# Neutrino Factory Front End (IDS) -Chicane & Absorber

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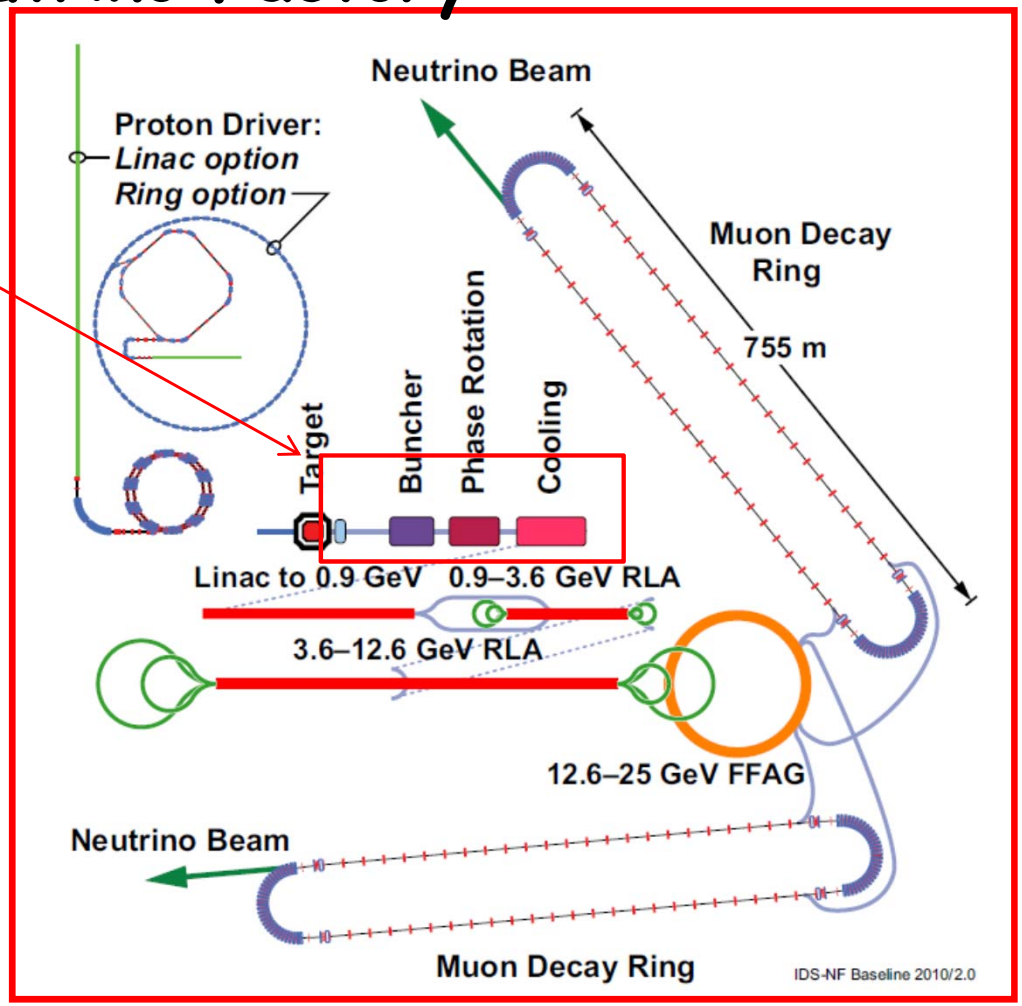
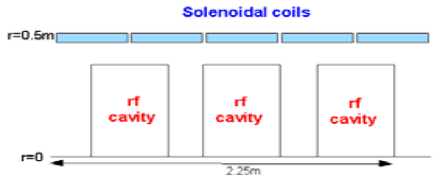
# Outline

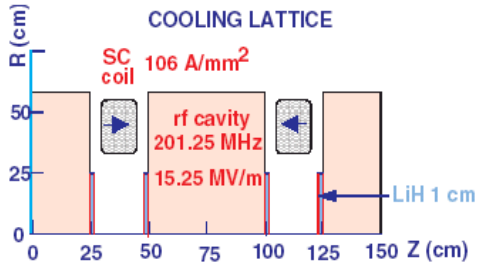
- **Front End for the IDS Neutrino Factory**
  - Basis for engineering/costs
    - Rf, requirements
    - Engineering required
- **Losses – control**
  - Chicane, proton absorber
  - rematching OK
- **rf gradient/ B concerns**
  - alternatives
    - gas-filled rf/insulated rf/low-B/bucked coil
  - gas-filled rf results ?

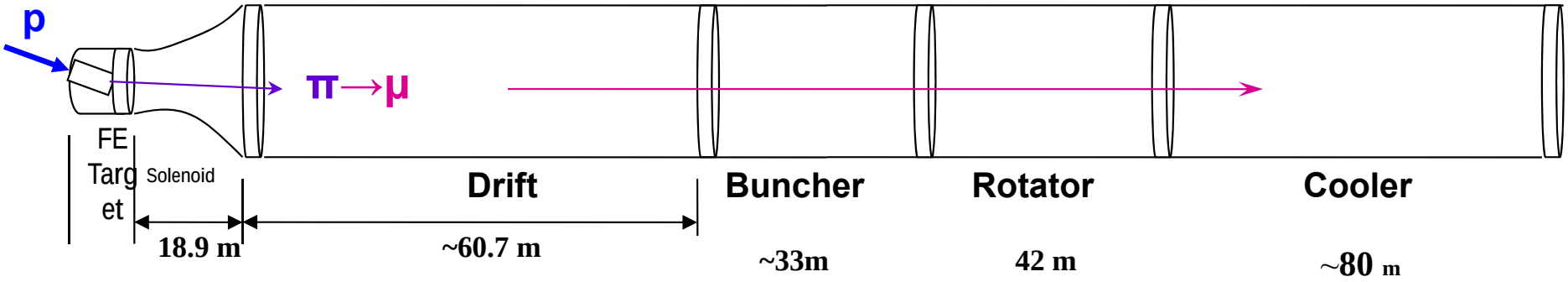


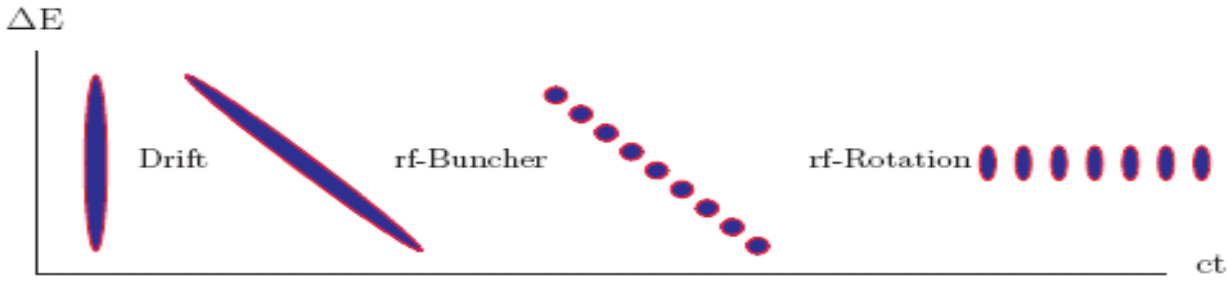
# IDS Baseline Buncher and φ-E Rotator

- Drift (π→μ)
- "Adiabatically" bunch beam first (weak 320 to 232 MHz rf)
- Φ-E rotate bunches – align bunches to ~equal energies
  - 232 to 202 MHz, 12MV/m
- Cool beam 201.25MHz



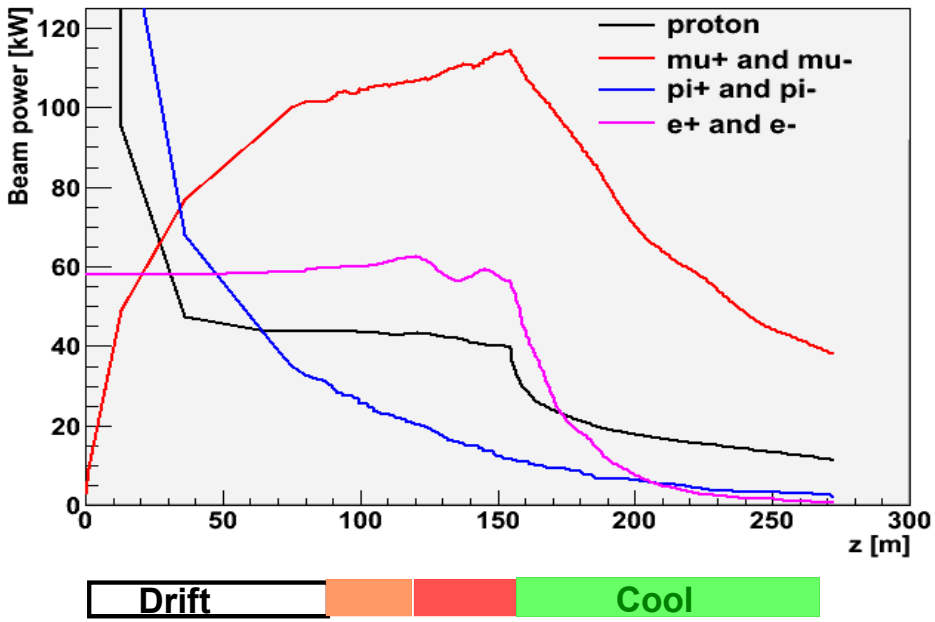



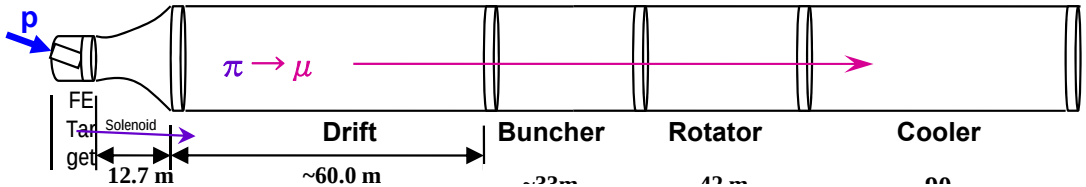



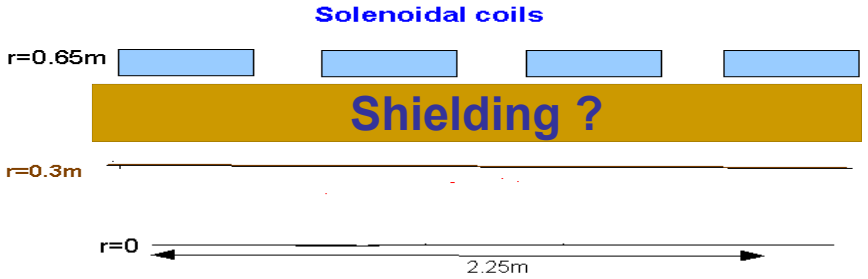
# Problem: Beam Losses along Front End

- **Start with 4MW protons**
  - End with ~50kW $\mu^+ + \mu^-$
    - plus p, e, π, …
    - ~20W/m μ-decay
  - ~0.5MW losses along transport
    - >0.1MW at z>50m




- **Want "Hands-on" maintenance**
  - hadronic losses < 1W/m
    - Booster, PSR criteria
  - Simulation has >~100W/m
    - With no collimation, shielding, absorber strategy

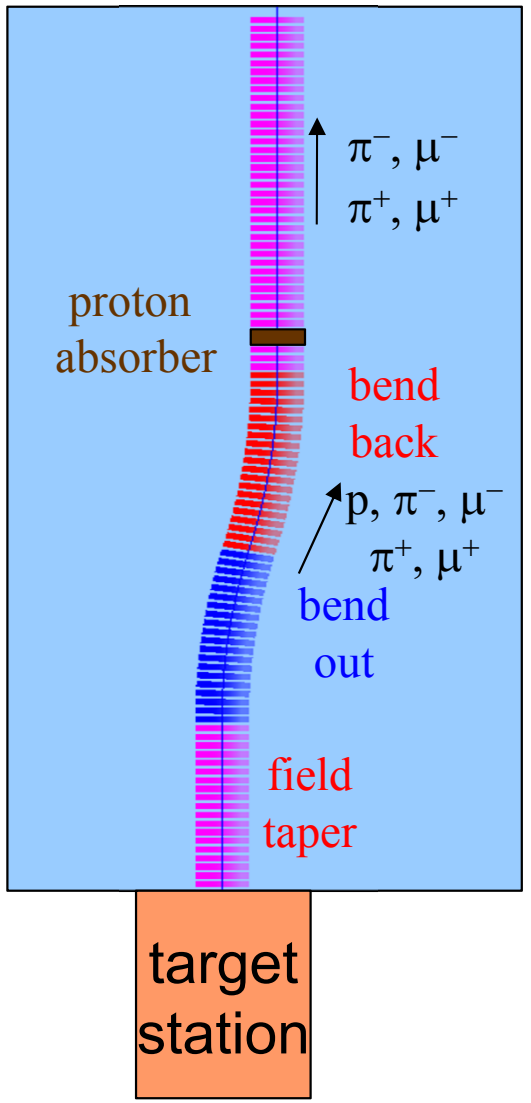


# Design Concept

- **Bent solenoid chicane induces vertical dispersion in beam**
  - bend out – 5m, 12.5°
  - Single chicane will contain both signs
    - Opposite signs have dispersion in opposite sense
  - Little disruption to the actual beam
  - High momentum particles scrape

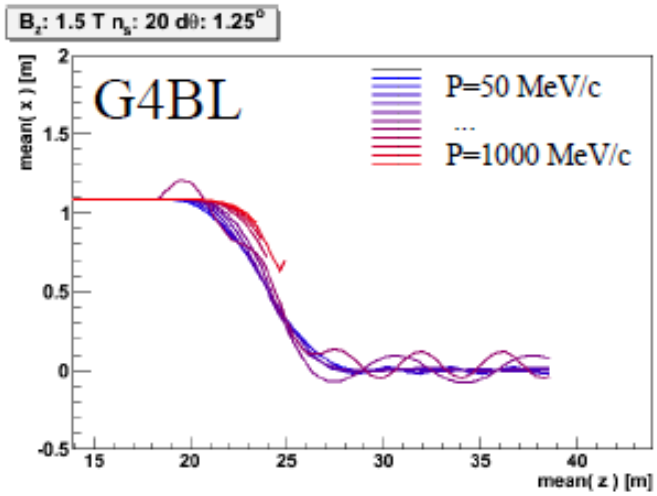
- **Subsequent proton absorber to remove low momentum protons**
  - Non-relativistic protons don't have much energy, even for relatively large momenta (~10cm Be)

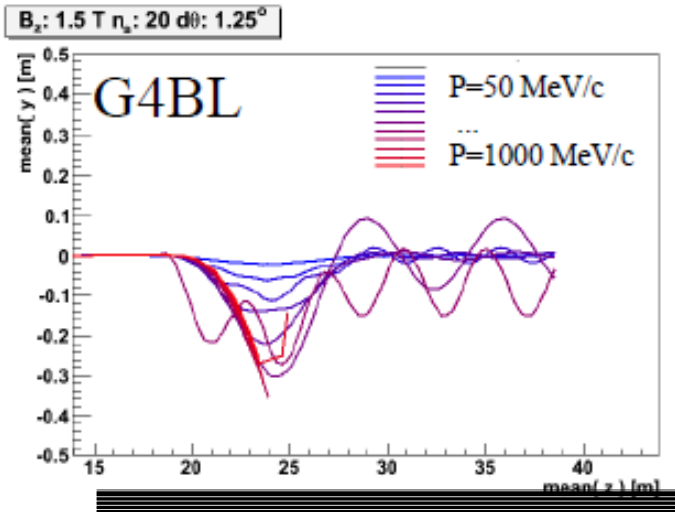


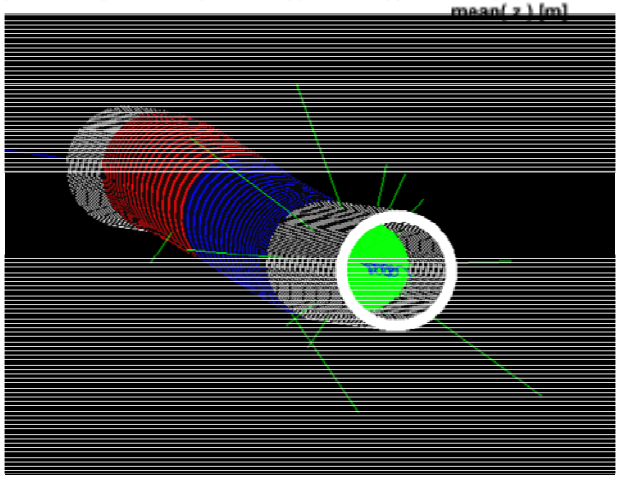
# Chicane + Absorber

- **Chicane effect:**
  - P > ~500MeV/c are lost
  - P < ~500MeV pass through
    - displaced by ~1.1m
  - Nominal Path length increased by only 8cm
    - orbits perturbed

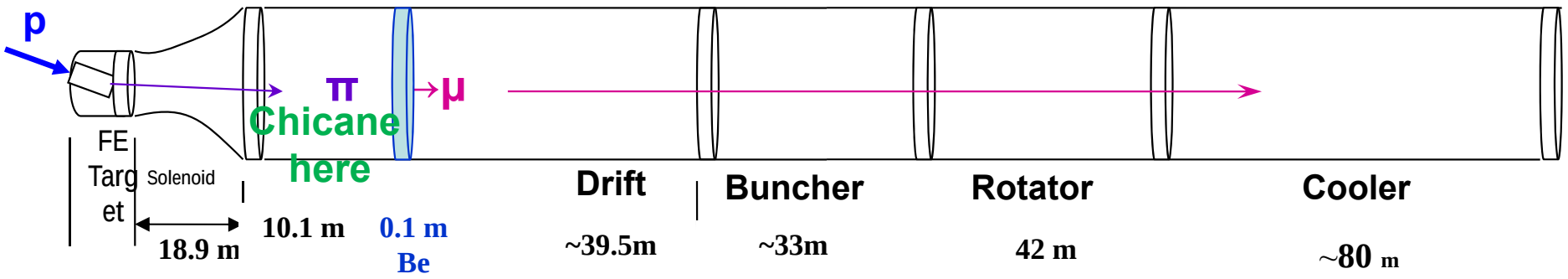
- **Absorber effect**
  - removes low energy particles
    - designed to remove protons
  - distorts energy distribution
    - energy phase-rotation distorted; must be rematched



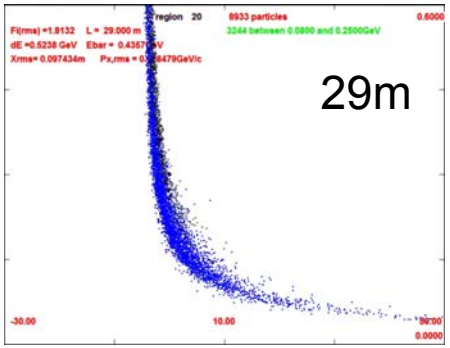



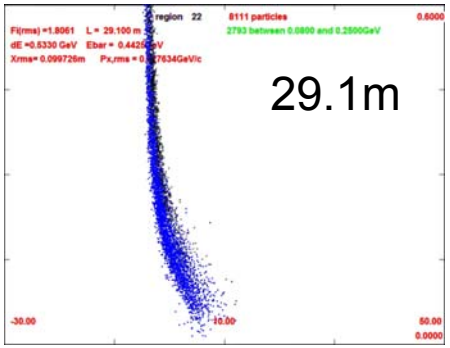



# Front End with Absorber-Rematch




- **with absorber**
  - particle 1-270 MeV/c
  - particle 2-185 MeV/c
  - absorber at 29m
    - 10cm Be
    - particle 1-237 MeV/c
    - particle 2-144 MeV/c
  - Bunch N=10
  - Rotate N=10.04
  - Cool -201.25MHz
    - $p_{ref}$=230 MeV/c

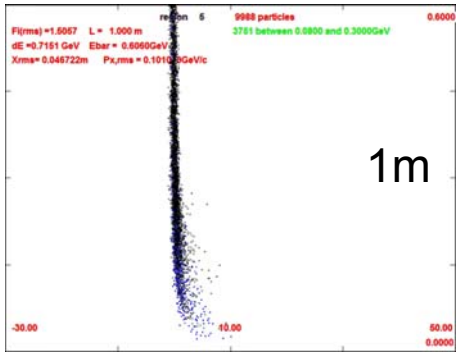


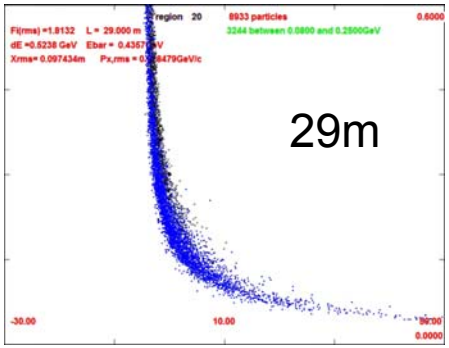



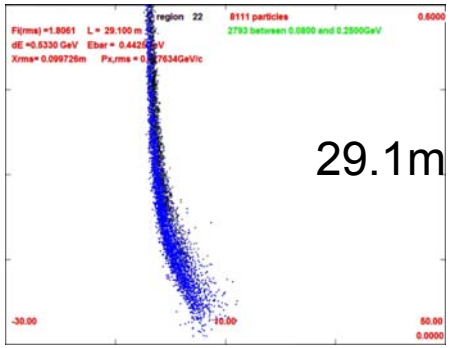
# Longitudinal Beam through System

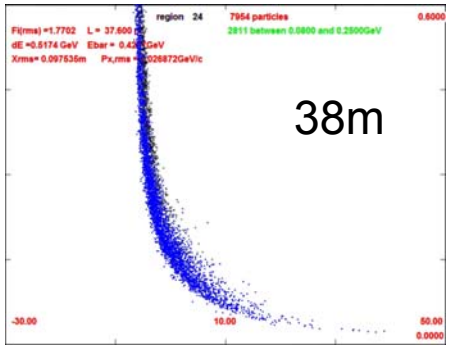
## ICOOL

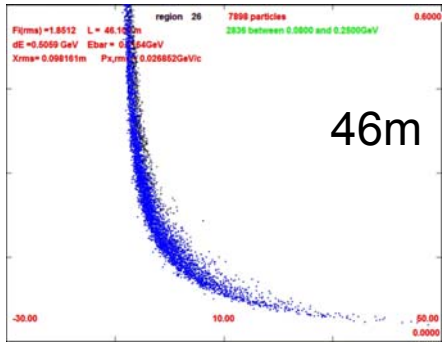
### 0.1m Be absorber

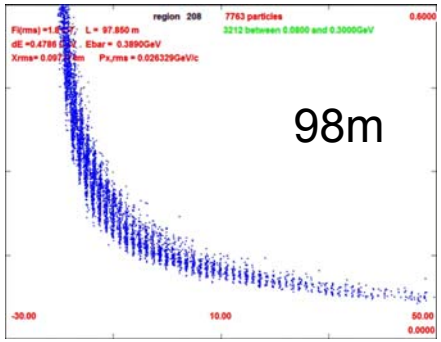


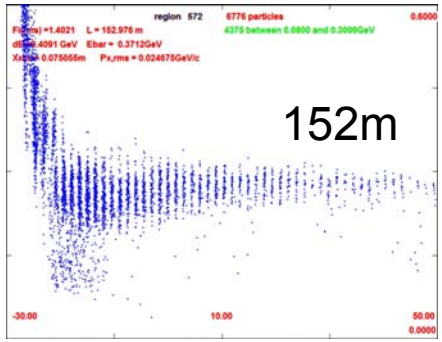



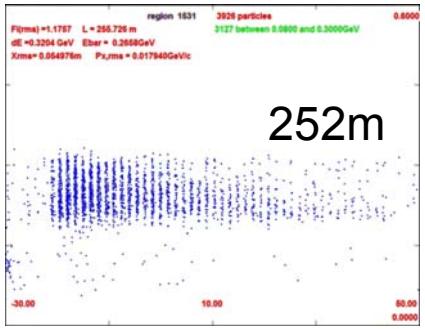



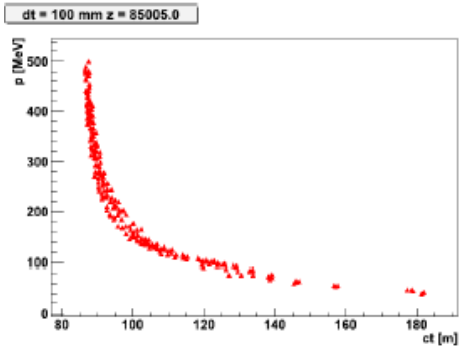



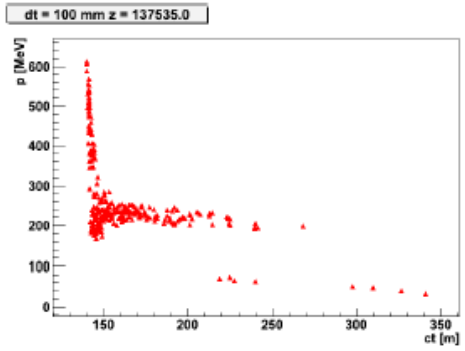



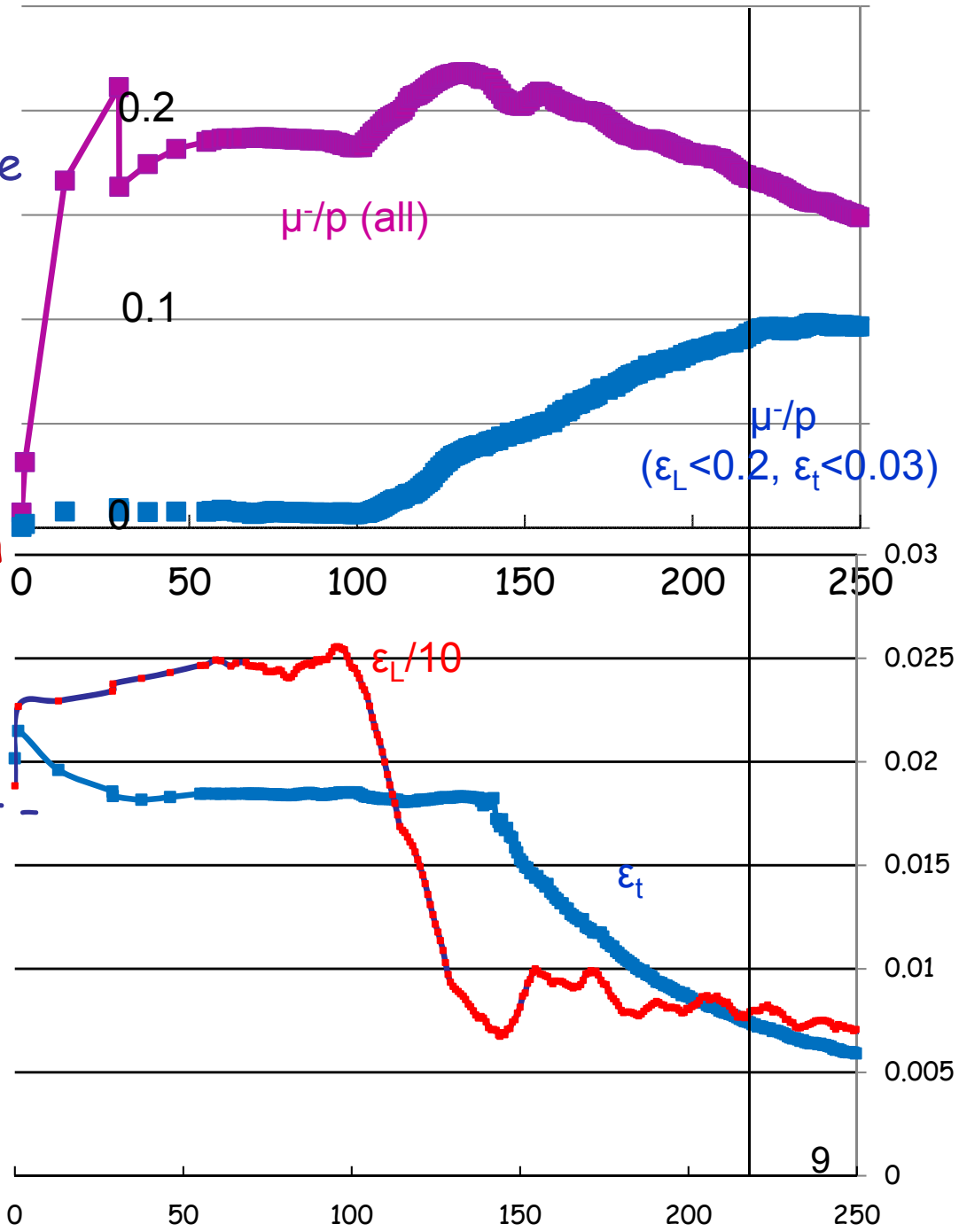

## G4BL



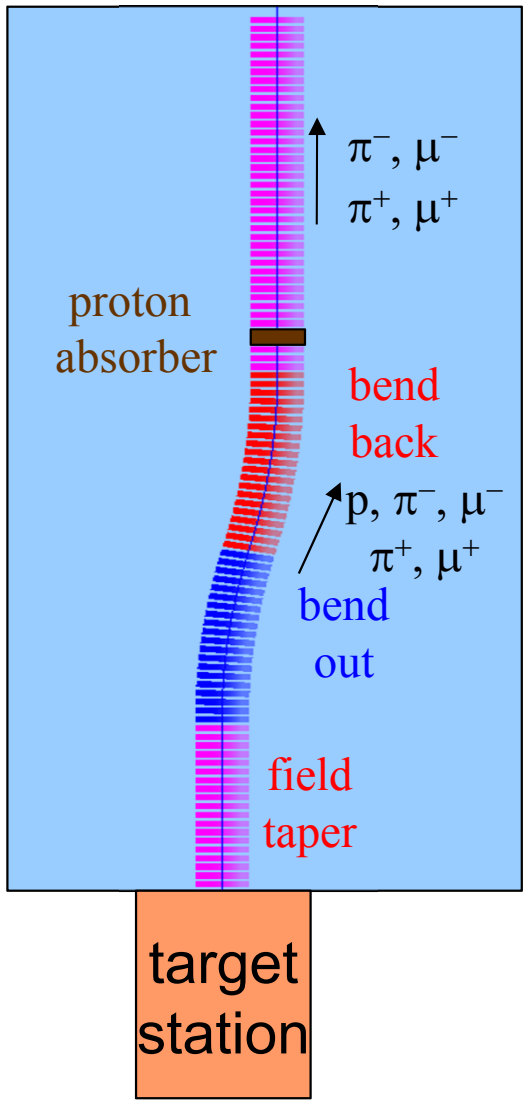
# ICOOL Simulation Results

- **Similar to without absorber**
  - ~10m shorter drift
  - ~10% fewer μ's within acceptance
  - drop of ~20% intensity at absorber
  - but longitudinal emittance also reduced
    - surviving μ's are stretched in longitudinal phase space
- **To do**
  - include chicane + absorber
  - establish beam loss improvement – μ loss level
  - **decide optimal configuration**



# Add Chicane to Absorber

- **Try in ICOOL**
  - 2 Bent Solenoids – 10m
  - 5m, 1.5T, 12.5°,0.27GeV/c
  - 5m, 1.5T, -12.5° ,0.27GeV/c
    - **bend radius is 22.92m (1/r=0.043636)**
    - $B_y$=0
- **Match to channel**
  - add 1m drift



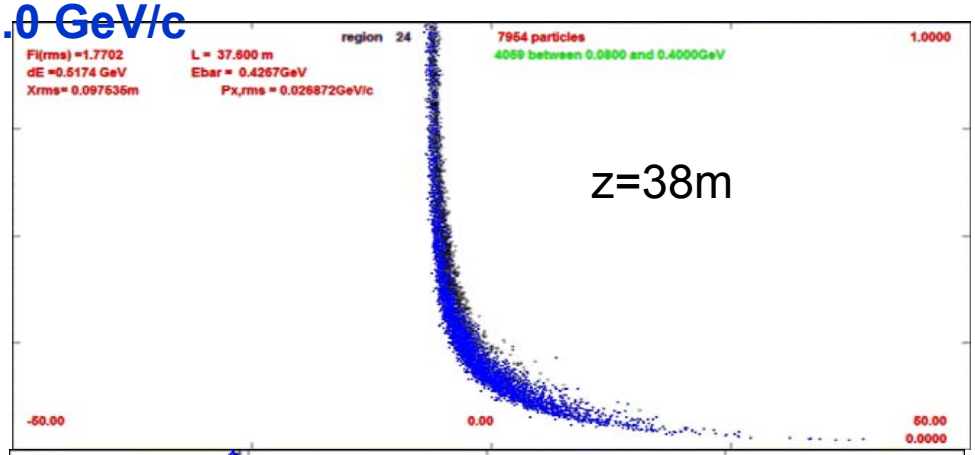

- **ICOOL BSOL element:**

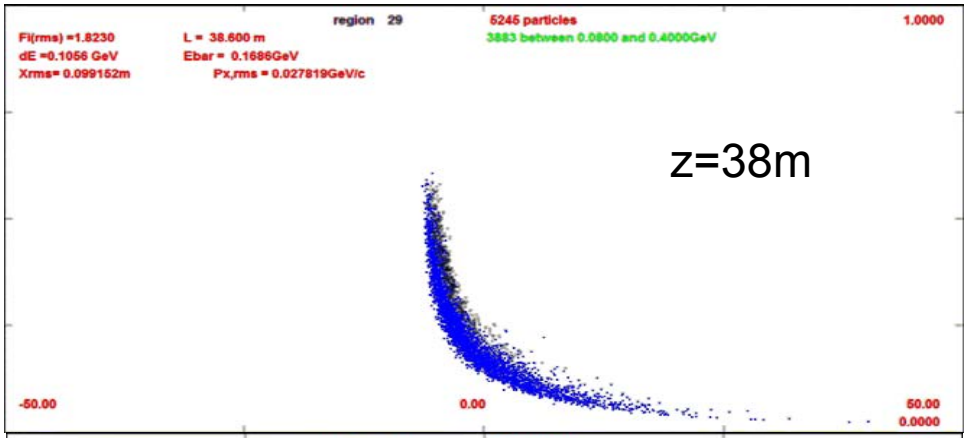
```
SREGION        ! bentsol
5.0  1   1e-2
1  0.   1.0
BSOL
1 1.5 0.0 1 0.27 0.0  0.043636  0.0 0.0 0.0  0. 0. 0. 0. 0.
VAC
NONE
  0. 0. 0. 0. 0.   0. 0. 0. 0. 0.
```

# Compare: Absorber *vs.* Absorber + Chicane

This compares absorber only (10cm Be) to chicane (BSOL) + absorber

**1.0 GeV/c**

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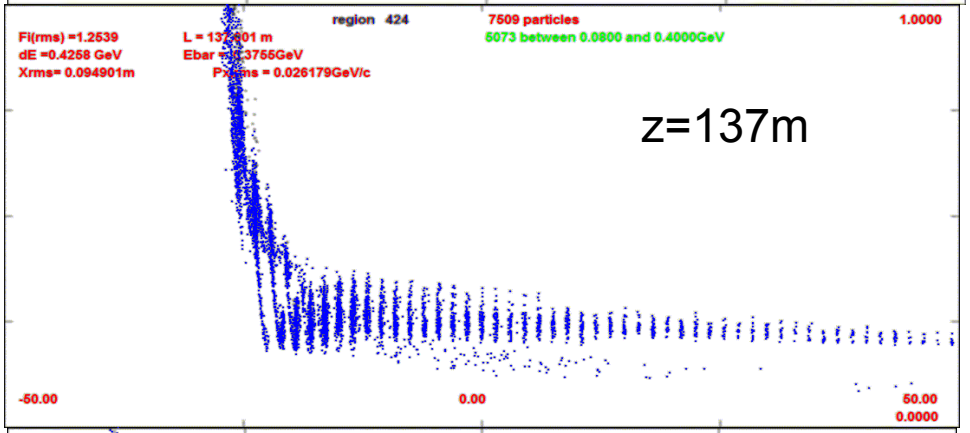
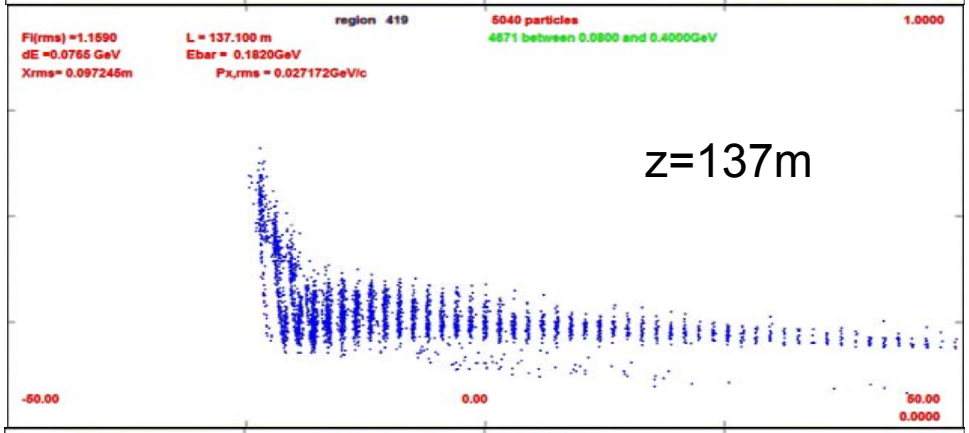
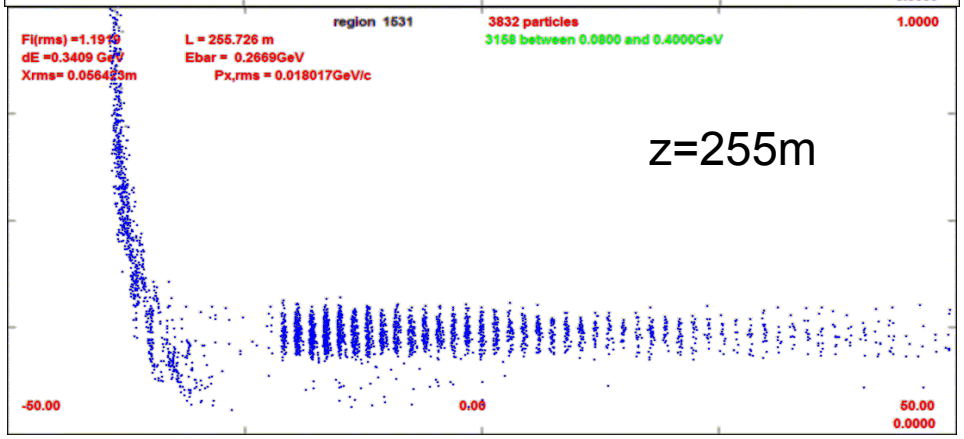
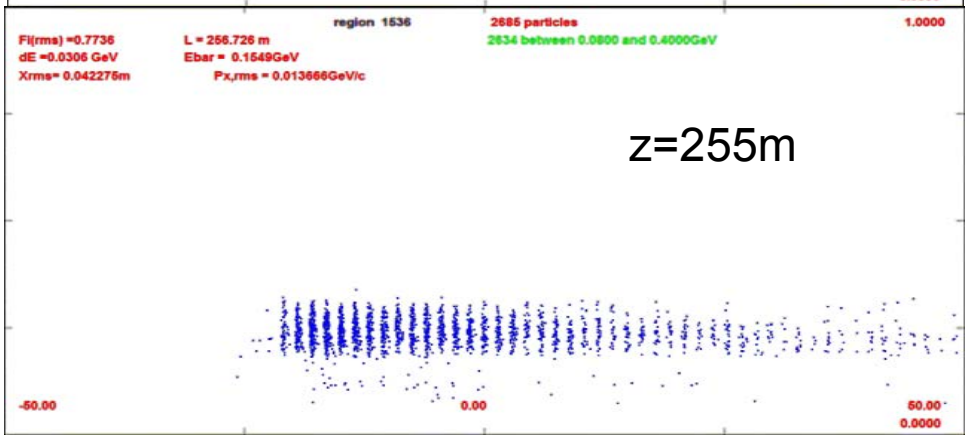


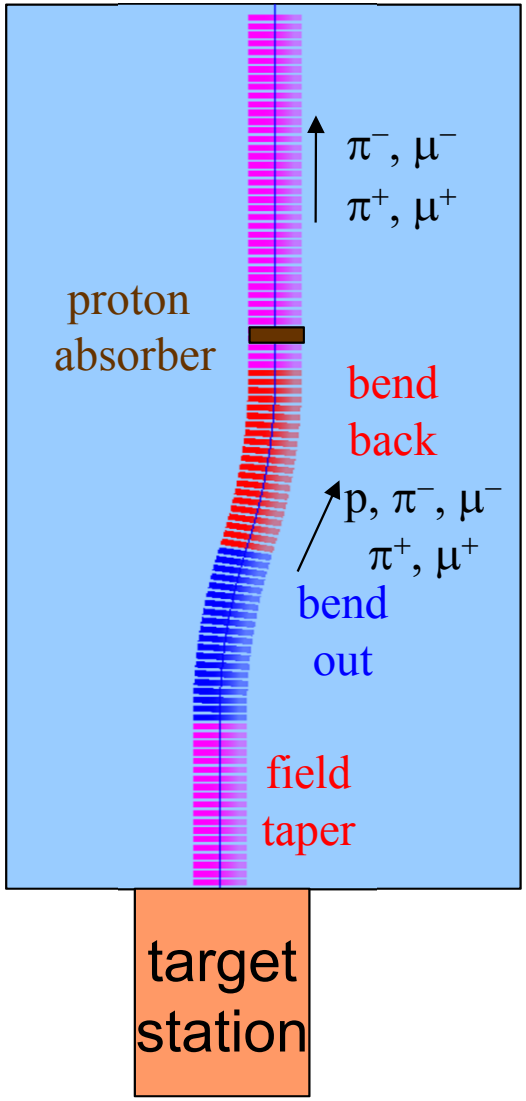



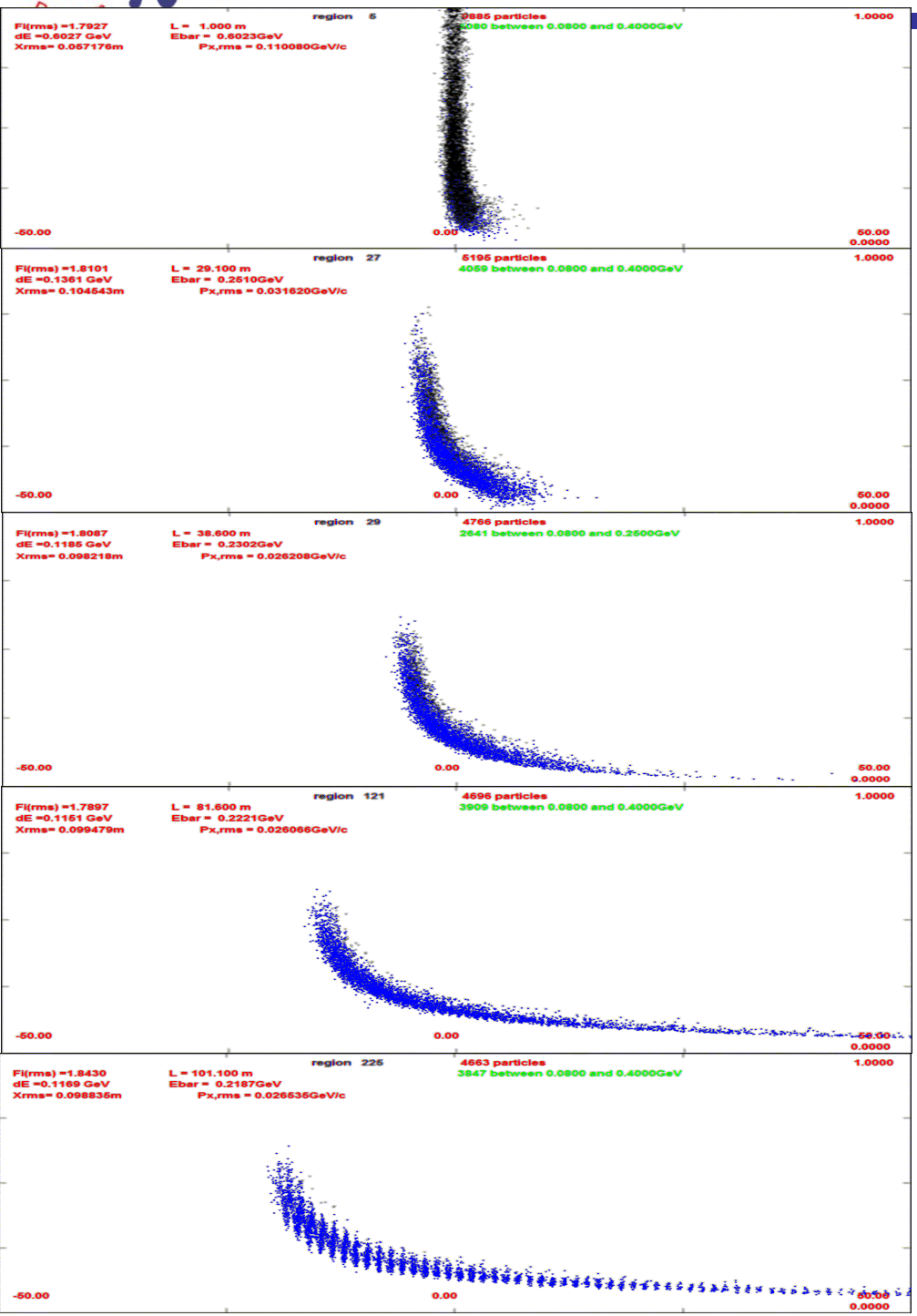



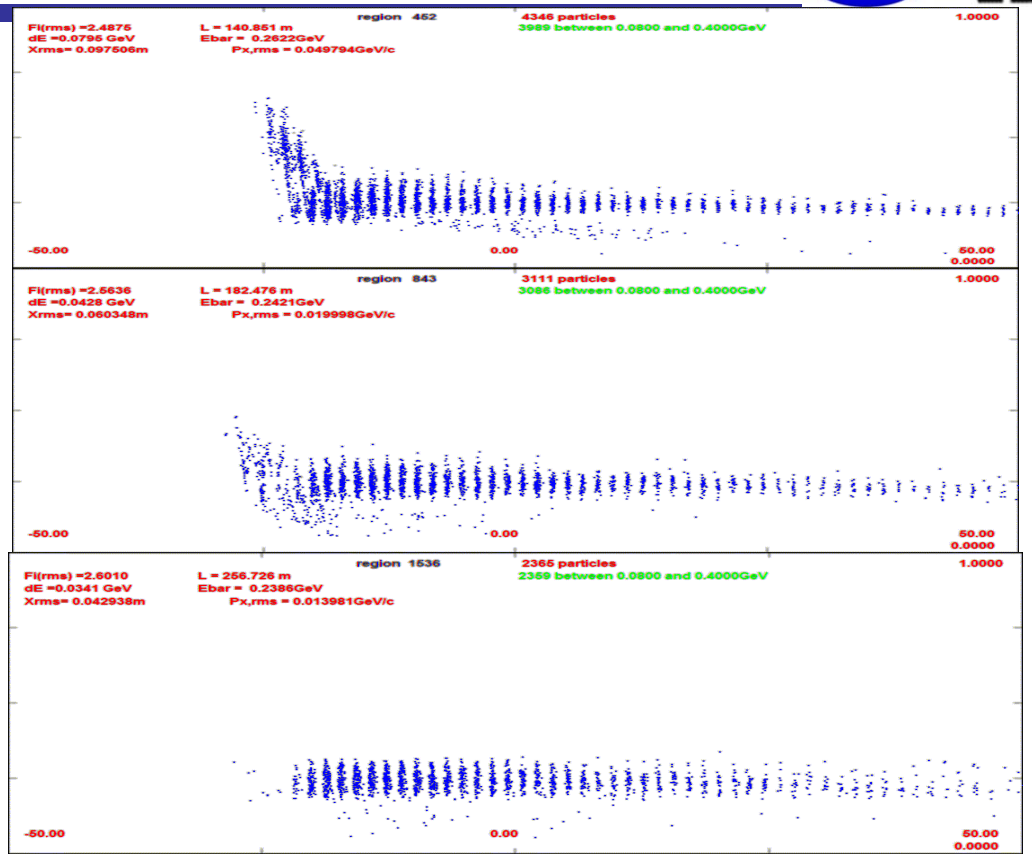
# Chicane + Absorber Works in ICOOL

- **Chicane does not reduce transmission by much:**
  - 0.098 → 0.094 (?) within acceptance
    - ~0.107 without chicane/absorber
  - Removes unwanted high energy particles
    - eliminates prepulse from high-energy muons
  - Works for both μ+ and μ-



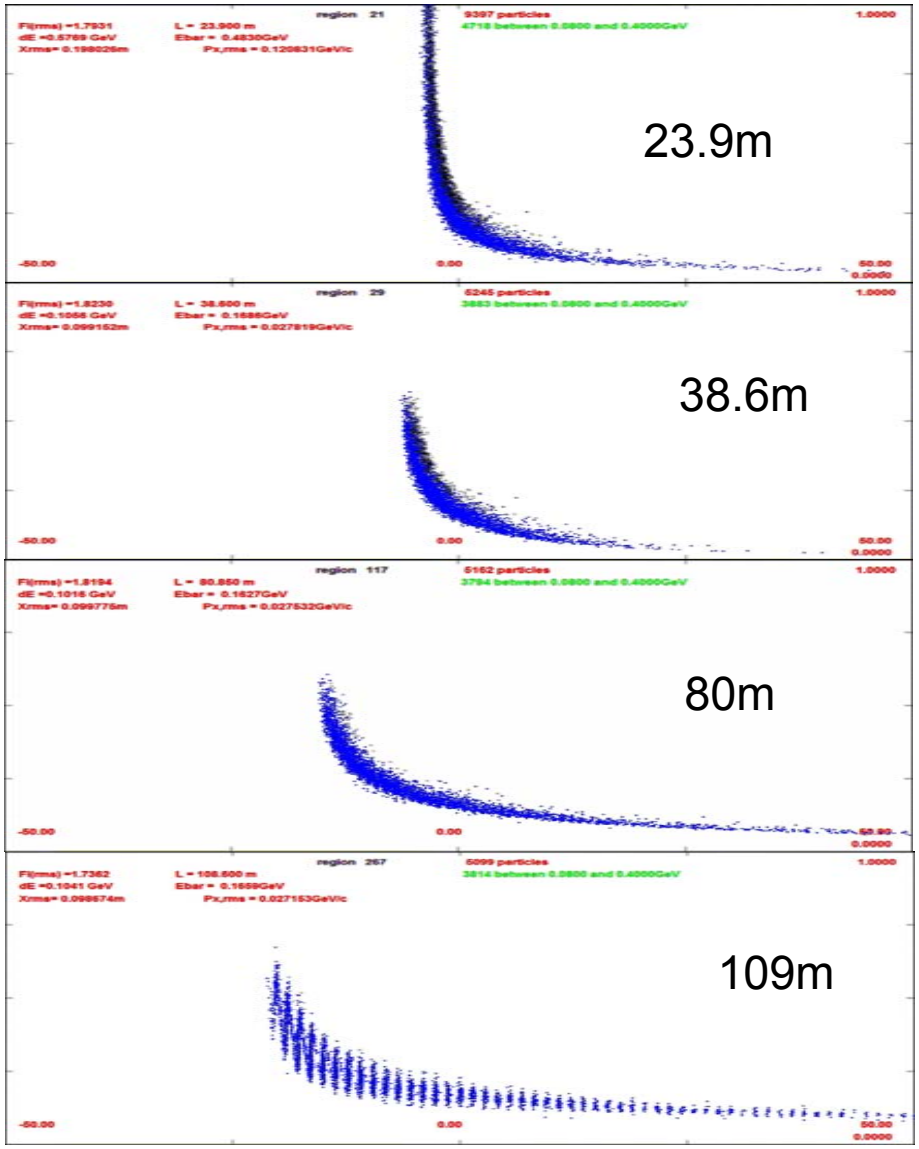
# Chicane + Absorber

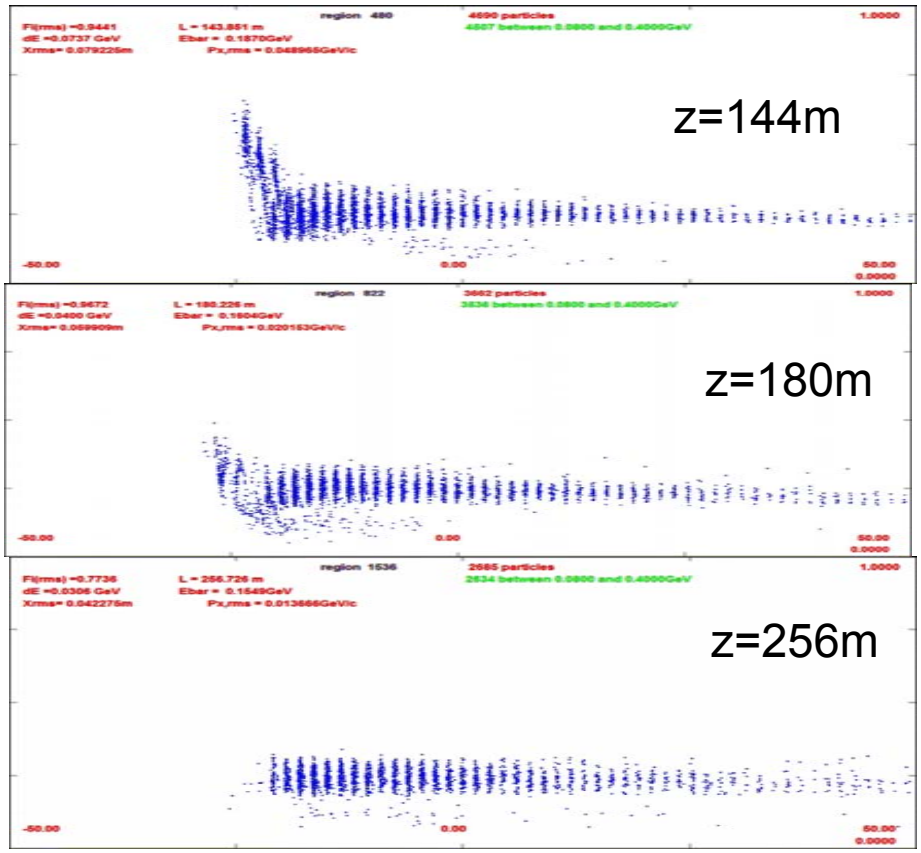



Negative initial beam from IDS study
~0.098 → ~0.094 μ/p
~0.107 without chicane absorber

# Chicane + Absorber Simulation

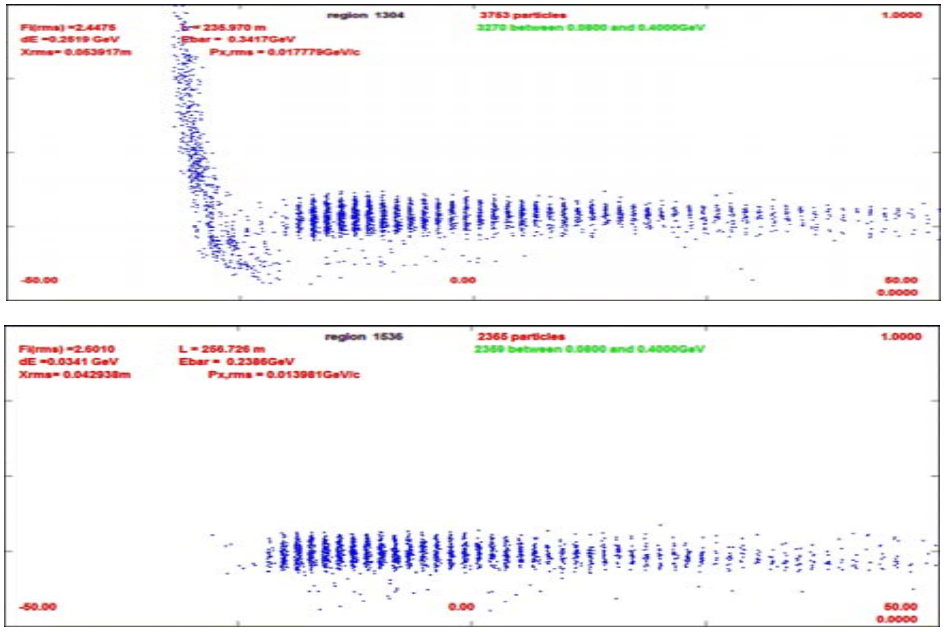



Positive initial beam
~0.075 → ~0.072 μ/p
~0.084 w/o absorber/chicane
~20% fewer $\mu^+$ than $\mu^-$

# Comments on Simulation Results

- chicane increases initial transverse rms emittance a bit
  - ~0.018→ 0.020m
- ecalc9 longitudinal emittance much smaller with absorber + chicane
  - ~0.10 m
  - →0.075 – absorber only
  - →0.046 – chicane + absorber ?
- early μ's are removed
  - μ's from higher energies do not propagate down the system, do not give added background



# Problems ?

- Chicane + absorber works better than expected
  - **Did I miss something?**
- Have not done any significant optimization
  - **Continuous frequency change**
- muon throughput (probably) reduced from baseline
  - **~15% ??**
  - **much cleaner throughput**
    - **high-energy preflash removed**
    - **smaller longitudinal emittance**