FRONTEND OPTIMIZATION STUDIES

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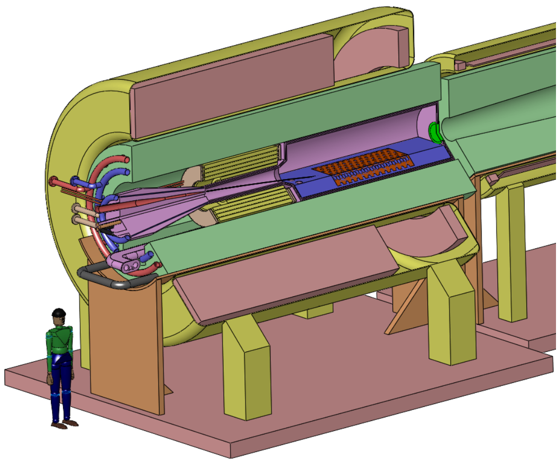
FRONT END OPTIMIZATION

OUTLINE

Goal : Optmize number of useful muons and limit the proton beam power energy transmitted to the first RF cavity in the buncher



Involved systems:

- Carbon target and carbon dump geometry
- Capture field
- Chicane design
- Be absorber

1- Target geometry parameters: Carbon target length, radius, and tilt angle to solenoid axis

2- Target Capture field: constant field length - taper length - end field

3- Chicane parameters: Length - curvature – focsuing field

4- Be absorber thickness and location

5- Energy deposition in the target area + Chicane will be evaluated and involved in the optimization.

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CARBON TARGET GEOMETRY OPTIMIZATION

- Target geometry parameters:

  Carbon target length -- radius -- tilt angle to solenoid axis

- Objective: optmize at z=50 m

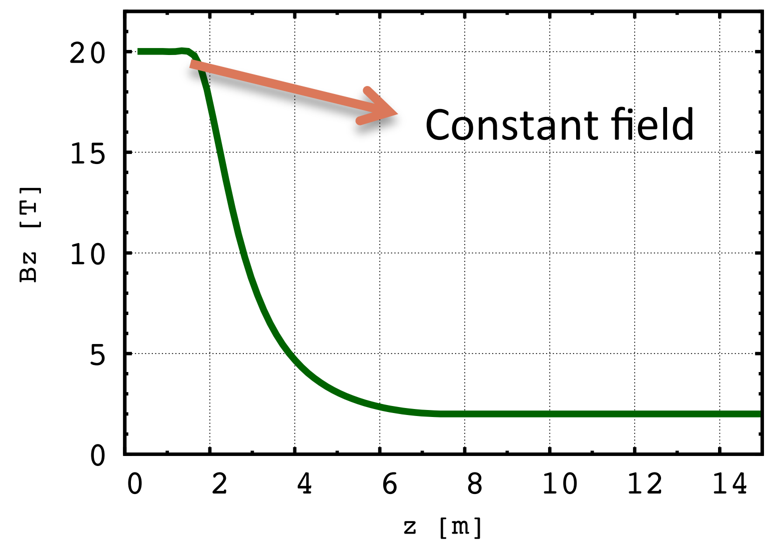
  $\Sigma\ \pi+\mu+\kappa$ within 0 <pz < 450 MeV/c (to compensate for the Be absorber effect)

  & 0 < pt < 150 MeV/c

Initial lattice in G4Beamline – using GEANT4 physics list QGSP (Benchmarekd with HARP data – Bungau *et al* PRSTAB 2014)

- Bz=20-2.0 T over taper length = 6.0 m
- Constant field length is fixed to the target length

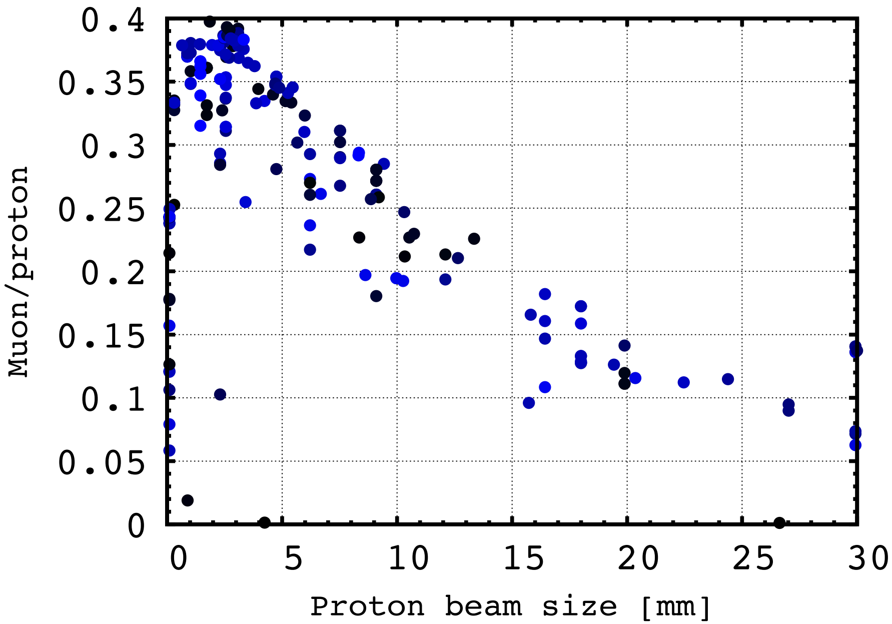
- Initial protons K.E. = 6.75 GeV
- Target radius fixed at 4 times the proton beam size



- The whole optmization process 6 hours on 192 cores at NERSC

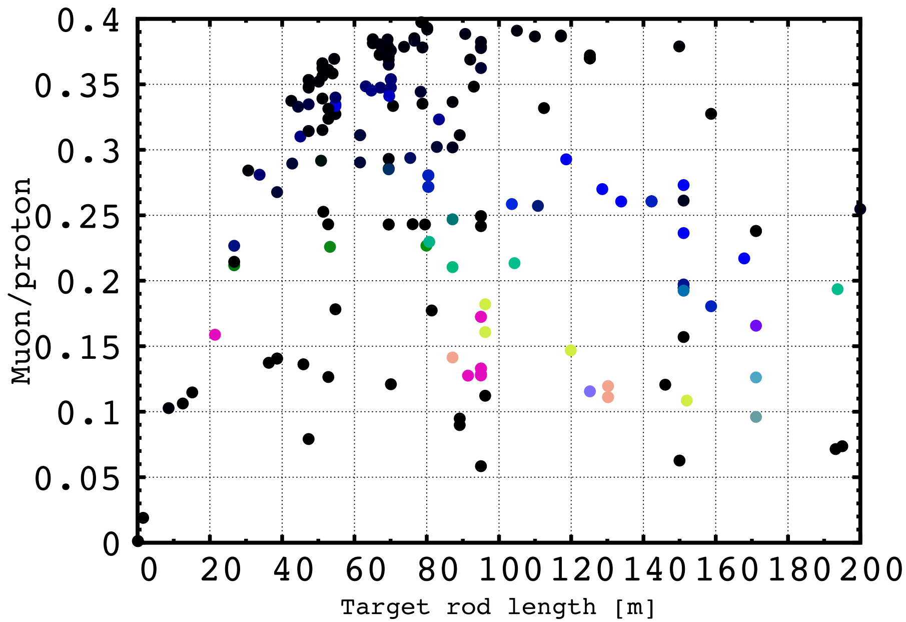
NERSC

CARBON TARGET GEOMETRY OPTIMIZATION

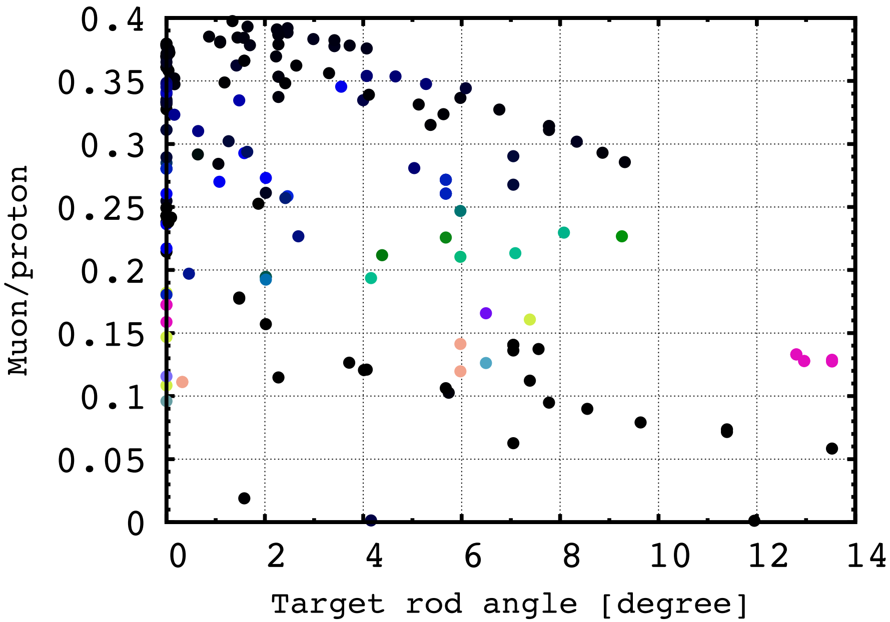


Optimal working point 2-3 mm
Different colors → different target lengths & angles

Optimal working point 70-120 cm
Different colors → different target angles & radii



CARBON TARGET GEOMETRY OPTIMIZATION



Optimal working point 1-3 degrees
Different colors → different target lengths & radii

Beam radius [mm]	Target angle [degree]	Target length [mm]	N(μ)/Np
1.85292	1.34088	785.00294	0.39745
2.59974	1.64588	801.56101	0.39305
3.08659	2.45955	801.56101	0.39184
2.71093	2.24632	1049.69876	0.39097
3.08659	2.45955	906.74622	0.38844

CARBON TARGET GEOMETRY OPTIMIZATION

- To do list
  - Add carboon beam dump
  - Integrate to the chicane (see next slide)
  - Consider the capture filed in the optimization

- The whole optmization process 6 hours on 192 cores at NERSC

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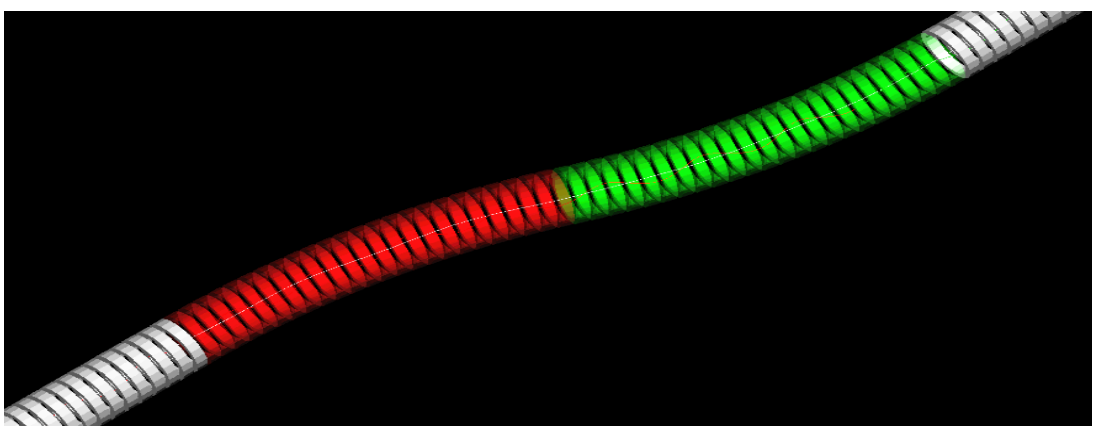
CHICANE

- Short taper (6 m) integrated with the new chicane from Pavel's G4BL lattice (same parameters as in ICOOL)
- Started optimizing the chicane parameters (initial values - D. Neuffer's icool lattice)
    - Chicane length L (initial value L = 6.0)
    - Chicane radius of curvature h (initial value = 0.05818 m)
    - Be absorber length (initial value = 100.0 mm)
    - On-axis field is a free parameter – optimization will be carried for B= 2.0 – 2.5 – 3.0 T
    - Chicane aperture 40 cm (might be a free parameter as well)
- Objectives → minimize total KE of transmitted protons $\Sigma\ KE_{protons}$

  → Maximaiz number of transmitted muons $\Sigma\ \pi+\mu+\kappa$ within 0 <pz < 450 MeV/c (to compensate for the Be absorber effect) & 0 < pt < 150 MeV/c

Run 100 K particles through the chicane with initial parameters $\Sigma\ KE_{protons}$ = 29 GeV & $\Sigma\ N_{mu}$= 4377



CHICANE

Run 500 K particles through the chicane with automated optmization algorithm

B0= 2.0 T

H	L	Be thickness [mm]	Σ $Ke_{protons}$ [GeV]	Σ N_{mu}
0.057587951	10.23983	101.88068	0.547549	13522
0.057587951	10.23983	101.88068	0.547549	13506
0.057587951	10.23983	101.88068	0.547549	13506
0.057587951	10.23983	101.88068	0.547549	13506
0.04063443	10.99894	259.19359	0.380618	11975

Chicane

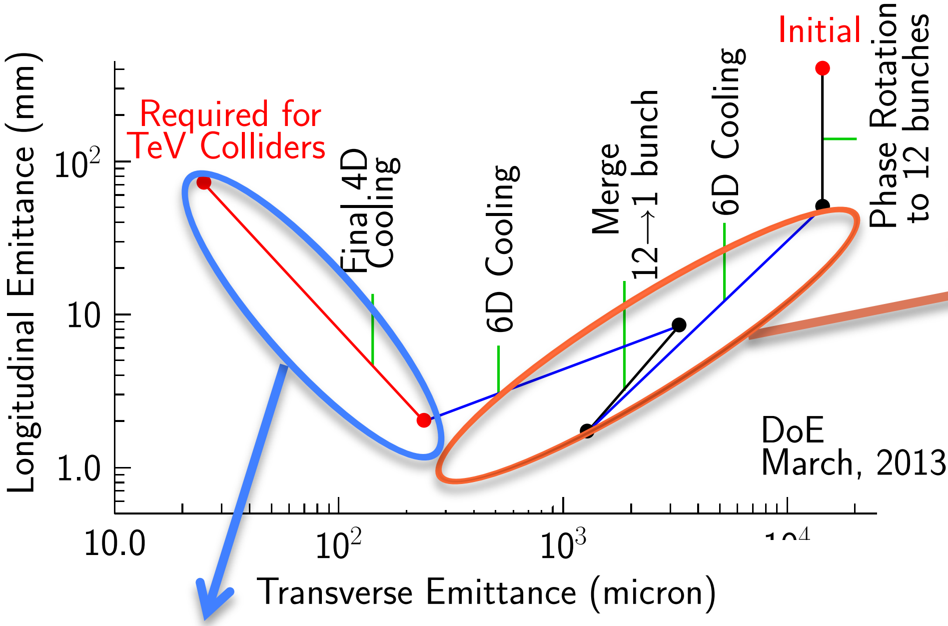
B0= 2.5 T

H	L	Be thickness [mm]	Σ $Ke_{protons}$ [GeV]	Σ N_{mu}
0.020371496	21.82107	327.90203	0.741961	13143
0.058173286	9.66614	249.48609	0.230776	12303
0.020371496	23.3482	353.23063	0.0487631	12018
0.083906168	8.56258	101.88068	0.625911	12439
0.083906168	8.56258	101.88068	0.625911	12439

B0= 3.0 T

H	L	Be thickness [mm]	Σ $Ke_{protons}$ [GeV]	Σ N_{mu}
0.063239202	12.35924	101.88068	0.856025	17690
0.063239202	12.35924	101.88068	0.856025	17690
0.063239202	12.35924	101.88068	0.856025	17690
0.063239202	12.35924	101.88068	0.856025	17690
0.059079316	15.31618	121.18716	0.04844	15307

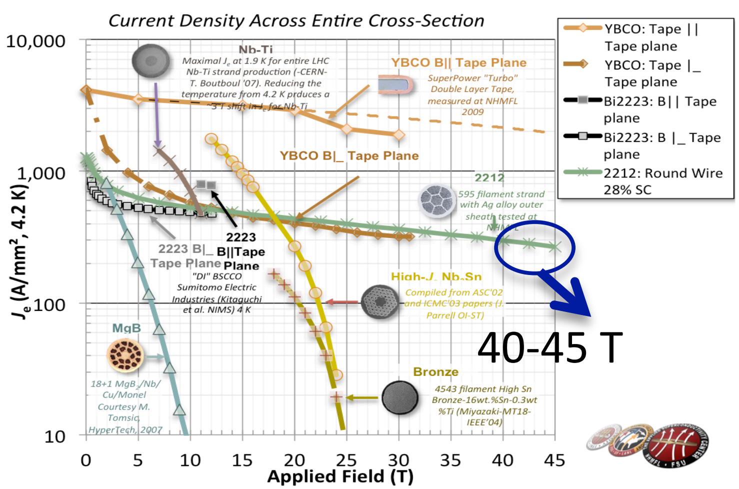
Muon Collider cooling Concept



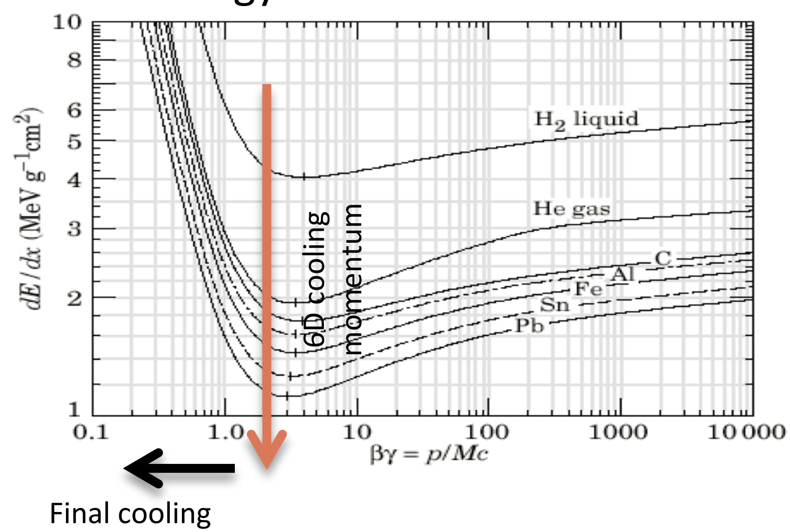
- Muon production
- Muon Capture
- Bunching into 12 microbunches
- Energy phase rotation of microbunches to a common central energy

6D cooling Channels:
Target :ε_T= 300 μm ε_L= 1.5 mm

- **High field cooling Channel (40 T solenoids)**
- **Target :ε_T= 25 μm ε_L= 72 mm**



Energy loss in low z material



$$\epsilon_{equ,N} = \frac{\beta_\perp E_s^2}{2\beta mc^2 L_R (dE/ds)}$$

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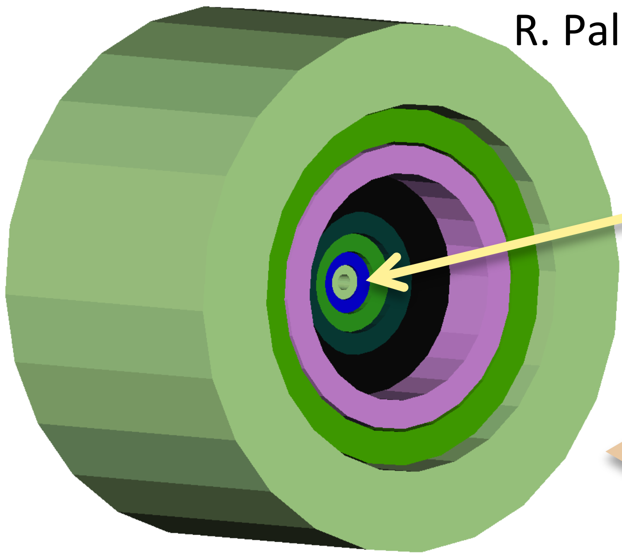
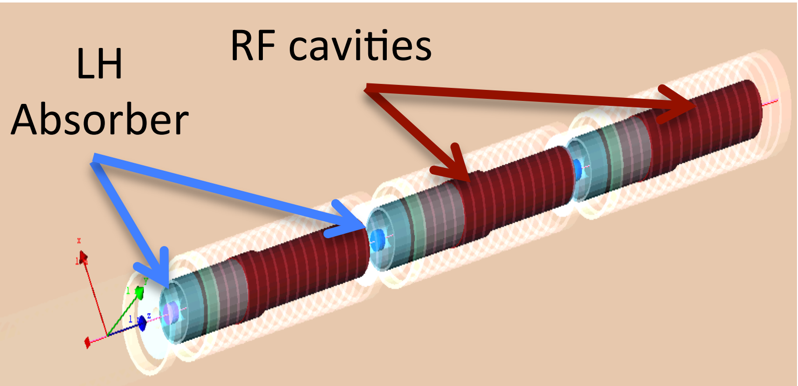
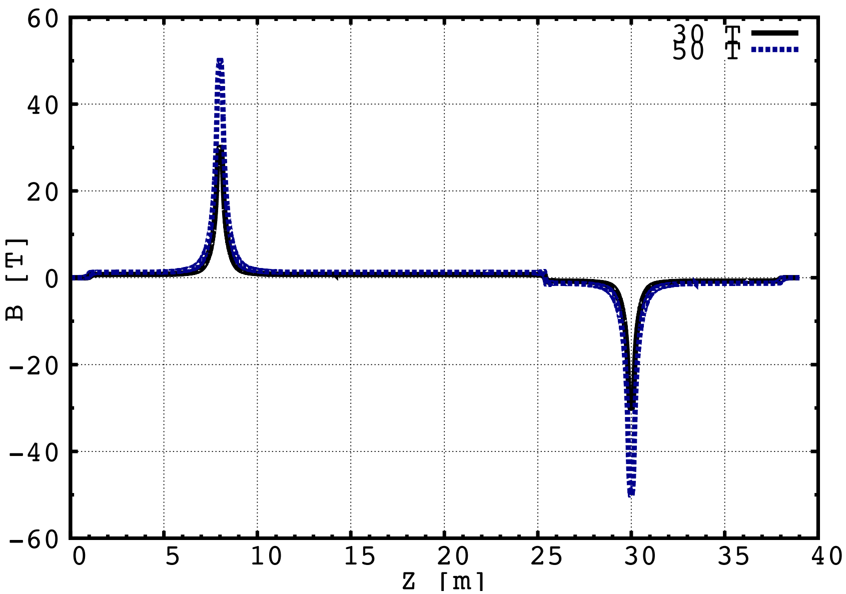
HIGH FILED MAGNET

R. Palmer – B. Weggel

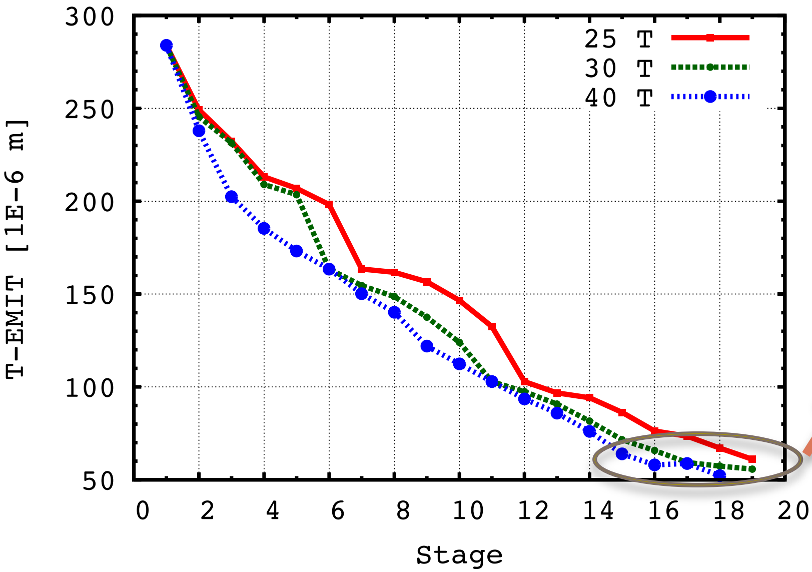


Length [m]	Inner radius [m]	Thickness [m]	I/A [A/mm^2]
0.317	0.025	0.029	164.26
0.337	0.055	0.041	142.43
0.375	0.098	0.056	125.88
0.433	0.157	0.067	119.07
0.503	0.228	0.120	85.99
0.869	0.355	0.089	39.60
0.868	0.454	0.104	44.30
0.992	0.575	0.252	38.60



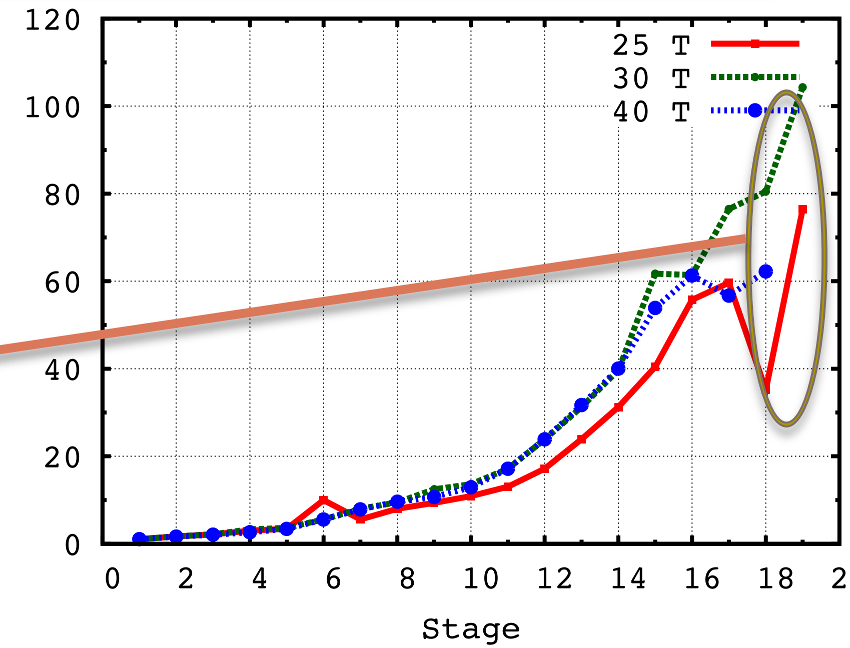


25 - 30 - 40 T CHANNEL



Transverse emittance [µm]

B = 25 T can achieve 60 µm without re-optmization
Equi. Emittance may limit further cooling



Longitudnal emittance [mm]

B = 25 T has better long. Emittance heating
RF in the last 3 stages is not well optmized

Transmission is ~ 40% in all cases

Conclusion & Summary

- A Complete design and simulation of 40-25 T channel → ε_T = 50 µm ε_L > 72 mm with G4Beamline
- Re-optmize the 30-25 T channels
- Replace the current sheets used for focusing filed with Weggel's coils (may need to remove one or two coils ?!)