Capture & Cooling Update

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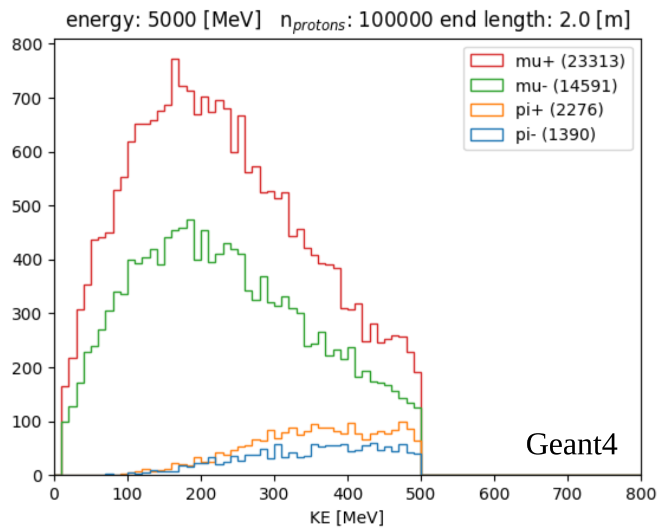
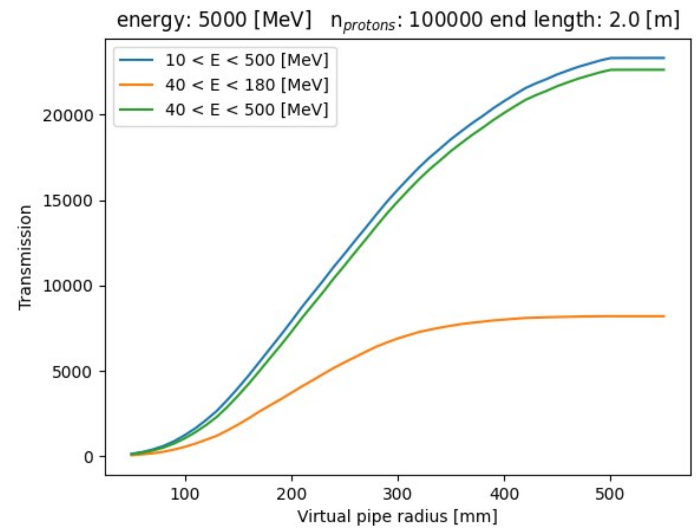
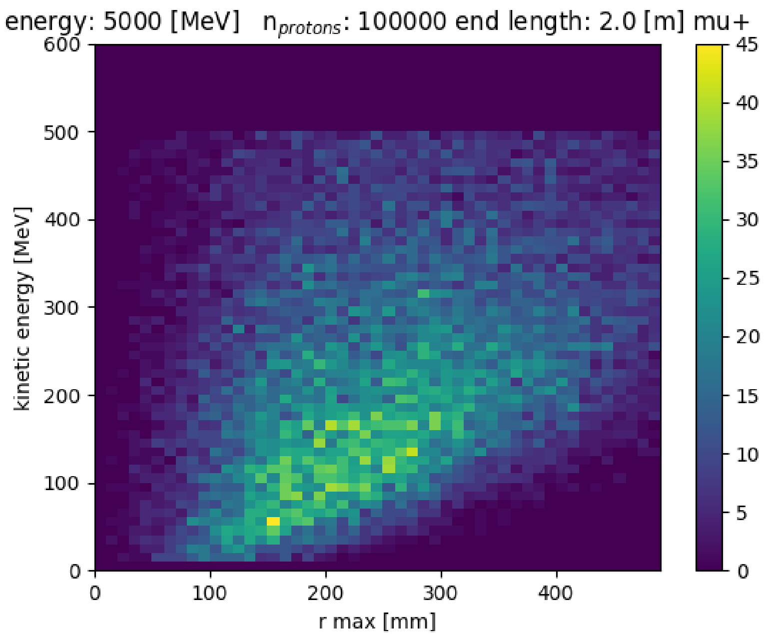
DA and cooling optimisation

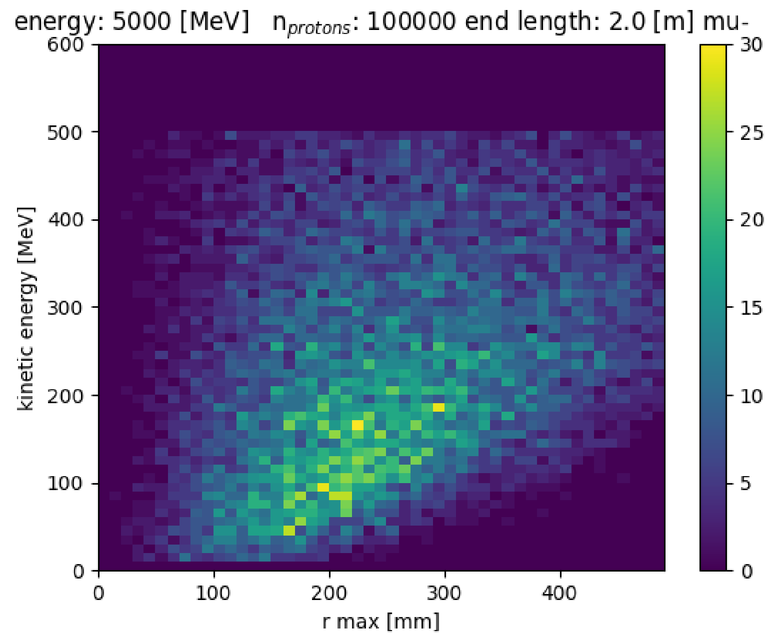
- Rectilinear cooling design is approaching a release version
  - Thanks to Ruihu!
  - Ruihu's design now frozen → publication
  - http://arxiv.org/abs/2409.02613
- Major beam loss at entrance to the cooling system
  - Associated with aperture at 352 MHz
  - Investigate 176 MHz instead
    - Half frequency → double the aperture!
- Can we capture at 176 MHz?
  - Update to the front end…
  - Also of interest to look at few other front end optimisations
- Reminder: challenge is to improve muon production by x2

Muon/pion yield (from last time)

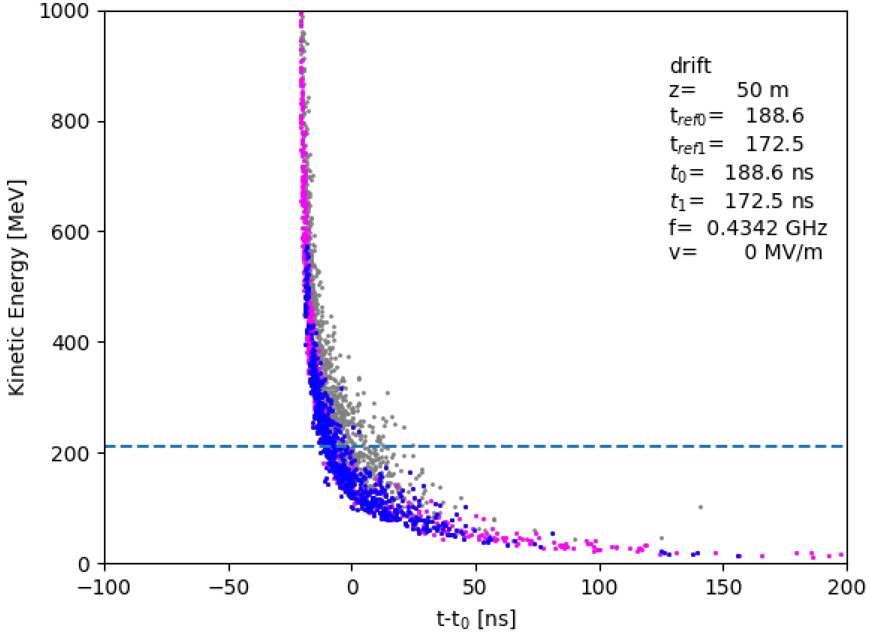


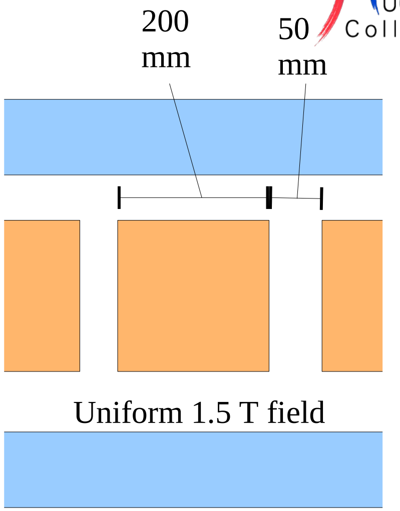






RF Capture





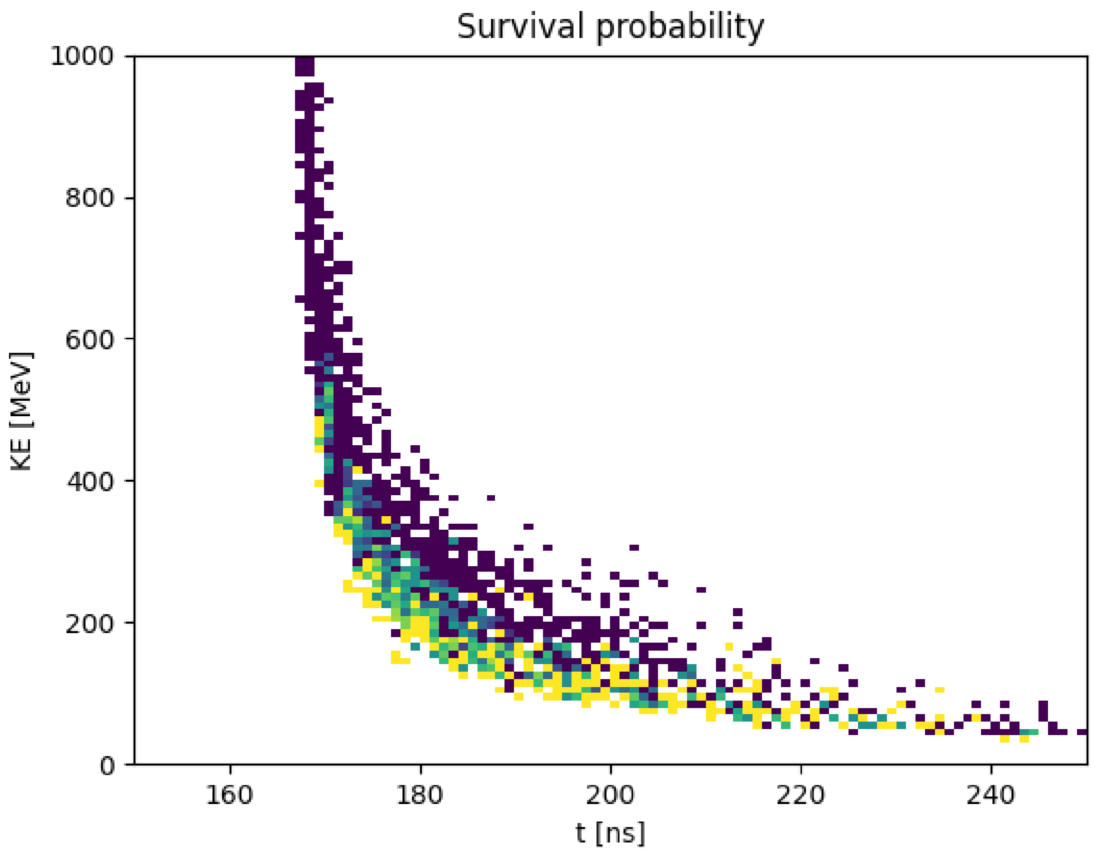
$E = V \sin(2\pi f (t - t_0))$
TM_{010} Bessel functions
No windows

- Looking at full beam capture performance
  - 50 buncher cells
  - 100 rotator cells
- Two loss mechanisms:
  - Longitudinal loss
    - Not captured in the RF
  - Transverse loss – hitting the RF cavity iris
    - Assume iris factor ~ 0.5
  - Successfully captured

Movie

- Seemed like last time, longitudinal capture performance was pretty flat with buncher length
  - Prefer instead to go for largest apertures → transverse acceptance
  - Push for shorter buncher/phase rotator systems

Survival probability

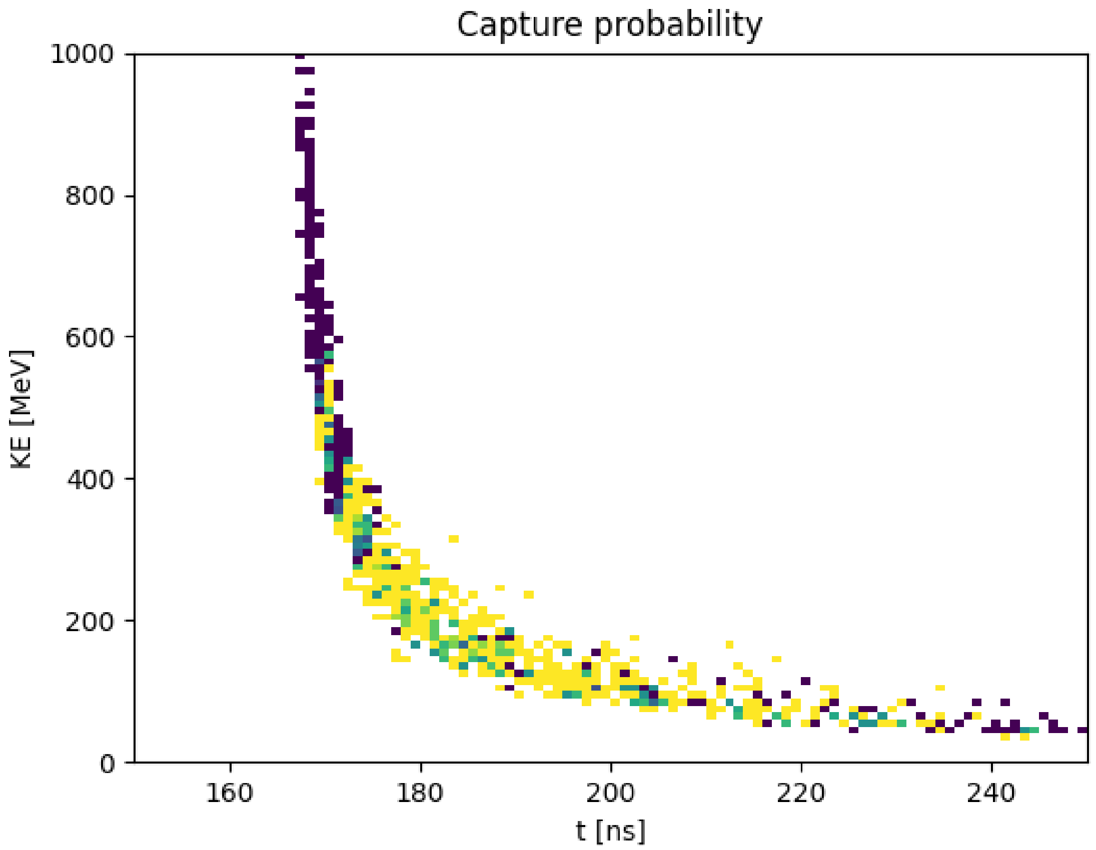


Look at initial sample of muons

What is the probability that those particles are transmitted and captured

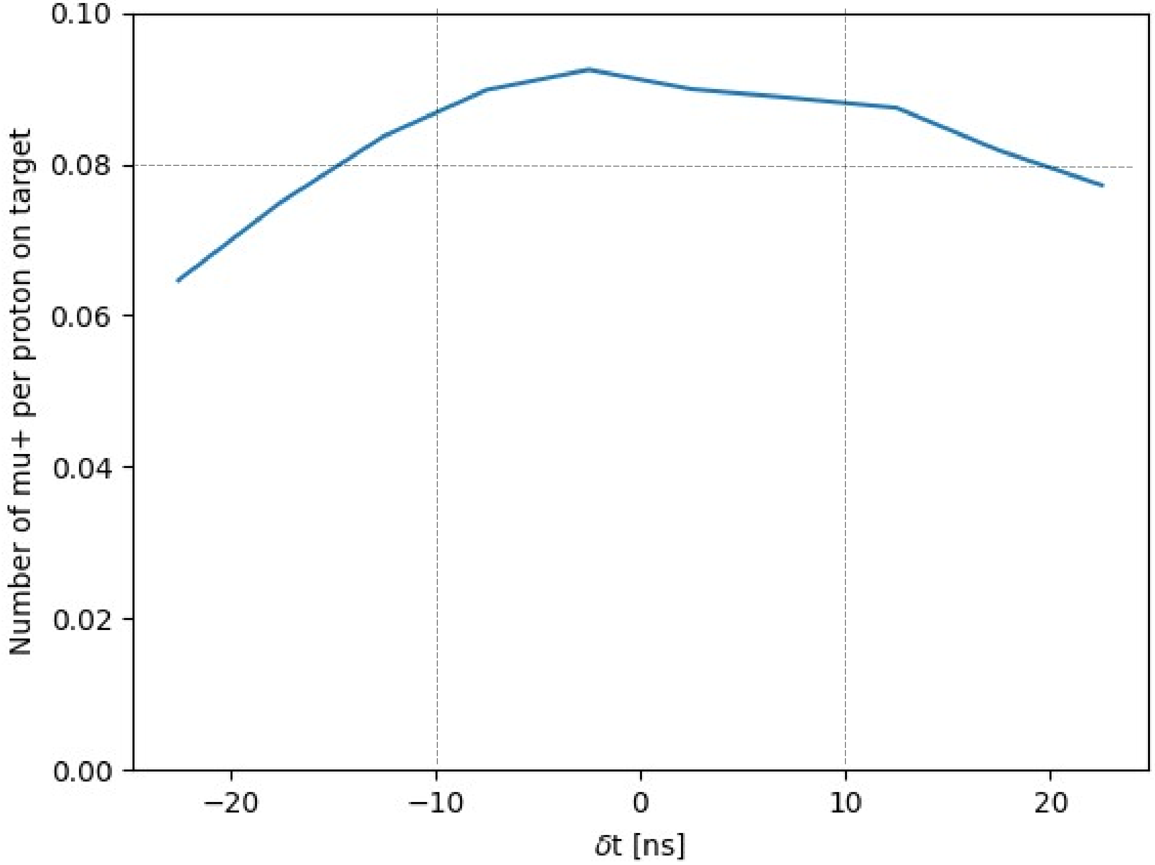
- First cavity had iris r=264 mm
- Yellow – 100 % captured; Blue – 0 % captured

Survival probability



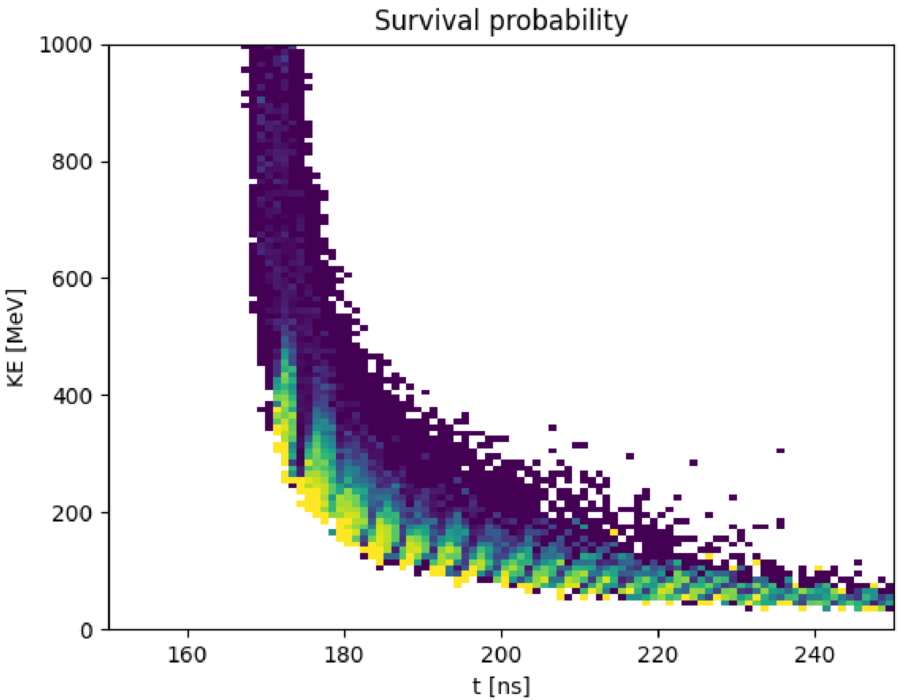
Look at sample of muons that make it to the end
What is the probability that those particles are also captured

Yield



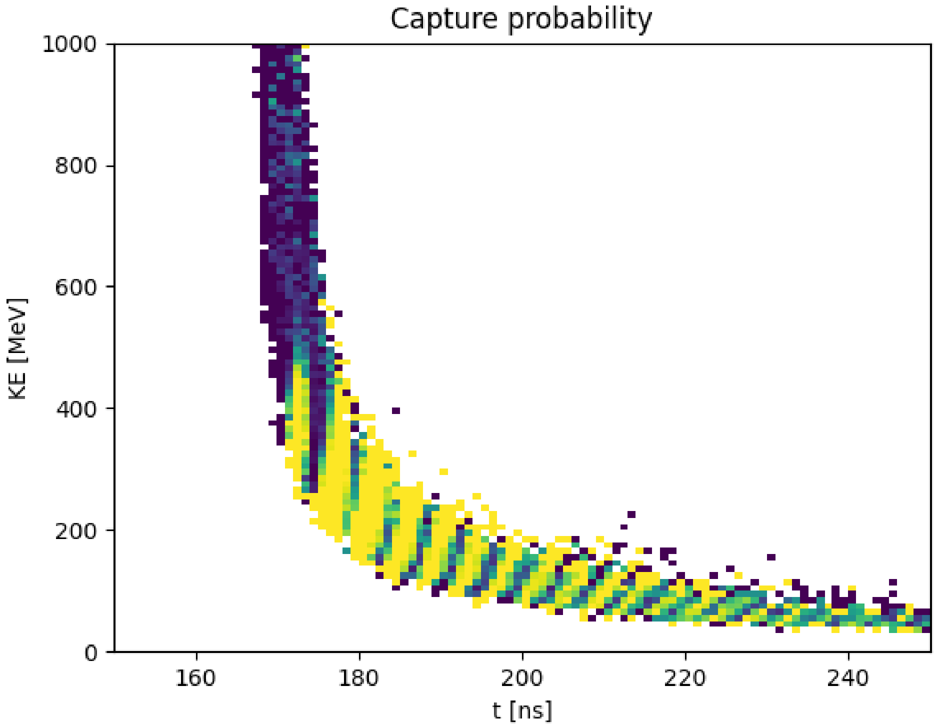
Calculate mu+ yield per [5 GeV] proton on target
Introduce time delay in muons;
What happens if a muon arrives early or late

No buncher



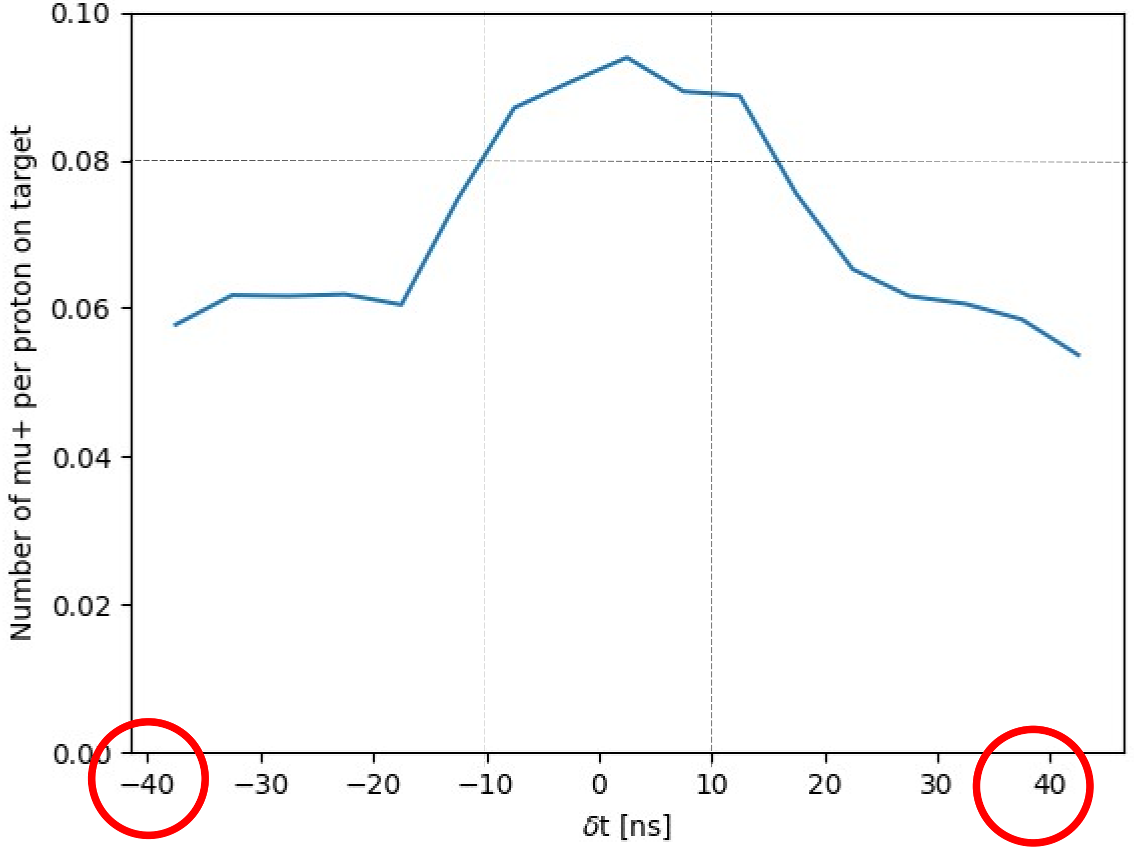
- Try with just the rotator
  - Just 100 rotator cavities (25 metres)
  - Max gradient is 12 MV/m and 80 % packing factor
  - First cavity had iris r=264 mm
  - Lower frequency → better transverse acceptance

No buncher



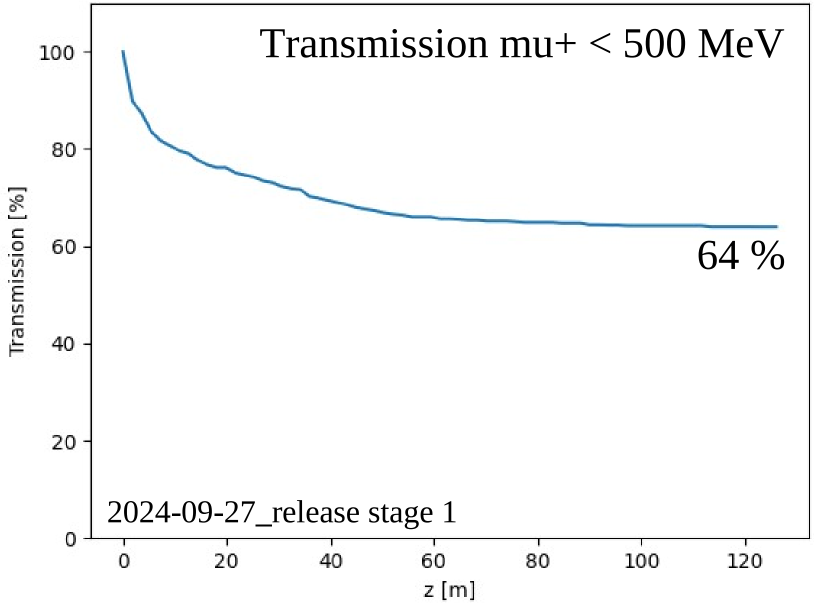
- Capture probability for those that survive the RF cavity aperture

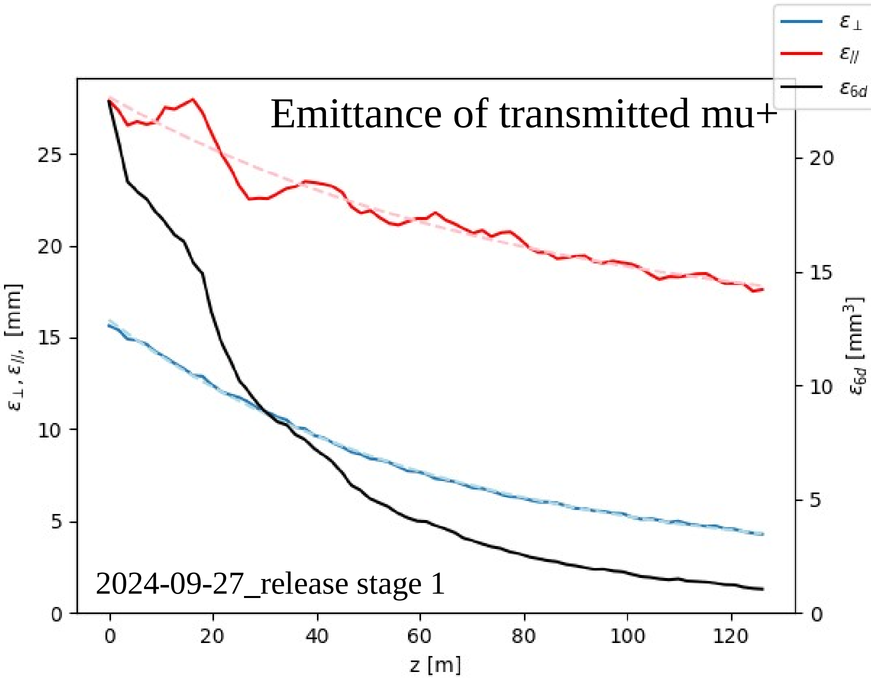
No buncher



Calculate mu+ yield per [5 GeV] proton on target
Similar yield for short proton bunch
Worse yield expected for long proton bunch

Cooling - Baseline



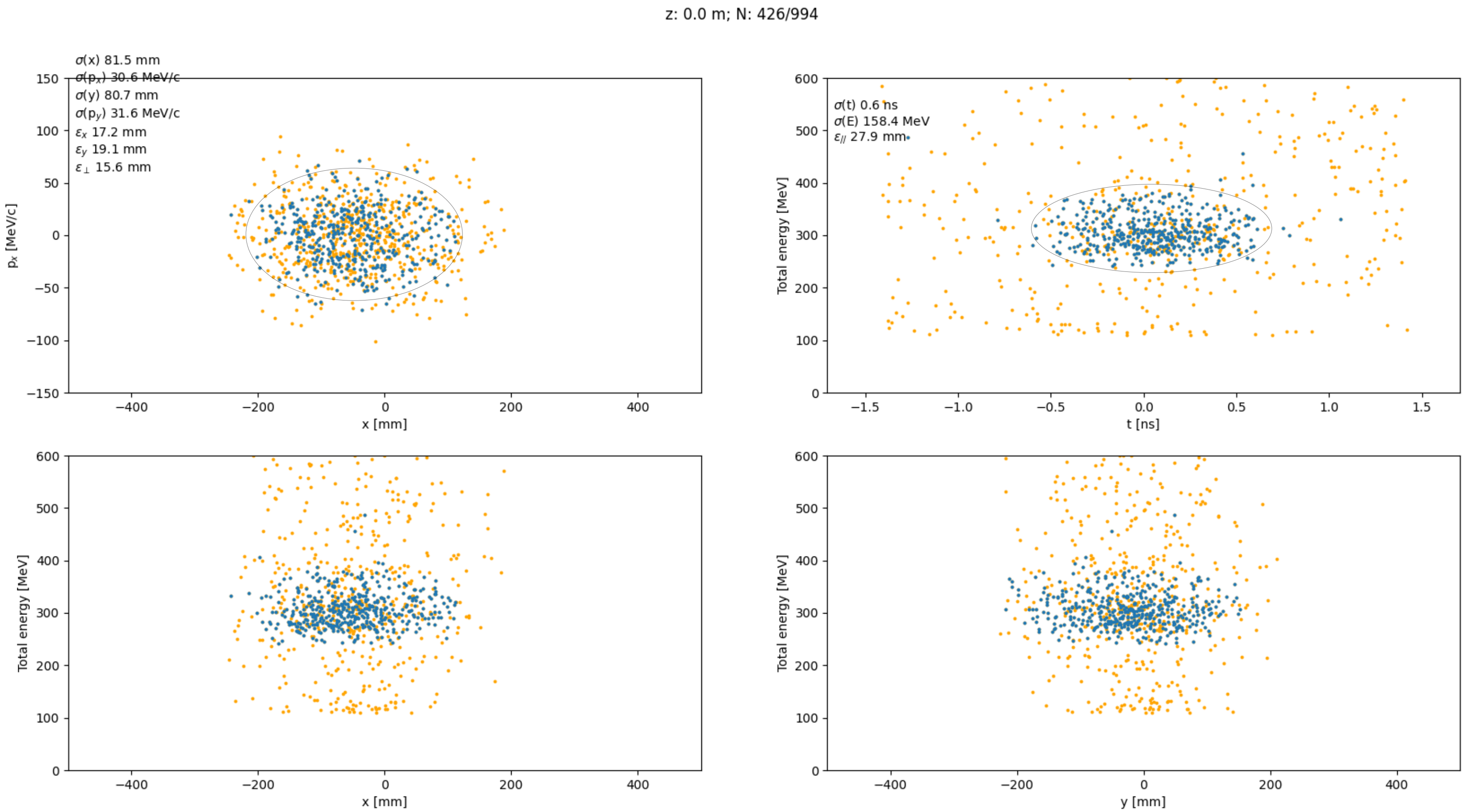


- How does this look for the cooling?
- Compare with Ruihu's lattice
  - Baseline on github
  - 2024-09-27_release version
  - Stage 1
  - Rogers analysis script (not ecalc9)
  - No decays

	Cell Length m	Stage Length m	Pipe Radius cm	Max. B_z On-Axis T	Int. B_y Tm	$\beta_\perp$ cm	D_x mm	lH_2 wedge On-Axis Wedge Len. cm	lH_2 wedge Wedge Angle deg
A-Stage 1	1.8	104.4	28	2.5	0.102	70	-60	14.5	45

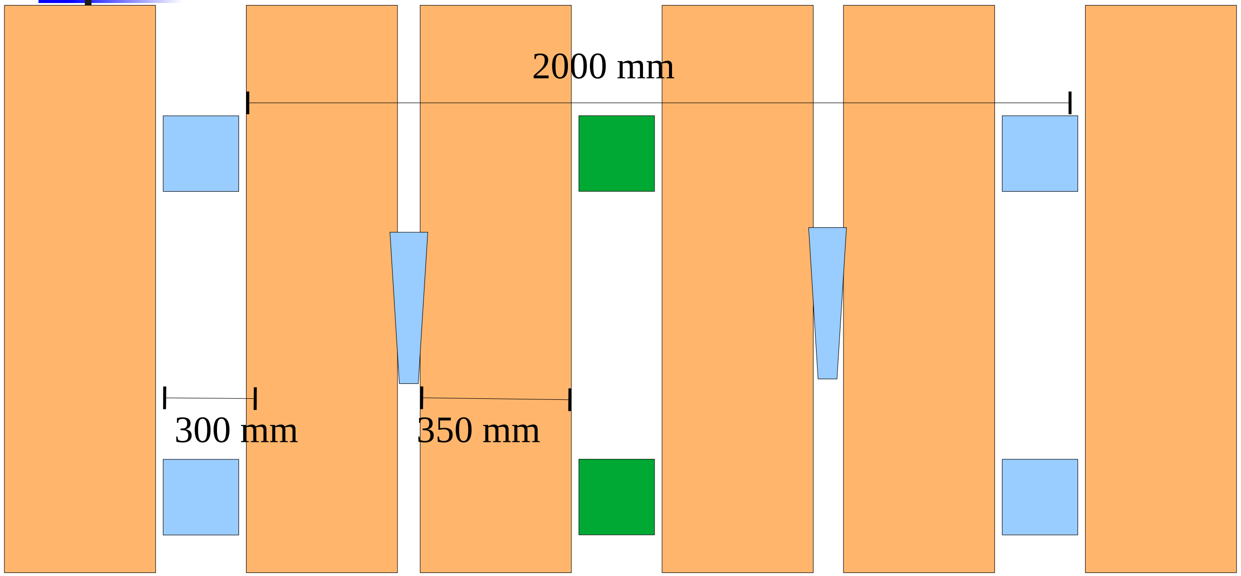
	RF Frequency MHz	Num. RF	RF Length cm	Max. RF Gradient MV/m	RF phase deg
A-Stage 1	352	6	19	27.4	18.5

Cooling - Baseline



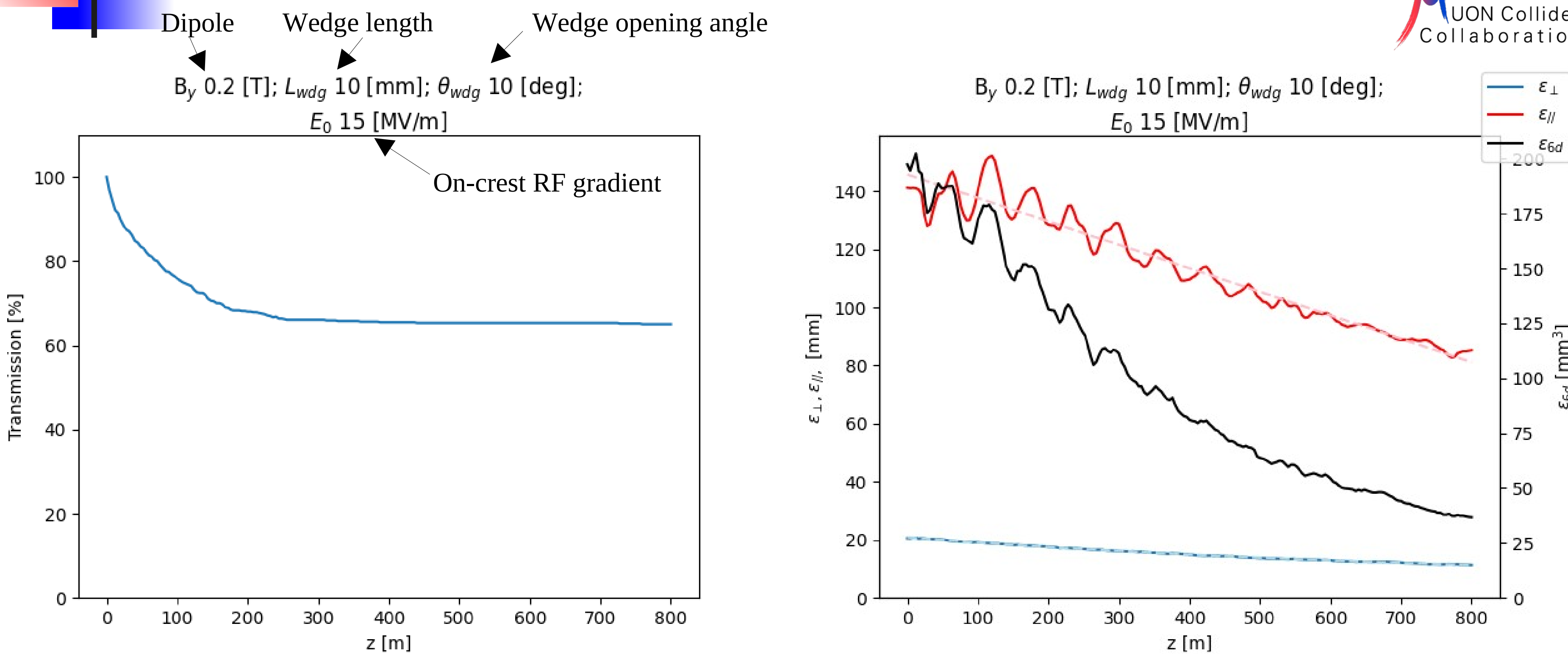
- Blue – transmitted
- Orange – lost
- Longitudinal and transverse losses

Cooling – 176 MHz alternative



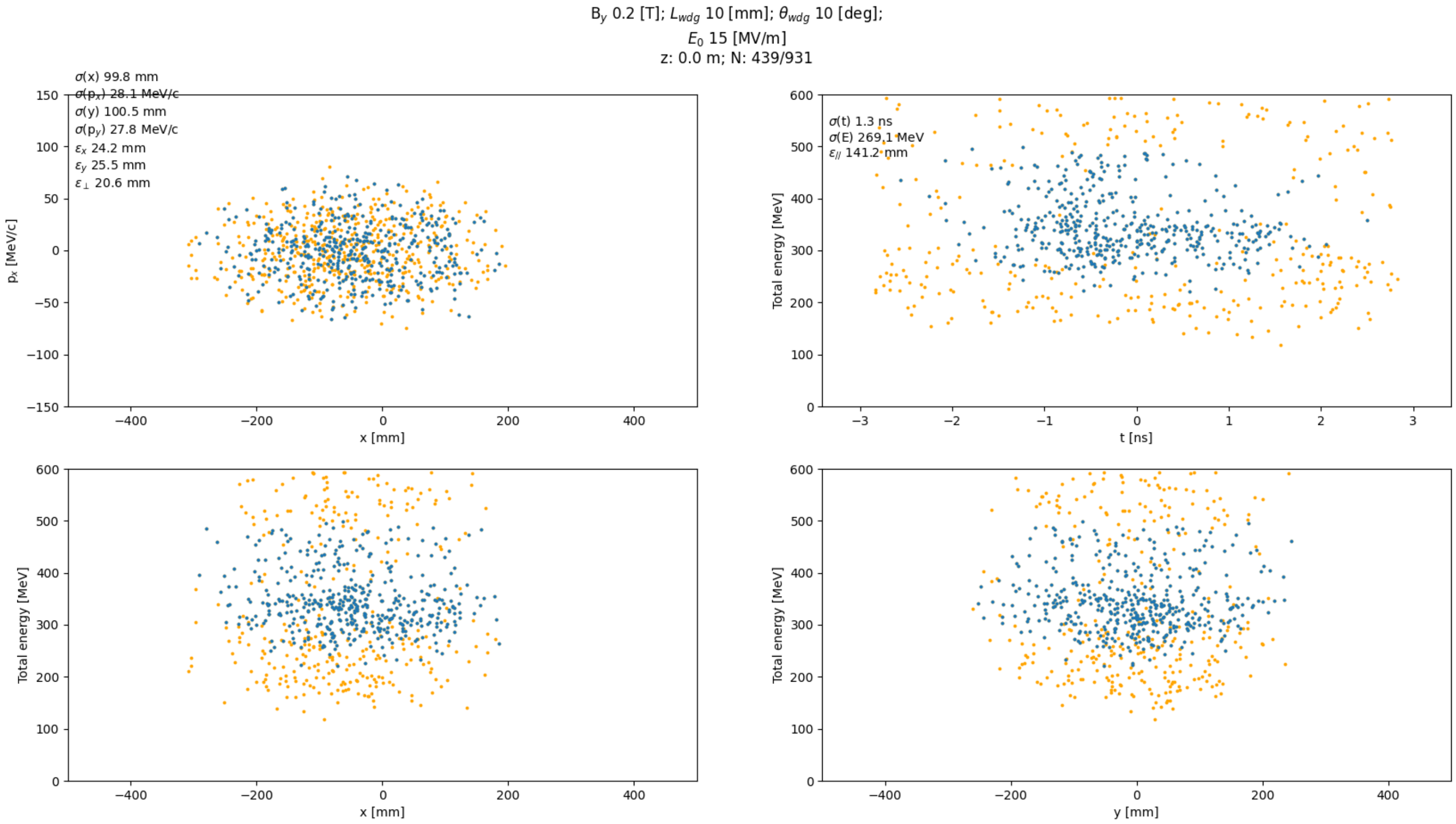
- Choose magnet parameters to enable decent RF packing fraction
  - Magnetic field given by:
    - Bz = 2.25 sin(kz)
  - (No real coil geometry simulated)
- Lithium Hydride wedge
- No decays (still)

Performance



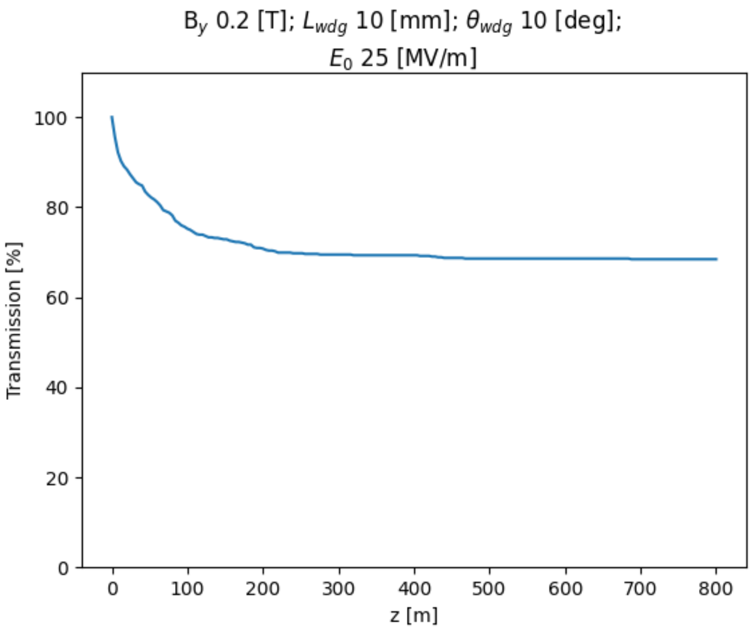
- Okay performance
  - Transverse emittance 20.6 → 11.4 mm
  - Longitudinal emittance 141 → 85.3 mm
  - Transmission 65 %
- But length (cost) is huge

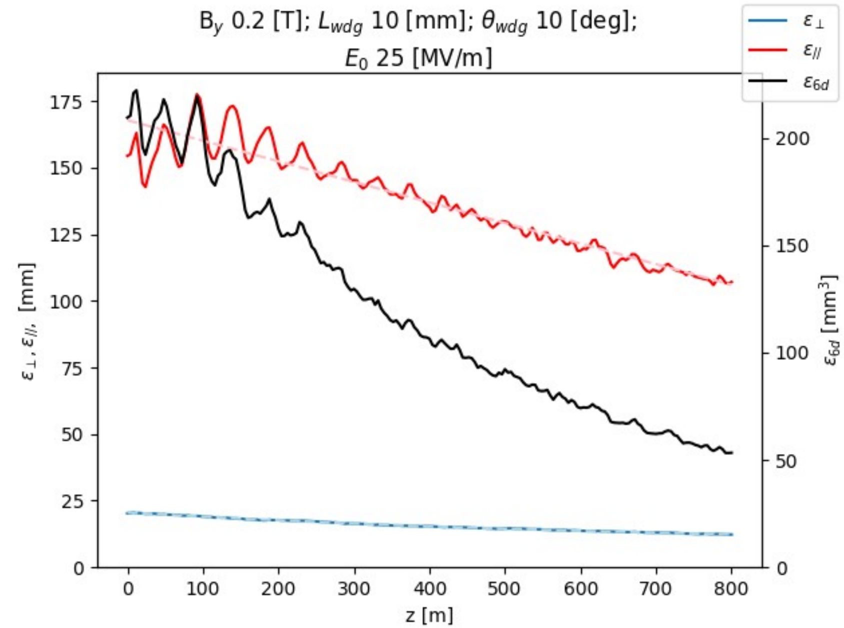
Loss



- Blue – transmitted
- Orange – stopped (no decays)
- Longitudinal acceptance is limiting!
  - Even for rather modest absorber

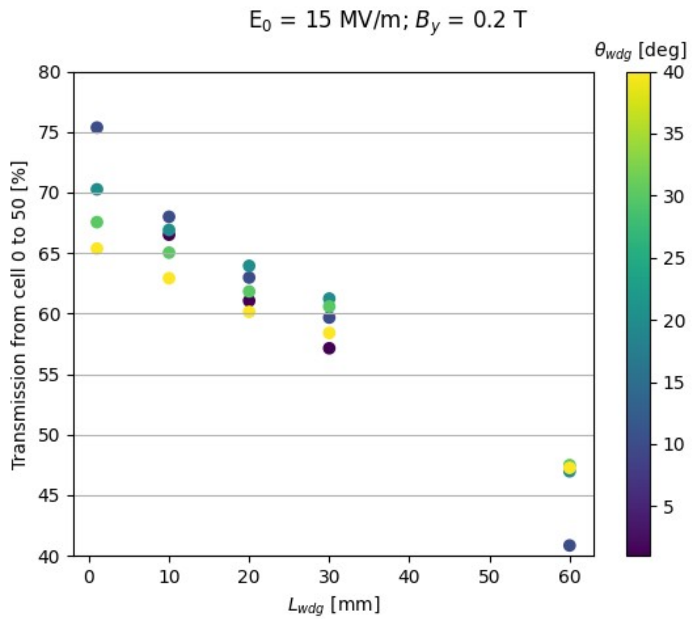
25 MV/m

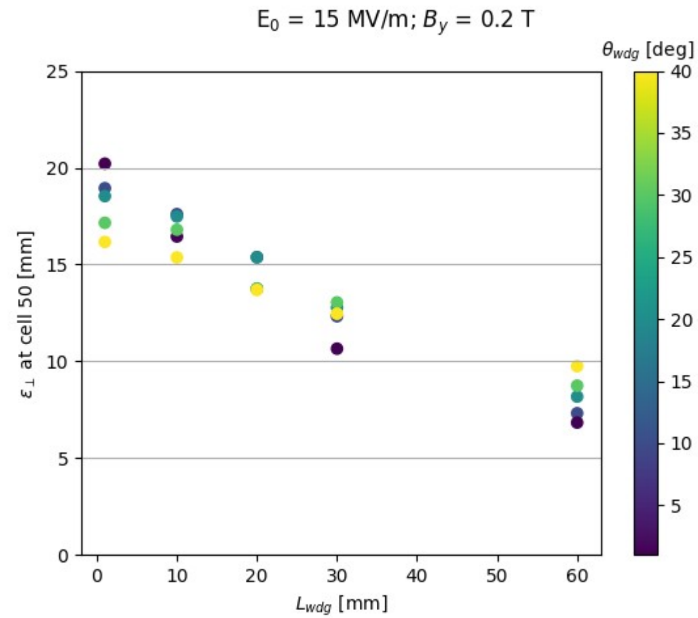




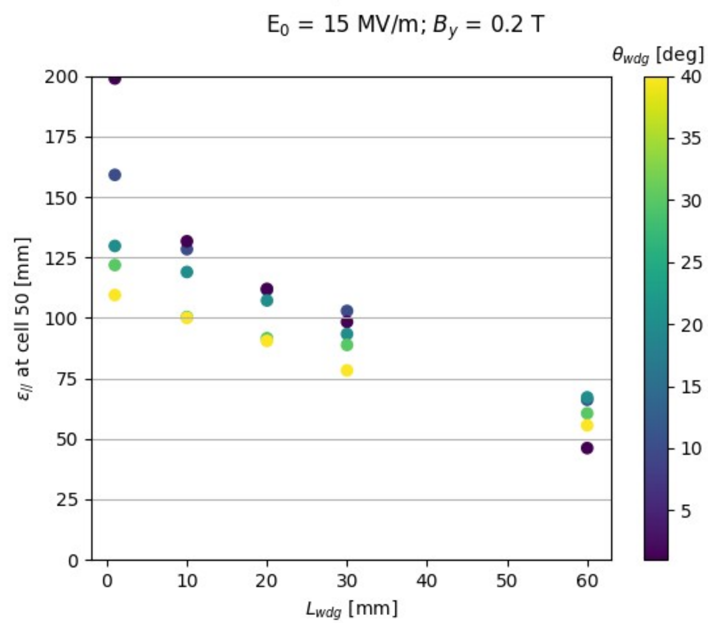
- Okay performance
  - Transverse emittance 20.3 → 12.3 mm
  - Longitudinal emittance 154 → 107 mm
  - Transmission 68 %
- But length (cost) is huge
  - Note mismatch

Parameter Scans – 0.2 T, 15 MV/m

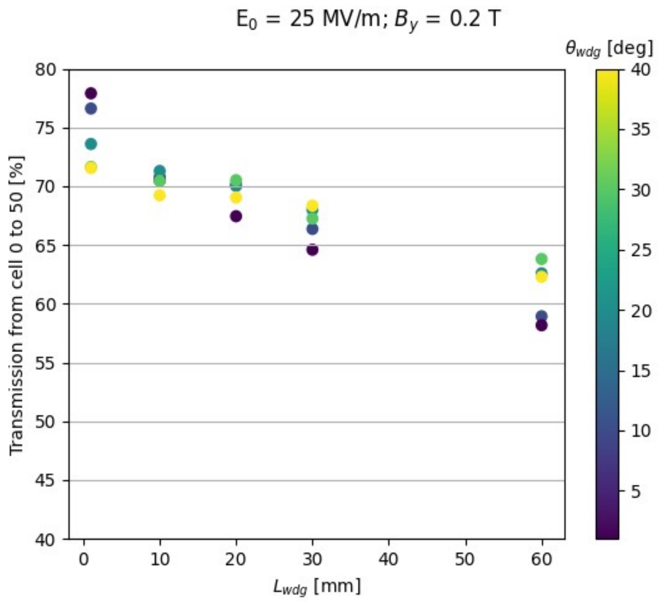


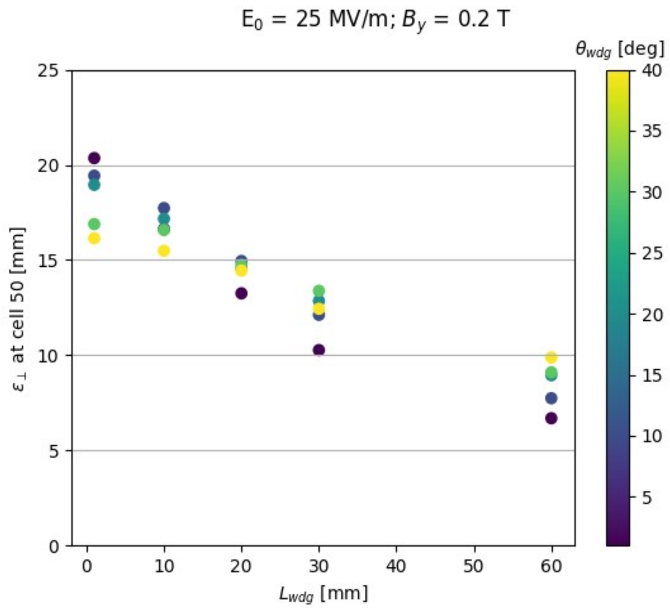


- Performance @ 200 m
- Okay performance

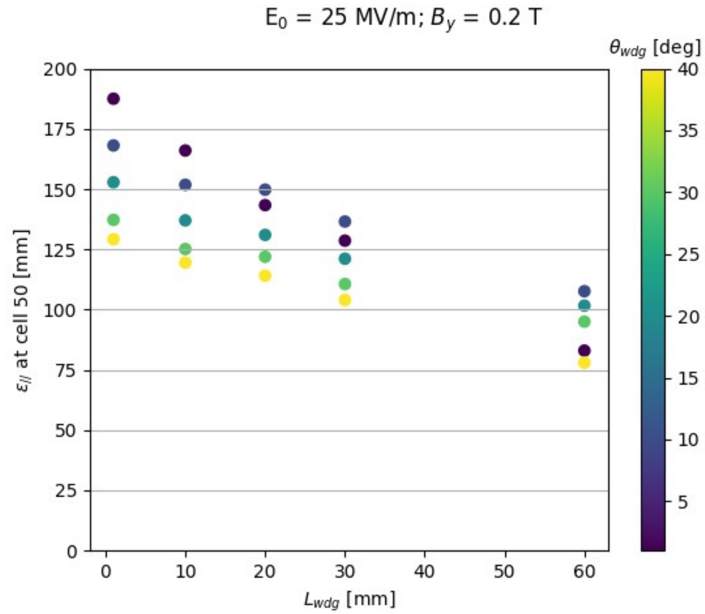


Parameter Scans – 0.2 T, 25 MV/m

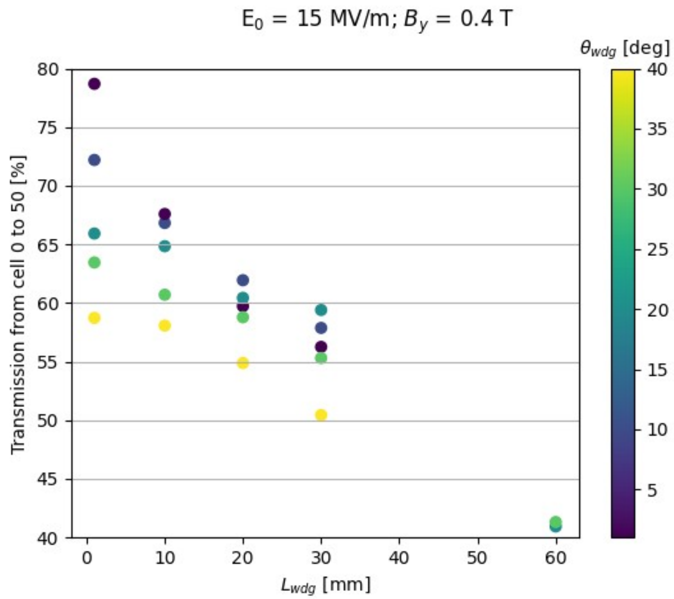


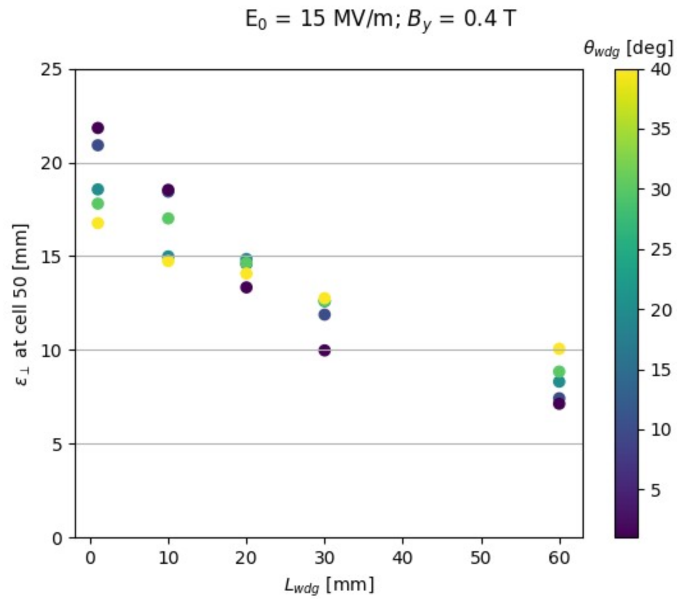


- Performance @ 200 m
- Better performance
- Higher longitudinal emittance → improved transmission



Parameter Scans – 0.4 T, 15 MV/m





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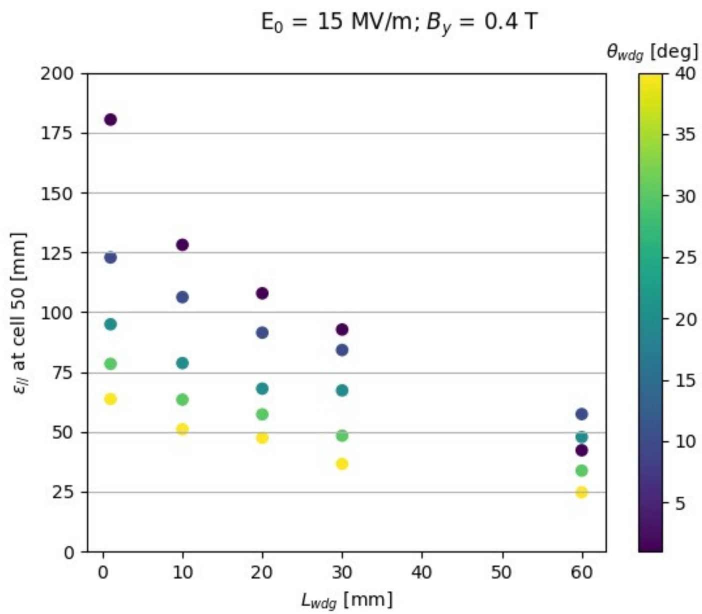
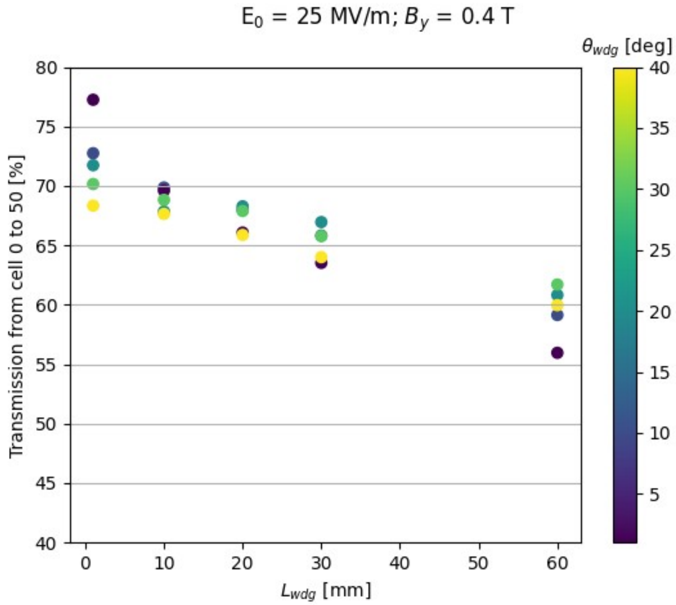
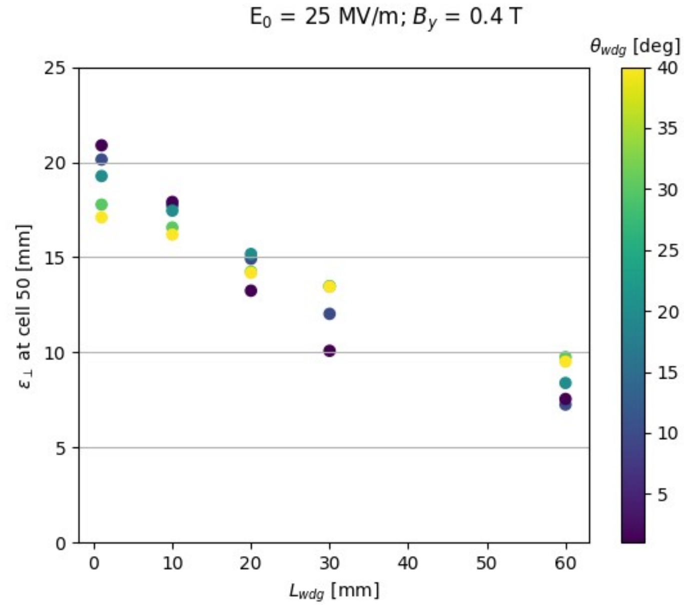


Parameter Scans – 0.4 T, 25 MV/m





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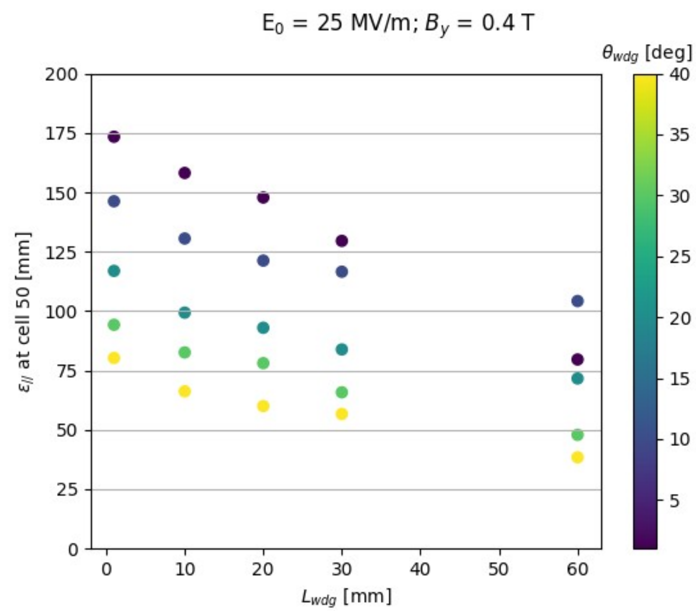
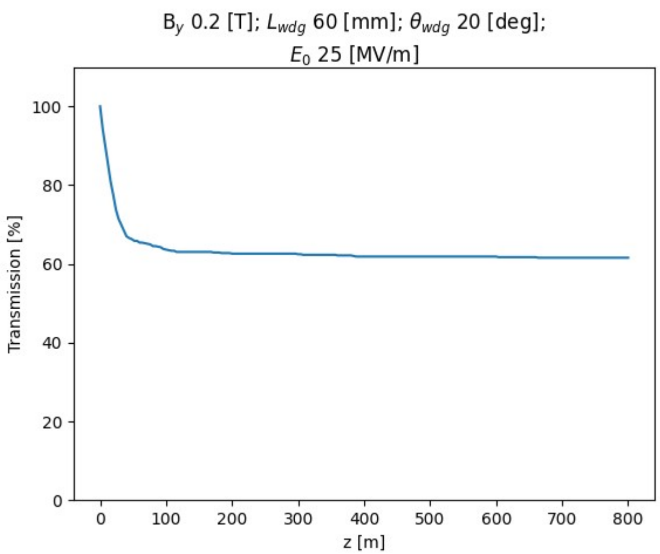
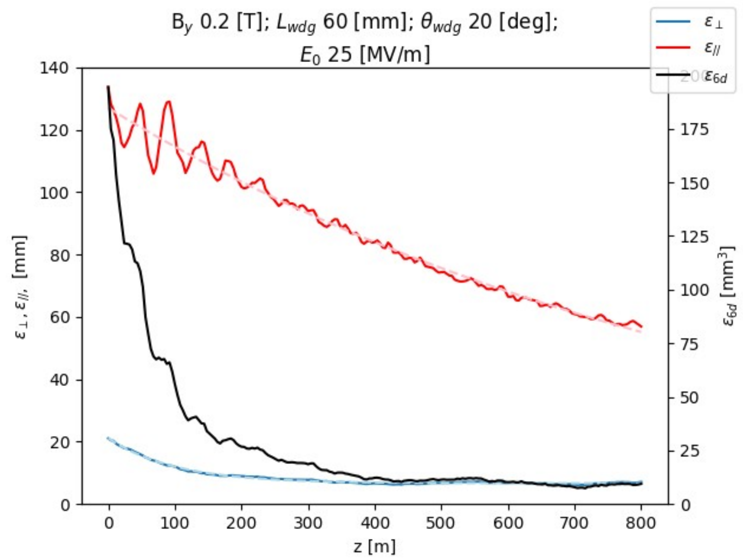


25 MV/m





- Rapid Transverse emittance reduction
- Longitudinal emittance ~ so-so
- Over full 800 m length
  - Transmission 62 % (@ 800 m)
  - Trans Emittance 21.0 → 6.3 mm
  - Long emittance 133 → 57 mm

Comments

- Optimisation “by hand”
  - No aggressive search routines or AS
  - Probably room for O(10%-20%) improvement
- Front End
  - Higher solenoid field would improve physical acceptance
  - Realistic RF would degrade performance a bit
    - Finite selection of frequencies
    - Space for solenoids
  - Chicane and proton absorber would degrade performance a bit
- Cooling
  - Design front end to capture higher emittance
  - It captures higher emittance
  - But now struggle to fit the beam in the cooling lattice!
- Note comparison with Ruihu’s lattice may be a bad one
  - Not clear what is transmission of 325 MHz Front End