中国科学院高能物理研究所
Institute of High Energy Physics
Chinese Academy of Sciences

Protons after bombarding the target at MOMENT

NuFact2015

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Cai MENG

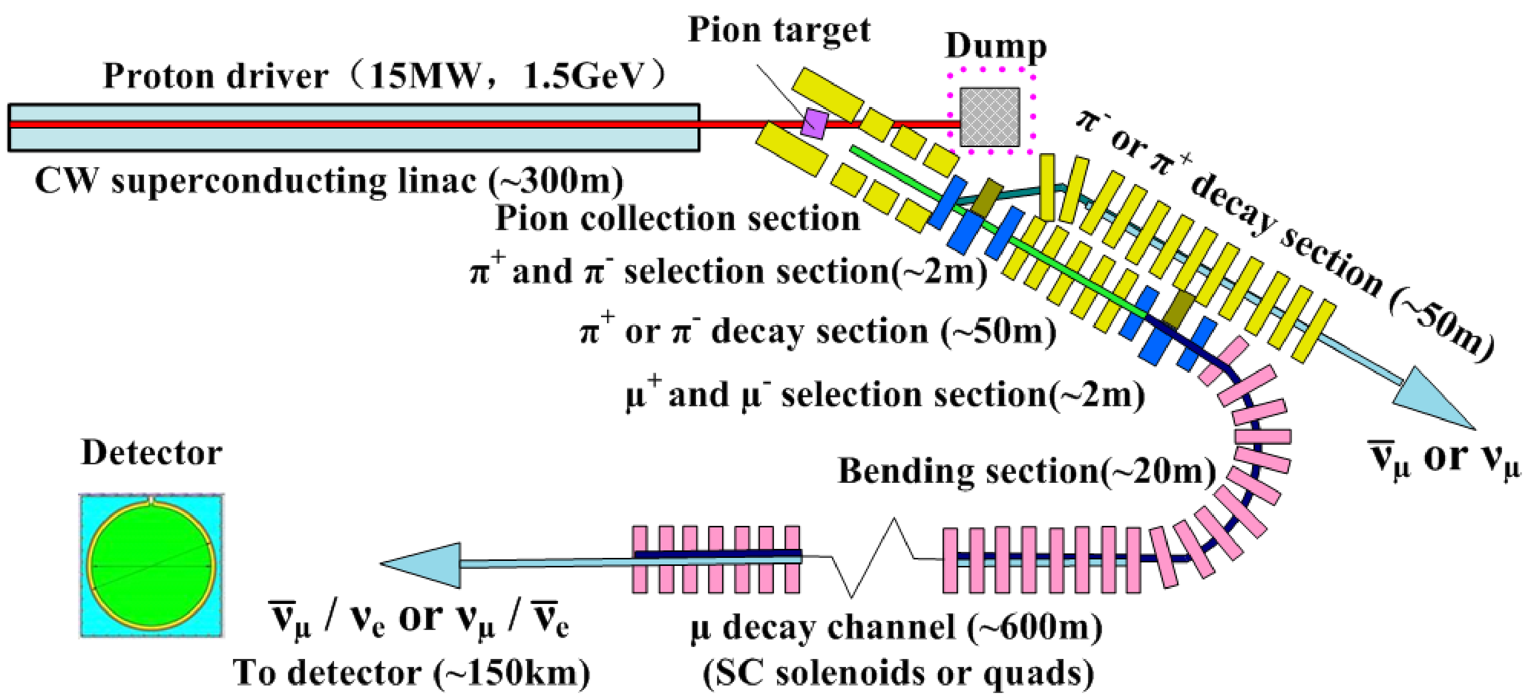
Institute of High Energy Physics, CAS, Beijing

Outline

1. Introduction: MOMENT

MOMENT

- MOMENT: A muon-decay medium baseline neutrino beam facility
  - *CW proton superconducting linac for proton driver*
  - *Beam: 15 MW / 1.5 GeV / 10 mA*



1. Introduction: MOMENT target station

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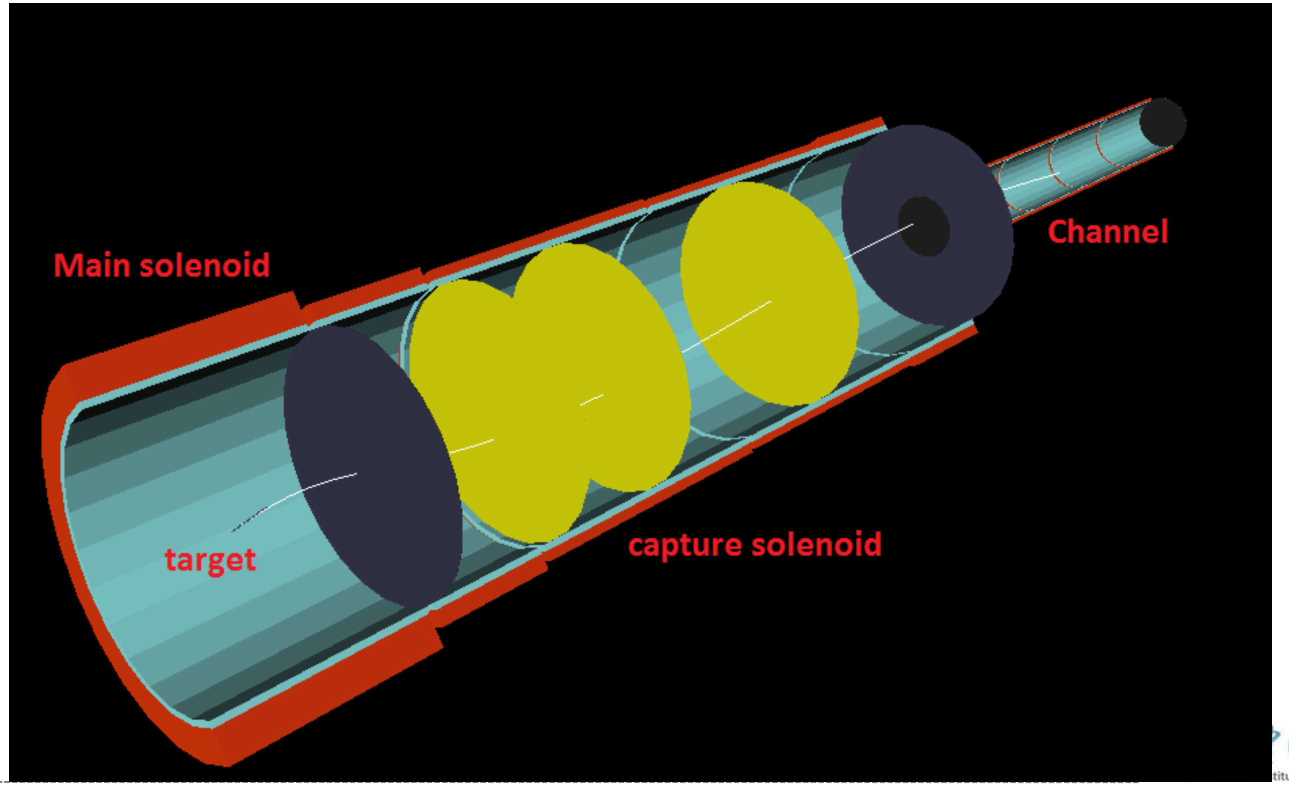
- Main solenoid: Pion target, 14 T, about 1 m
- Capture solenoid: adiabatic, about 3 T, about 1 m
  - End of capture solenoid (beam loss)
- Pion collection channel: about 3 T, about 0.3 m



1. Motivation

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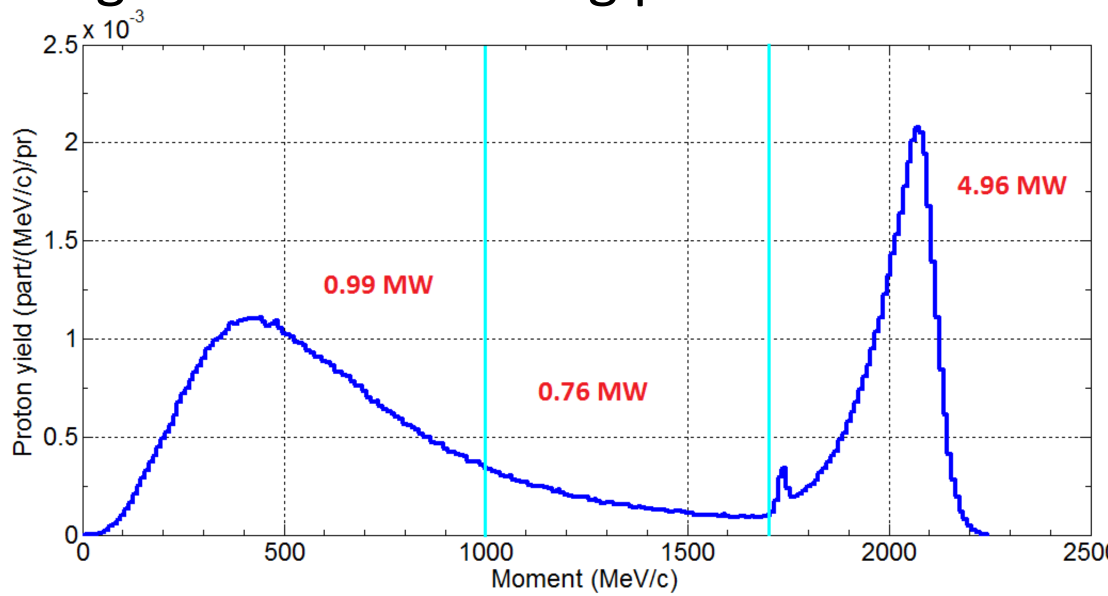
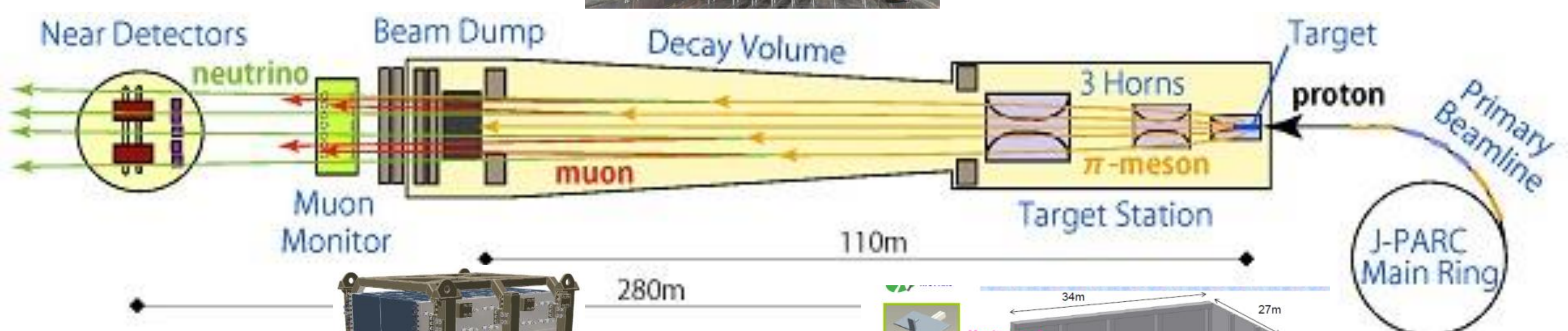
- Very high beam power at target 15 MW
- Protons after bombarding the target
  - High momentum proton ~ 5 MW
  - Medium momentum proton ~ 0.8 MW
  - Low momentum proton ~ 1 MW, same as Pion momentum
- Energy deposition: Cooling and Shield
- Separate high momentum proton from target area to reduce the difficulty of target design without reducing pion collection efficiency greatly

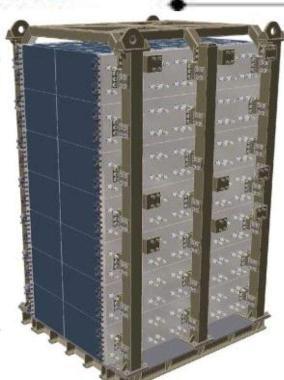


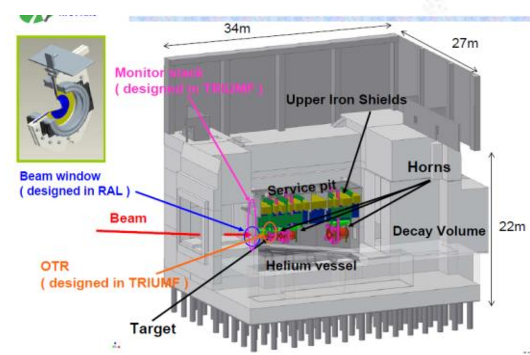
2. Method research ➡ J-parc Neutrino Facility

MOMENT

- Beam: 1.66 MW / 30 GeV
- 3 Horn->linear decay channel-> Beam Dump







2. Method research ➡ EUROnuSB

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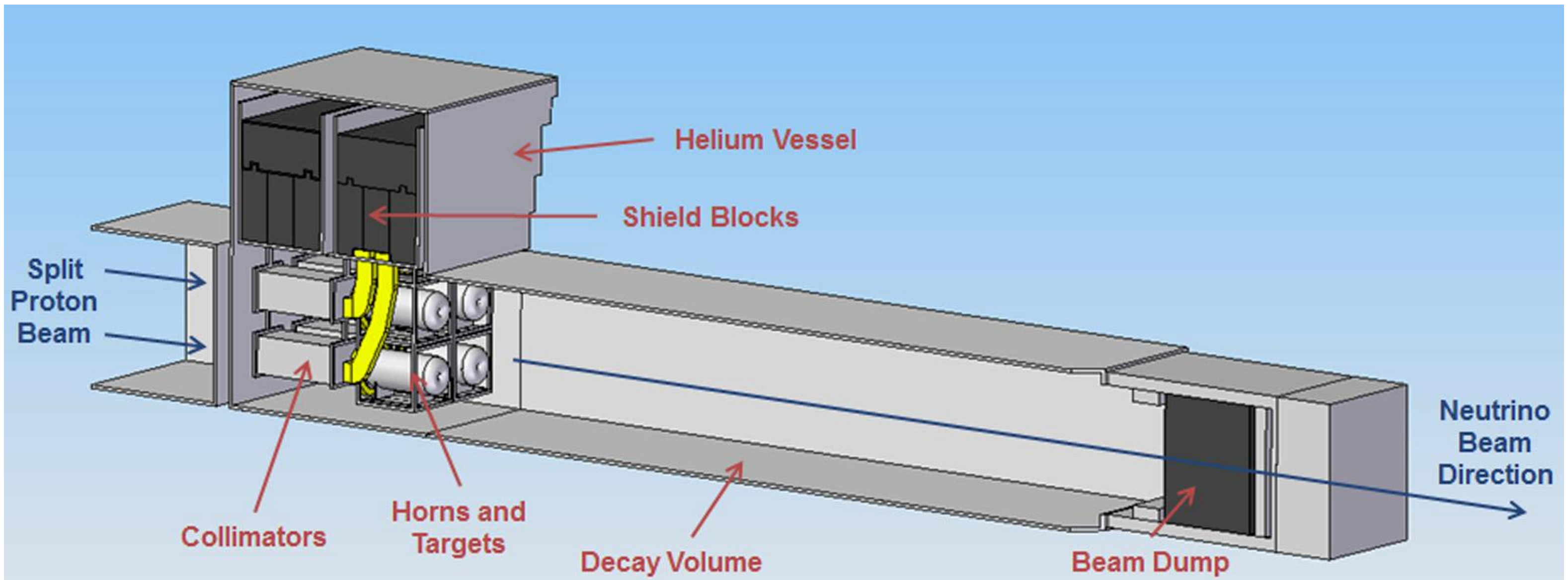
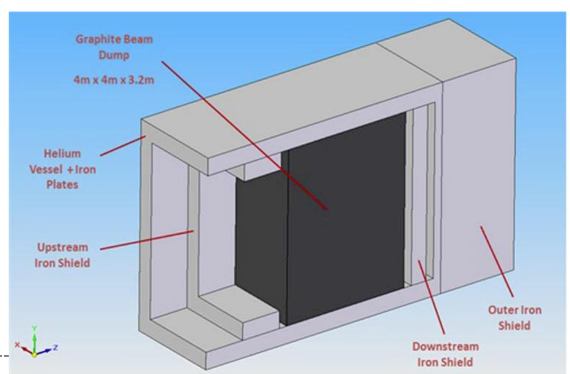
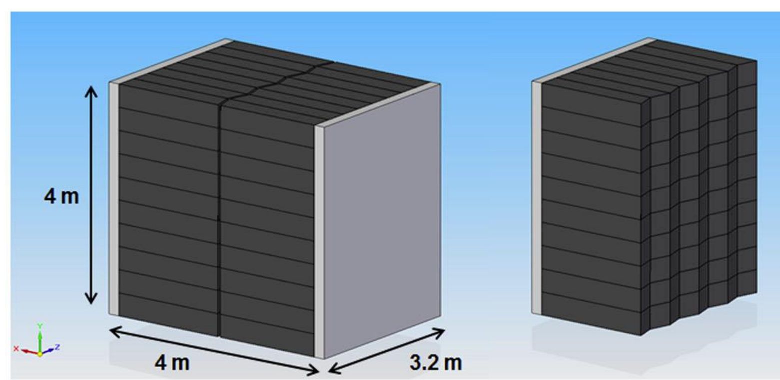
- Beam: 4 MW / 5 GeV
- Horns->linear decay channel-> Beam Dump

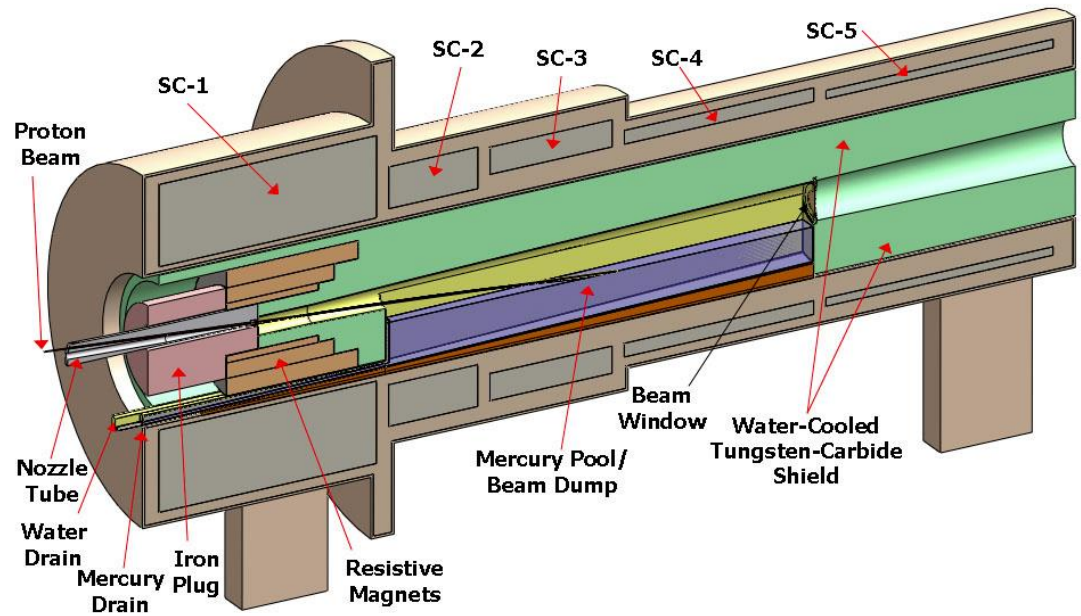


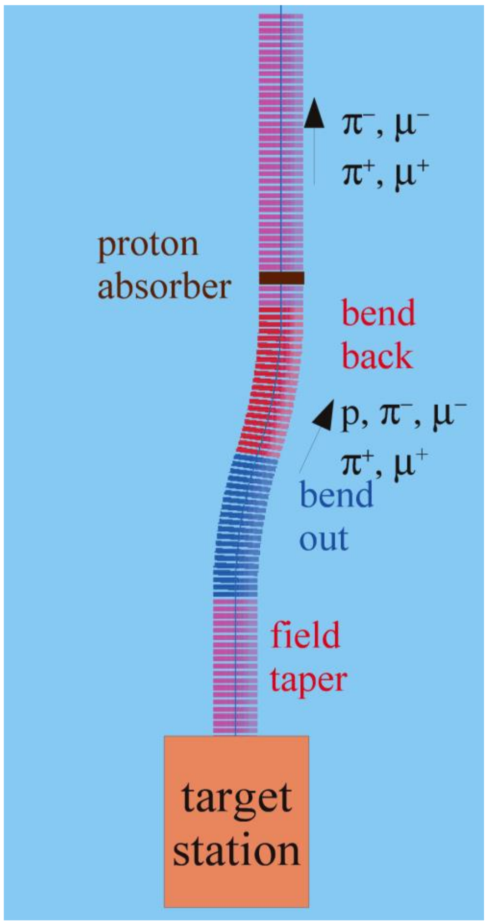


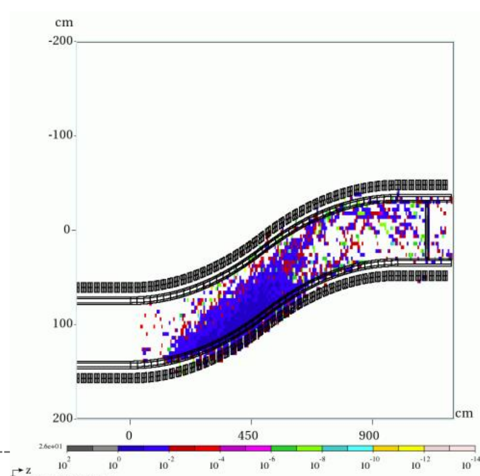


2. Method research ➡ Neutrino Factory

- Beam: 4 MW / 8 GeV







- ➢ Mercury pool serves as the proton beam-dump
  - ➢ High energy proton
- ➢ a 12.5◦ chicane angle
  - ➢ Medium energy proton
- ➢ 100 mm proton absorber （Beryllium）
  - ➢ Low energy proton

3. MOMENT ➡ Method study

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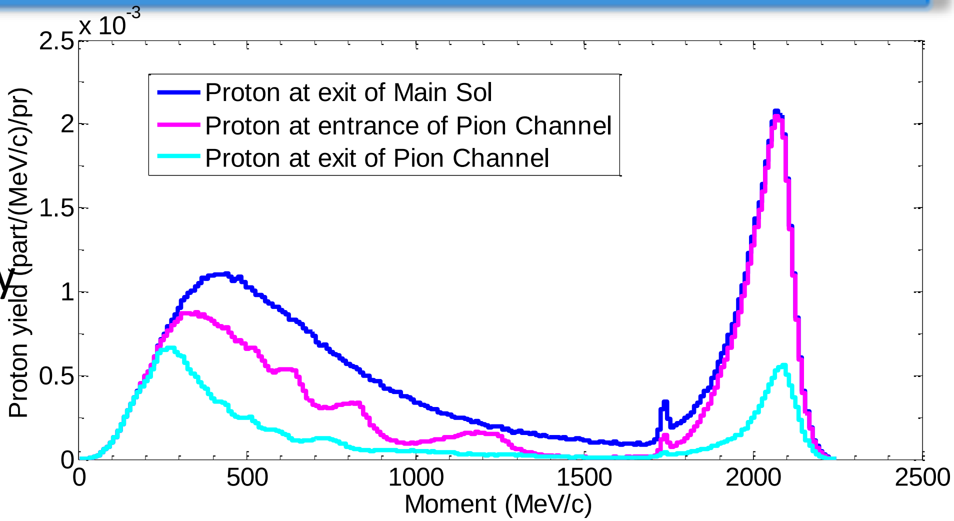
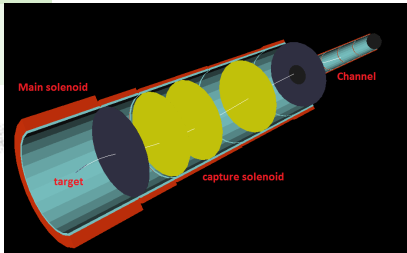
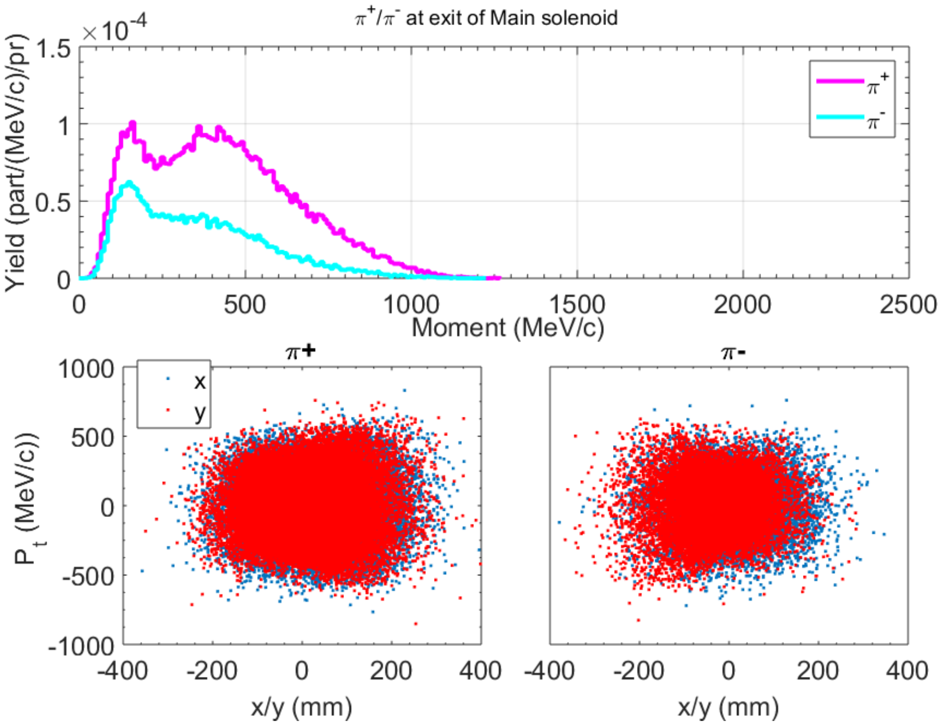
- Features
  - Beam:
    - 1.5 GeV, difficult to take beam power by mercury pool for low energy
    - 6.7 MW
  - Layout:
    - complex, not linear channel
  - Different momentum, different magnetic rigidity, different gyration radius
    - ***A separate channel for high momentum proton***

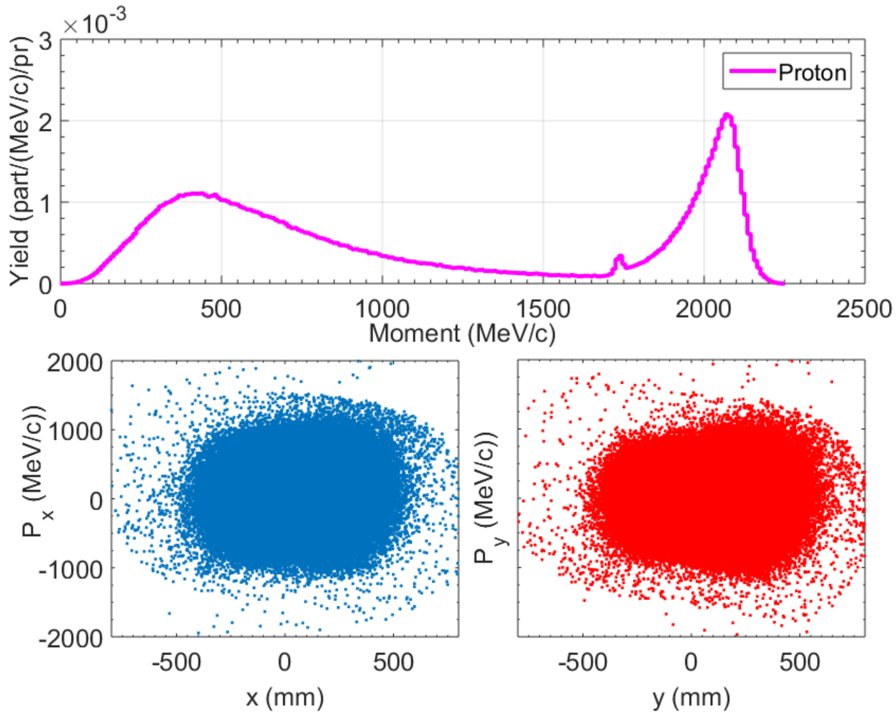


Proton	Low	medium	High	total
	MW			
Exit of main sol	0.99	0.76	4.94	6.69
Entrance of Pion channel	0.54	0.27	4.53	5.34
Exit of Pion channel (5 m)	0.2	0.1	1.14	1.44



- After Main solenoid
  - Pion momentum ~ low momentum proton



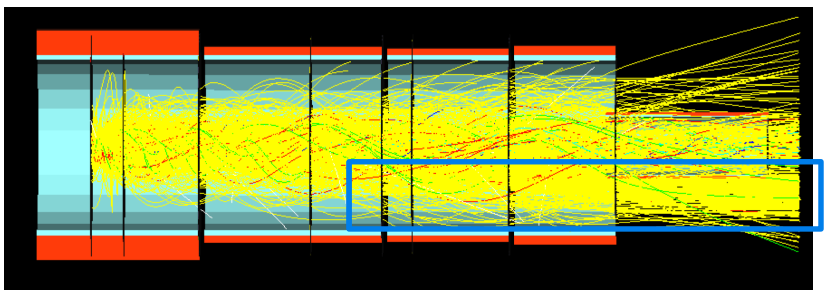


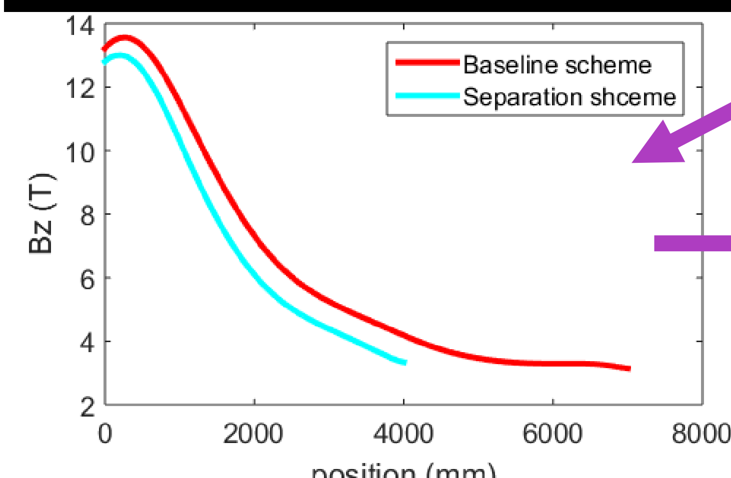
3. MOMENT ➡ Method study

- Different filed will cause different tracking with different momentum
  - Higher momentum->bigger gyration radius: **separation**
  - Lower field-> bigger gyration radius: **separation**
  - 10 T scheme (Capture solenoid) , obvious separation in different momentum
  - 14 T scheme (Capture solenoid), all particles transport in the center of solenoid

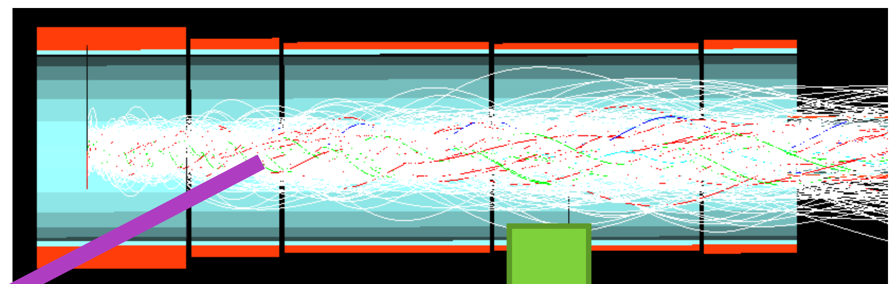
Field length

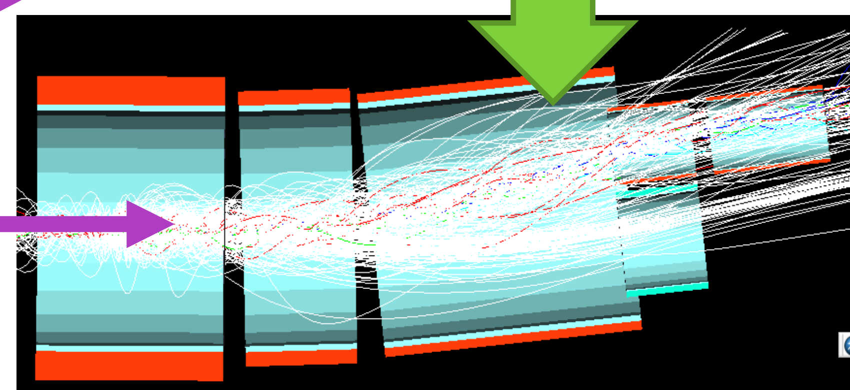
10T scheme





14T scheme: ***baseline scheme***





Separation scheme

3. MOMENT ➡ Method study

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- High momentum proton separation
  - Solenoid field: above analysis (magnetic filed & length)
  - Deflection field: different magnetic rigidity, high momentum proton and low momentum proton (same as Pion) will been separated.
  - Bending solenoid angle: important
  - Collection channel aperture:

- Complex filed
- large divergence angle

Optimization is difficult

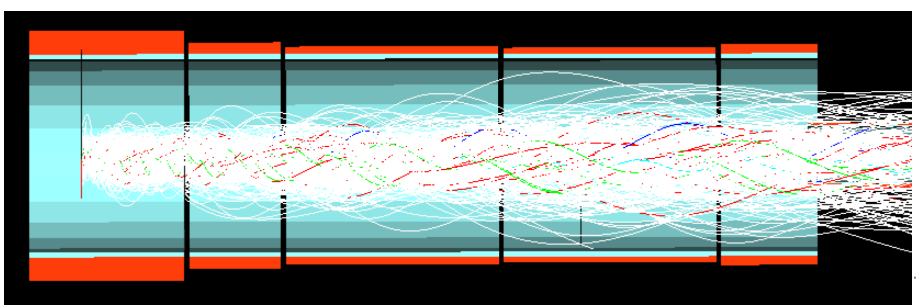
$$\frac{d\vec{p}}{dt} = q \cdot \frac{\vec{p}}{\gamma m} \times \vec{B}$$

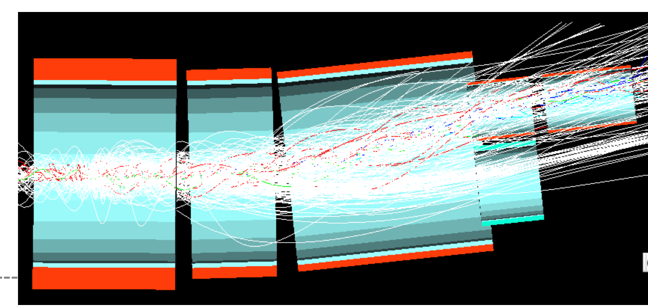
$$\begin{cases} \dot{p}_x = \dfrac{dp_x}{dt} = q \cdot \dfrac{p_z}{\gamma m}\left(y' \cdot B_z - B_y\right) \\ \dot{p}_y = \dfrac{dp_y}{dt} = q \cdot \dfrac{p_z}{\gamma m}\left(-x' \cdot B_z + B_x\right) \\ \dot{p}_z = \dfrac{dp_z}{dt} = q \cdot \dfrac{p_z}{\gamma m}\left(x' \cdot B_y - y' \cdot B_x\right) \end{cases}$$

$$\frac{dx'}{ds} = \frac{d\left(p_x / p_z\right)}{dt} \cdot \frac{dt}{ds} = \frac{1}{\beta_z c} \frac{\dot{p}_x - \dot{p}_z \cdot x'}{p_z}$$

$$\frac{dx'}{ds} = \frac{q}{\beta_z \gamma mc}\left[x'y' \cdot B_x - \left(1 + x'^2\right) \cdot B_y + y' \cdot B_z\right]$$

$$\frac{dy'}{ds} = \frac{q}{\beta_z \gamma mc}\left[-x'y' \cdot B_y + \left(1 + y'^2\right) \cdot B_x - x' \cdot B_z\right]$$

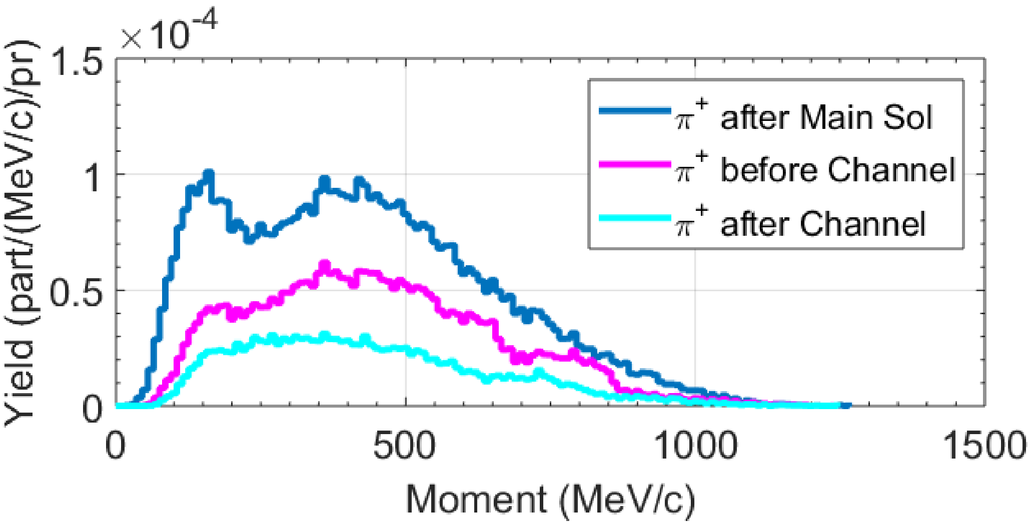


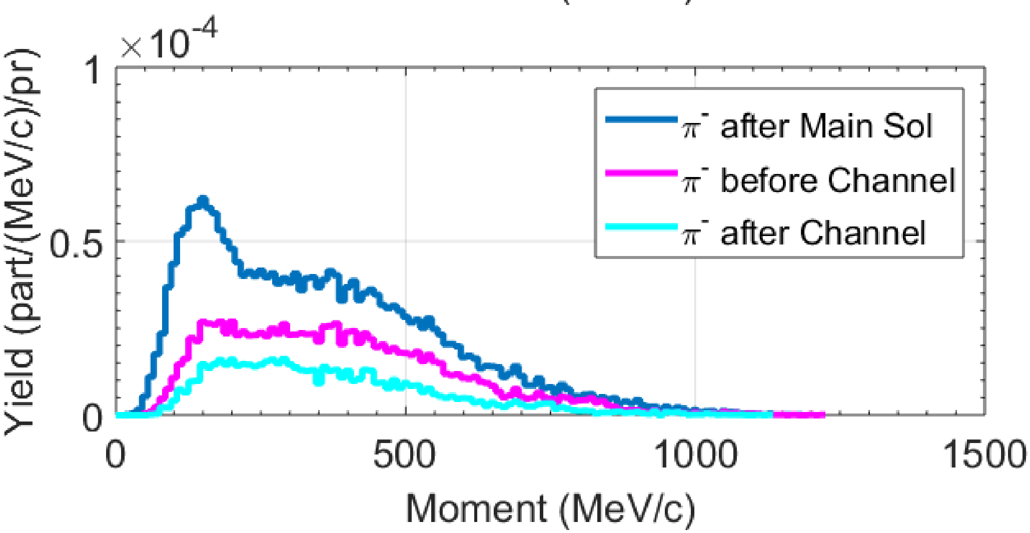


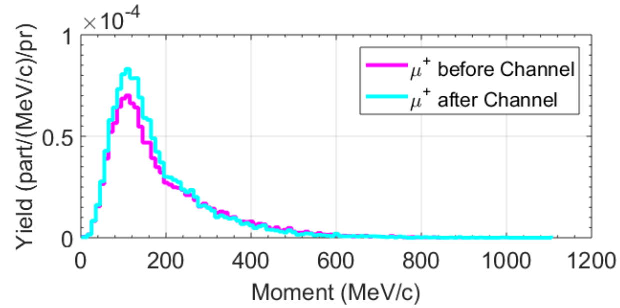
3. MOMENT → Simulation results

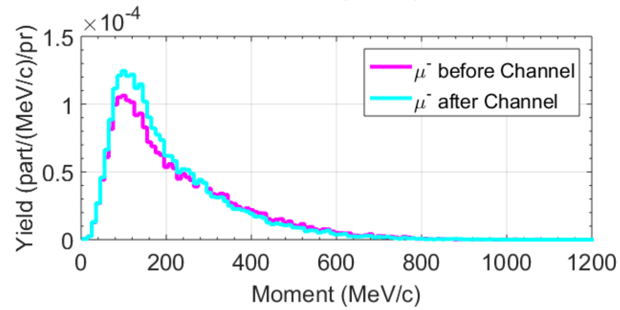
MOMENT

Pion collection at the baseline scheme



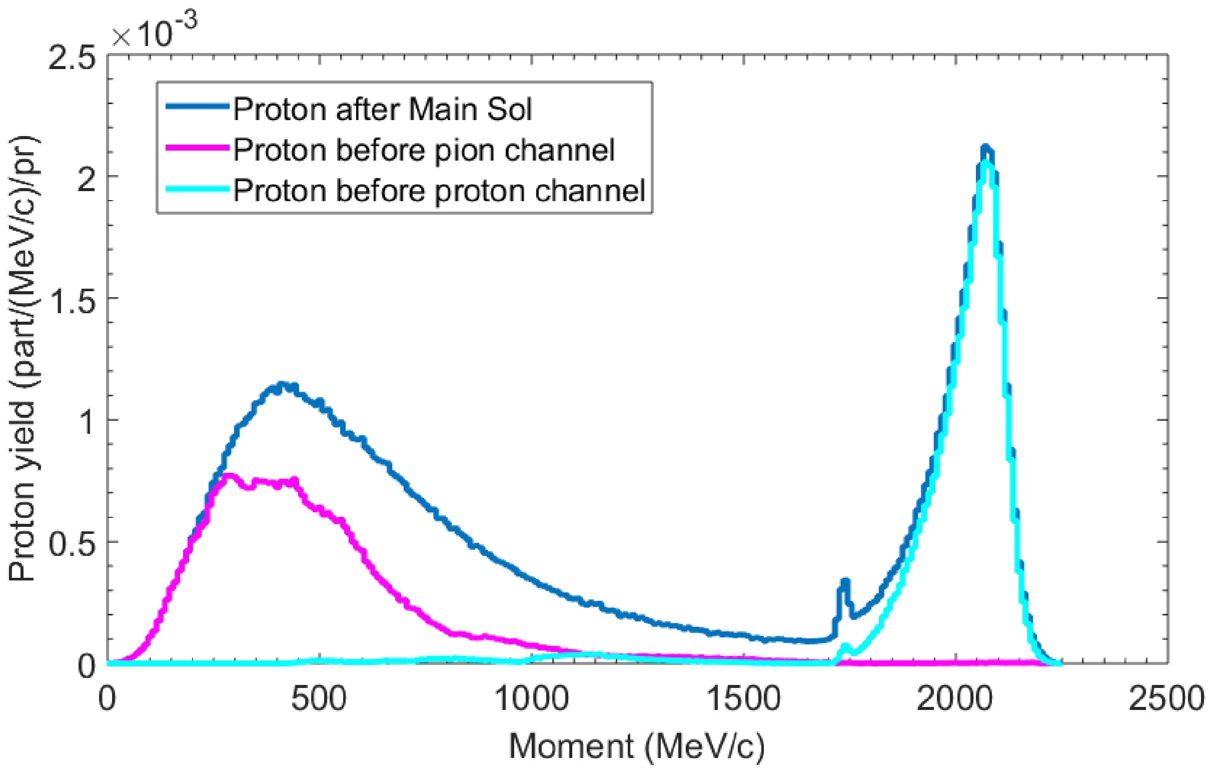






Yield/10^{-2}	π^+	π^-
Exit of main sol	5.55	2.33
Entrance of Pion channel	**3.10**	**1.25**
Exit of Pion channel (5 m)	1.56	0.64

Proton separation at the separation scheme

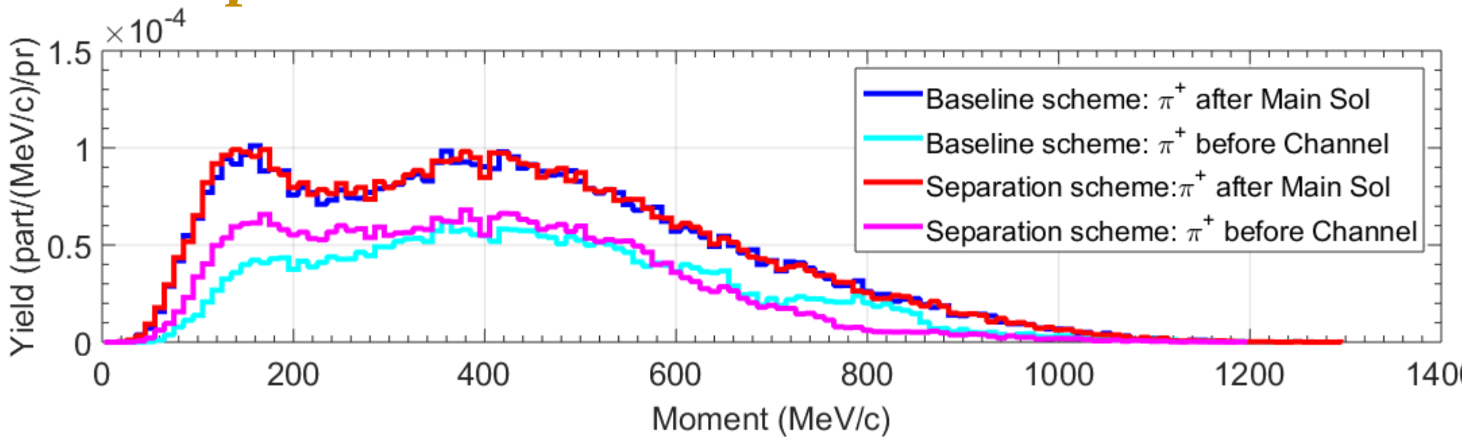


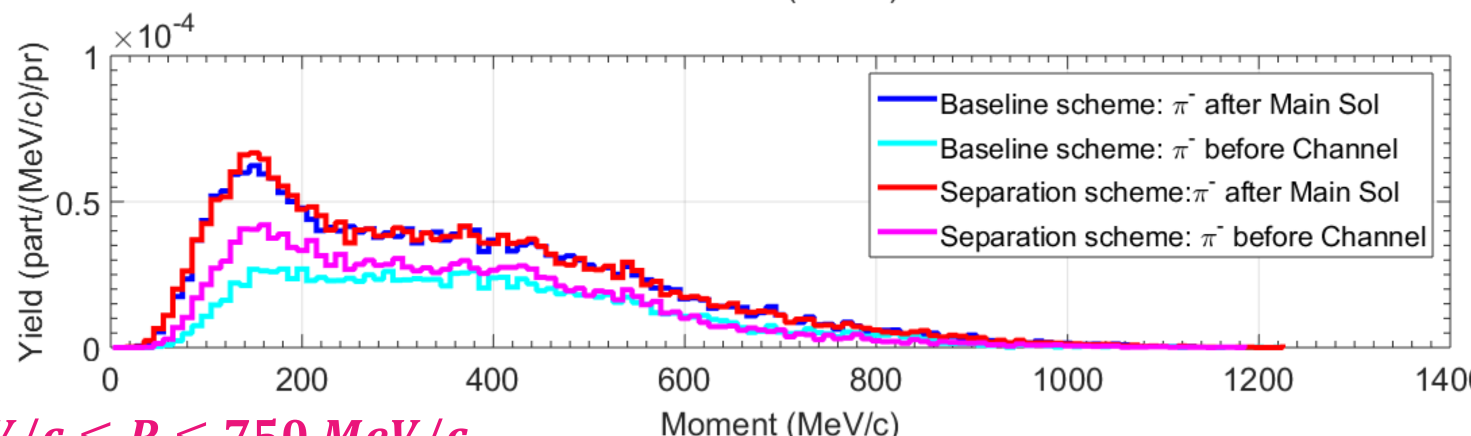
High momentum proton separation efficiency: **89%**

Still about 1.7 MW proton beam lost in target station

Proton	Low	medium	High	total
	MW			
Exit of main sol	1.01	0.76	4.97	6.74
Entrance of pion channel	0.41	0.11	0.01	0.53
Entrance of proton channel	0.016	0.06	4.43	4.51

Pion collection at the separation scheme





Cutoff: $200\ MeV/c \leq P \leq 750\ MeV/c$

Yield/10^{-2}	Total π^+	Total π^-	Cutoff π^+	Cutoff π^-
Baseline scheme	3.10	1.25	2.4	0.93
Separation scheme	**3.37**	**1.52**	**2.59**	**1.07**

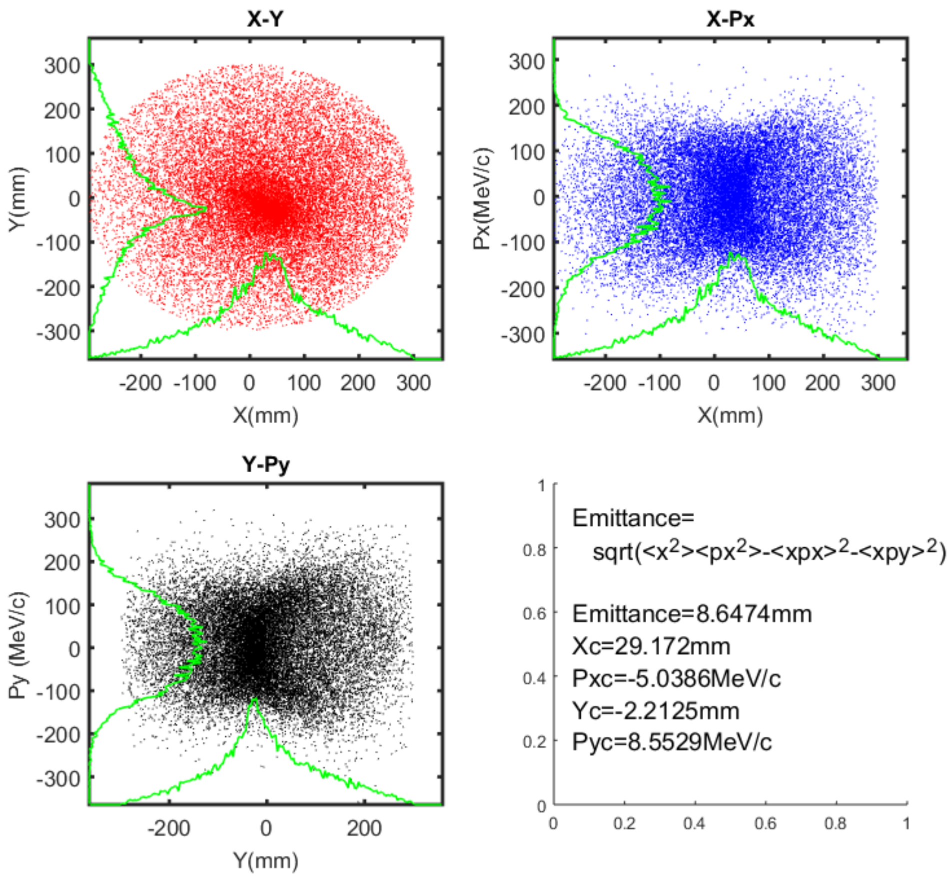
70%

3. MOMENT ➡ Simulation results

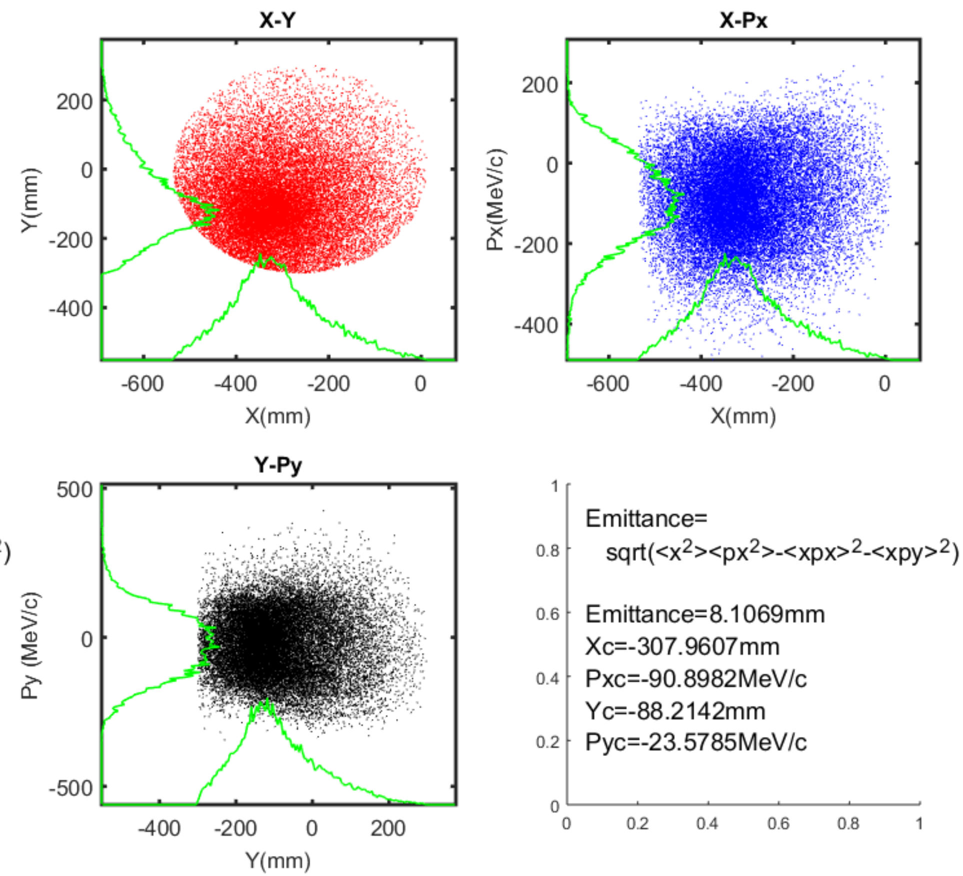
MOMENT

π^+ distribution before pion channel

Baseline scheme

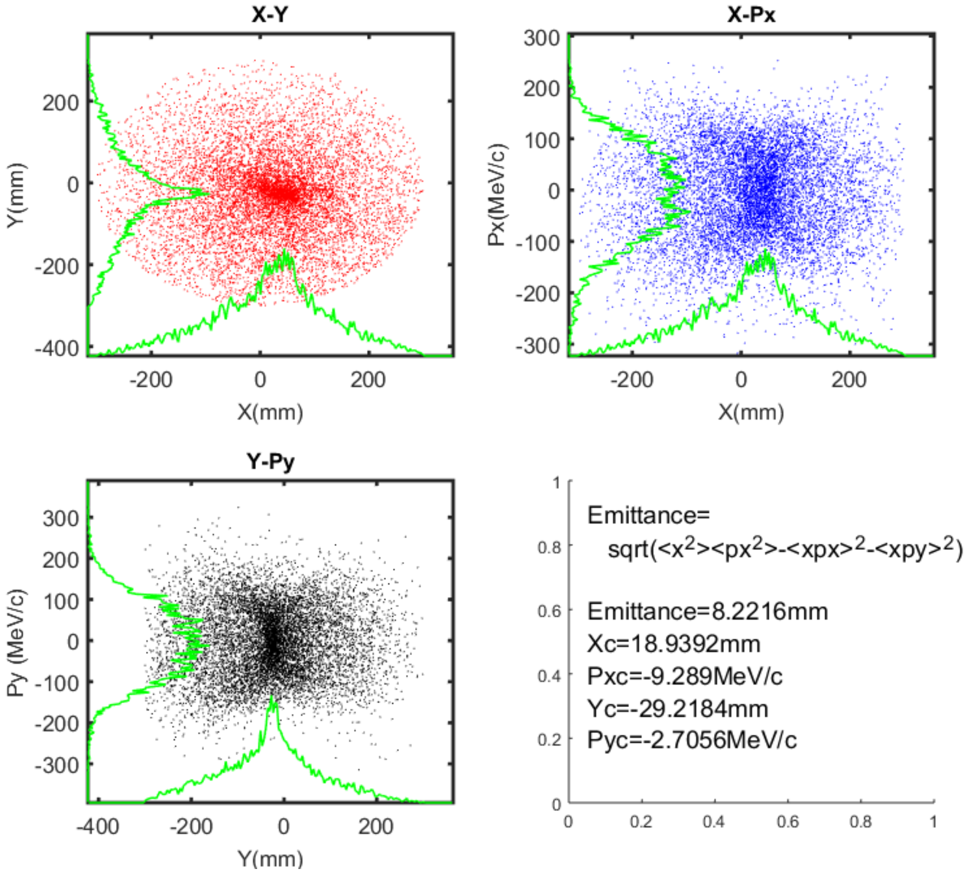


Separation scheme

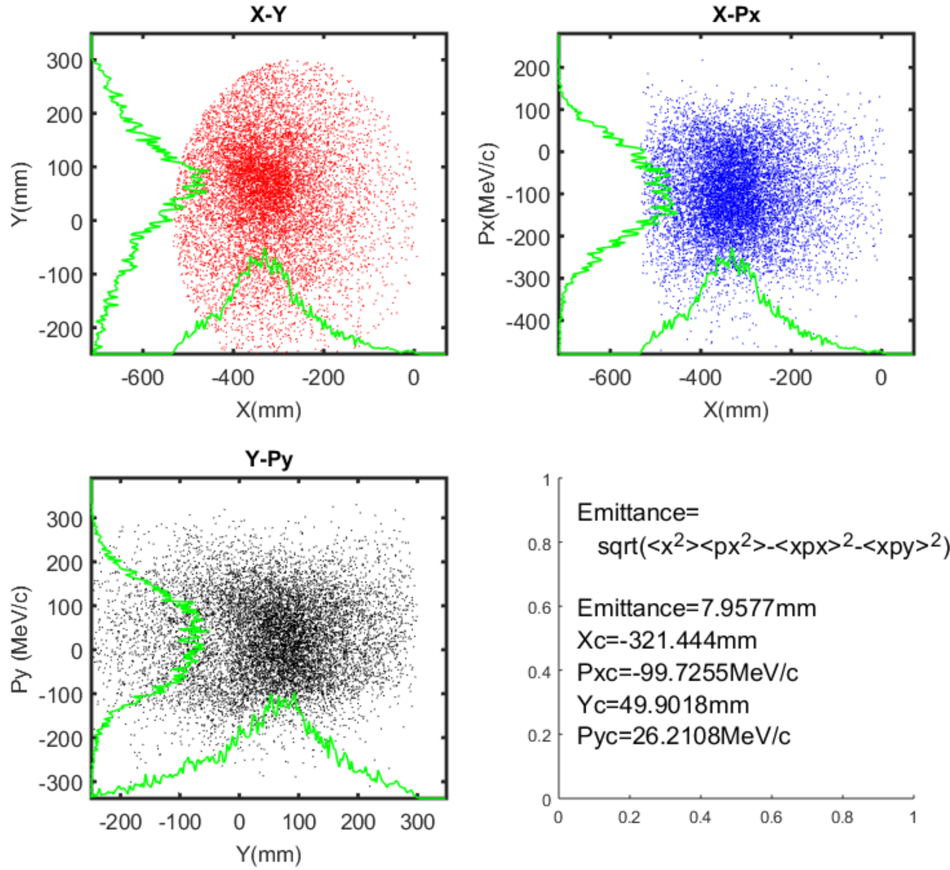


π^- distribution before pion channel

Baseline scheme



Separation scheme



4. Summary

- Detailed analysis proton momentum after bombarding the target for MOMENT
- One method to separation high momentum proton, about 89% separation efficiency, without reducing pion collection efficiency
- Next optimization to be continued

Thank you for your attention!