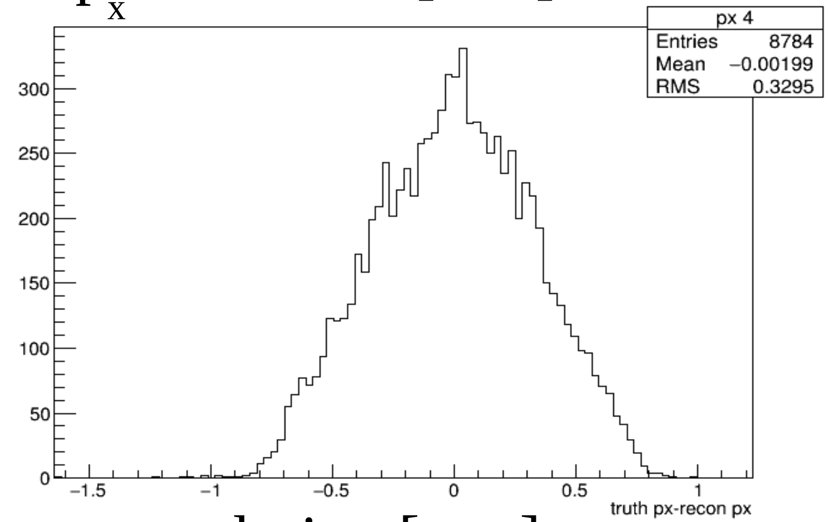
- Use x, y from TKD station 1
- Use x', y' calculated from TKD station 1 and station 2
- Extrapolate EMR track (incl x', y', x, y at EMR) back to tracker
  - Use Bethe Bloch formula to “undo” energy loss in TOF, air
  - Step size 1 mm
  - Use extrapolated total momentum to scale x', y' and deduce pz
- 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

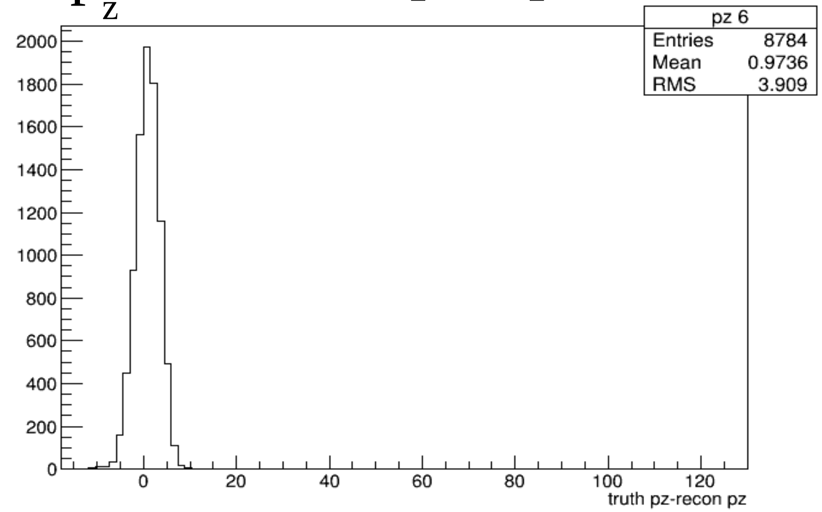
x resolution [mm]




$p_x$ resolution [mm]




$p_z$ 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

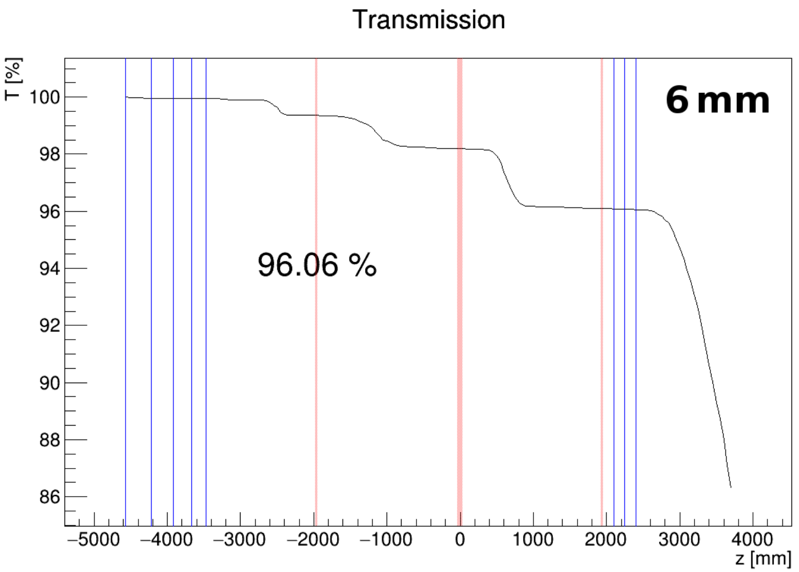
# Recon Performance

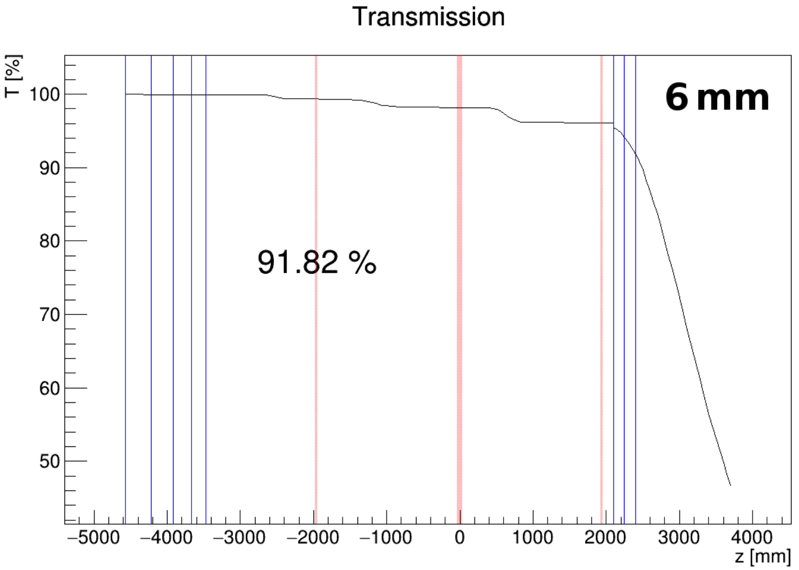
| True Emittance [mm] | Recon Emittance [mm] | Bias [%] |
|---|---|---|
| 2.18 | 2.22 | 1.73 |
| 3.02 | 3.05 | 1.29 |
| 5.12 | 5.17 | 0.86 |
| 6.94 | 6.99 | 0.78 |

- 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

# Transmission (F. Drielsma)

- Scraping bias is significant
- Consider aperture from TKD
  - Try 150 mm (TKD)
  - Try 300 mm cylinder (TOF2)
- 91.82 % for 3 station/150 mm spacing



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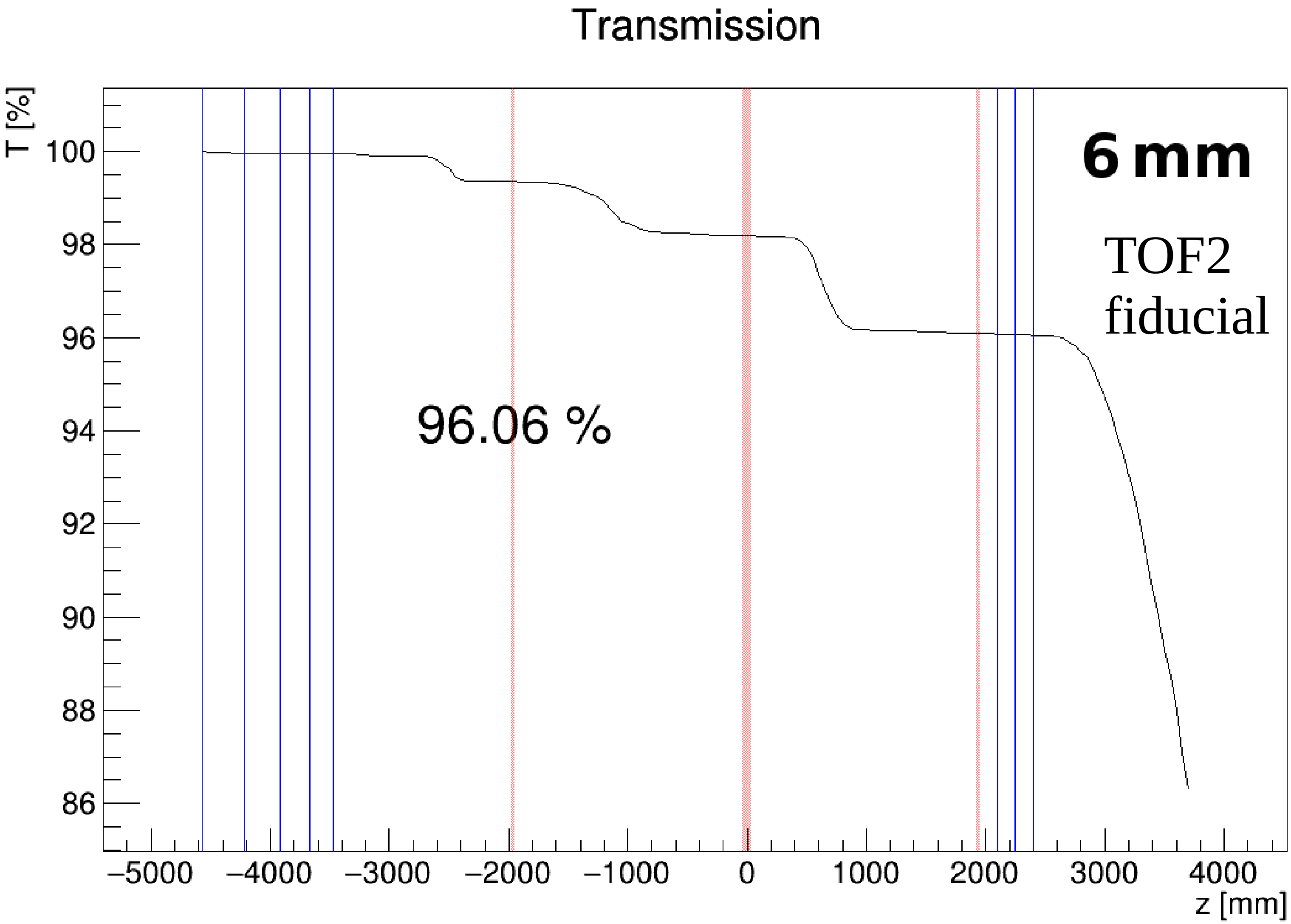

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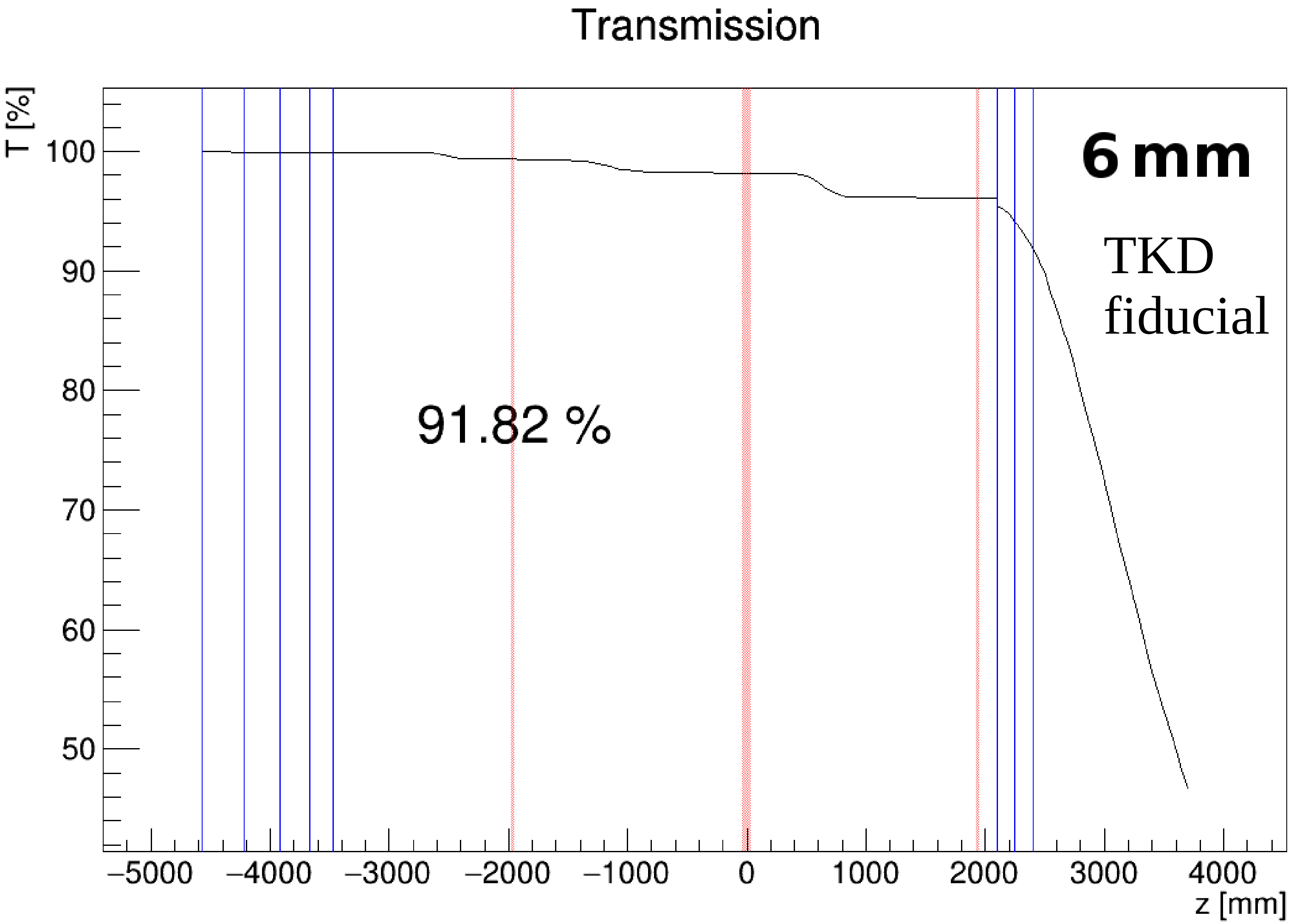
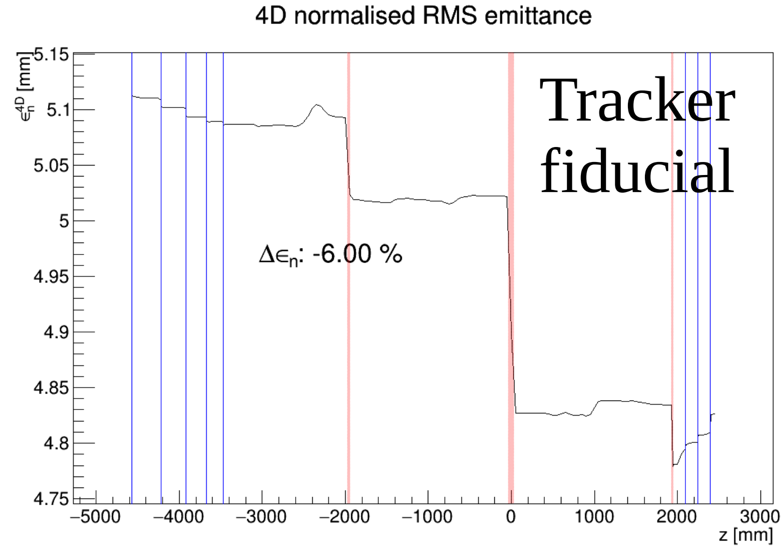
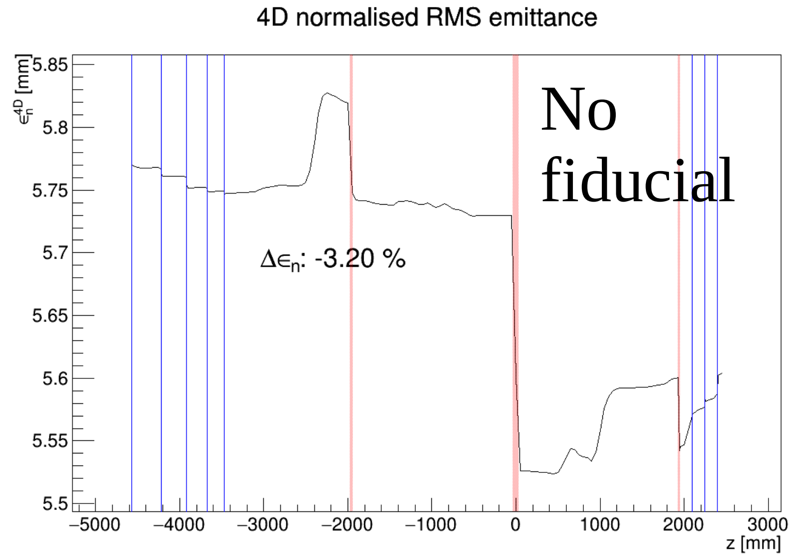


# Scraping Bias (F Drielsma)

- Scraping bias is significant
- → seek to make tracker as short as possible
- Difficult to distinguish between optical effects and scraping
  - Retry with transfer matrix driven transport?
  - Amplitude-based analysis?



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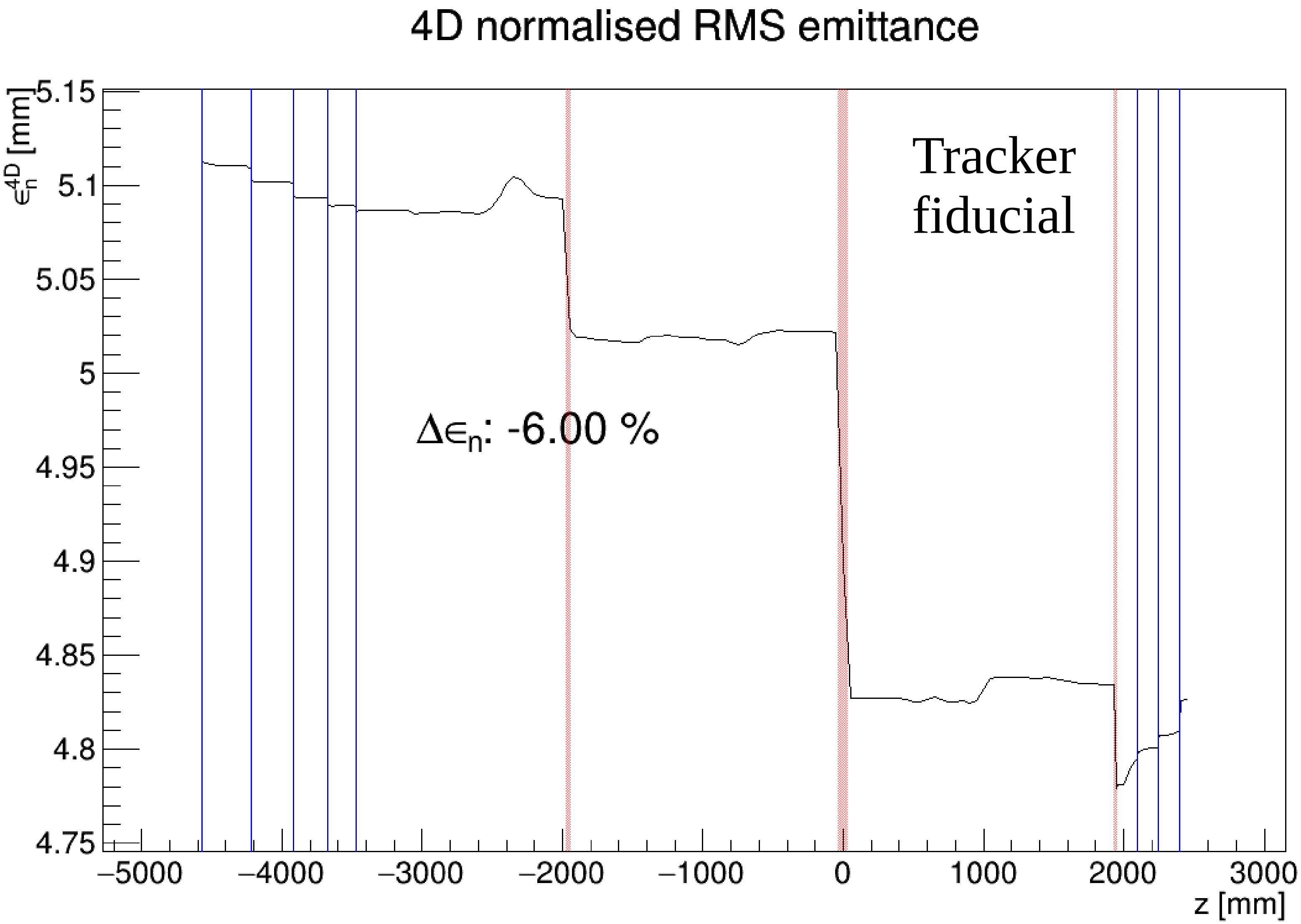

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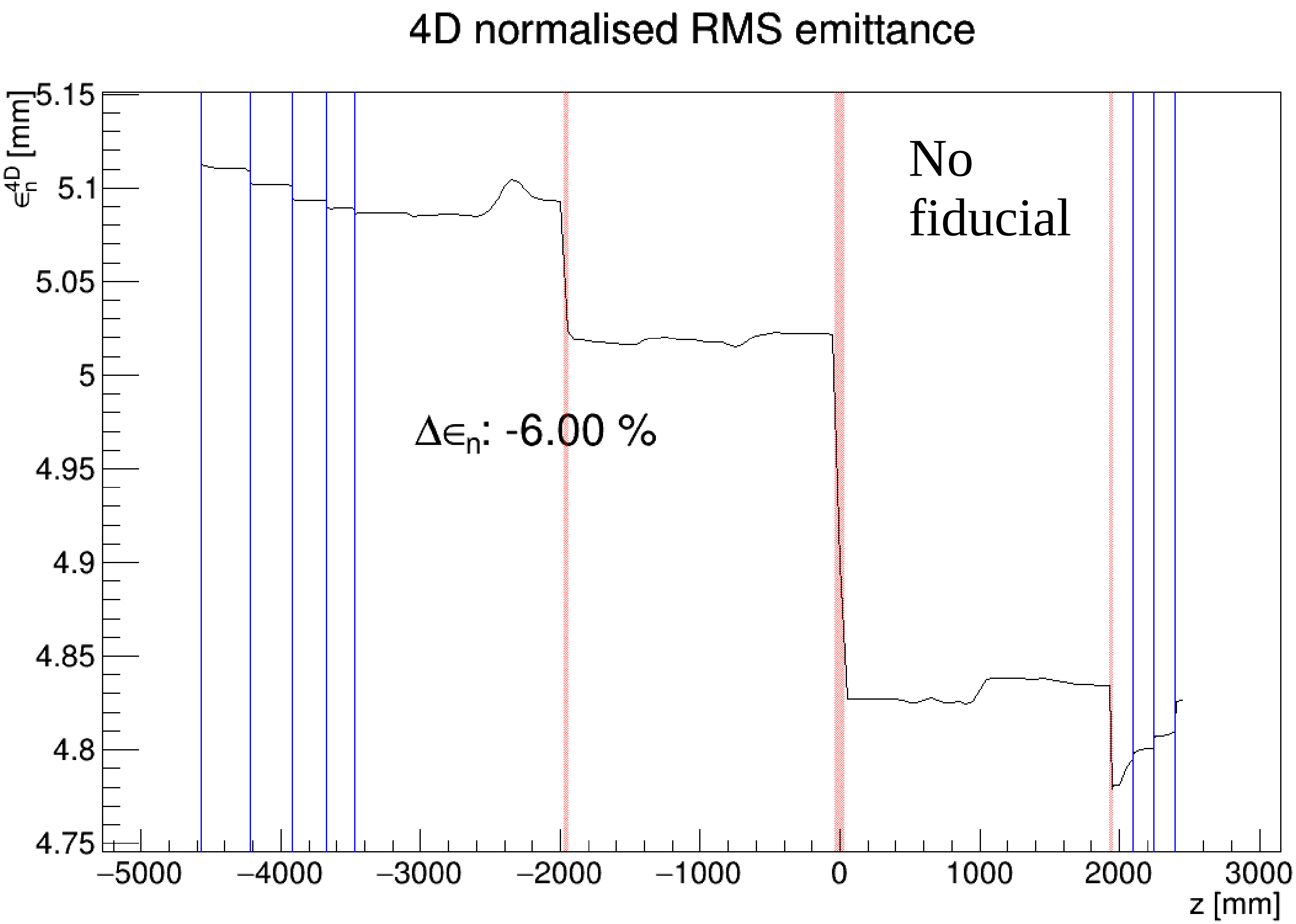


# Biases and Errors

| | 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 |

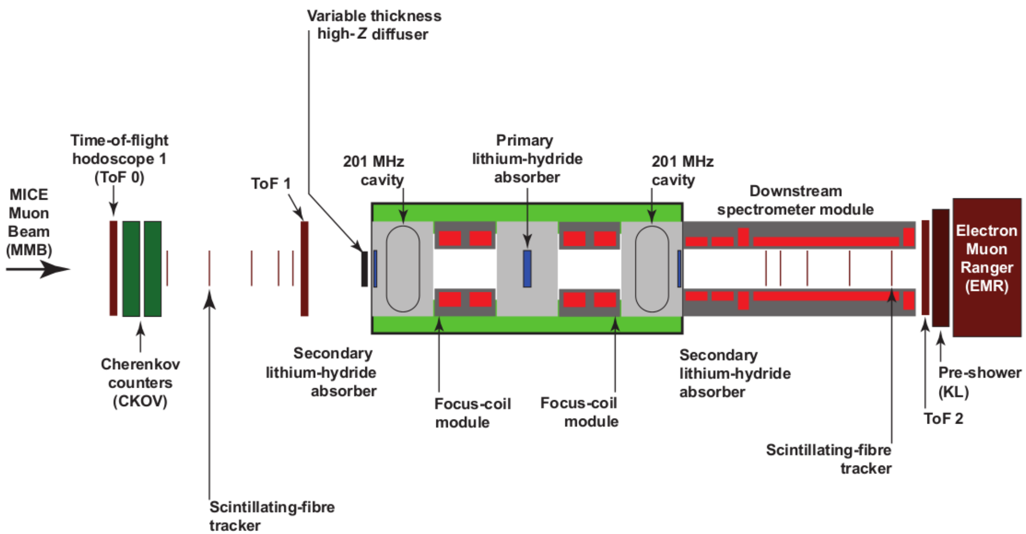
# Practical Matters

- 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)
- Study of TKD efficiency in progress
  - 3 stations or 4 stations?

# 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

# 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