Muon production based on ions incident on an internal target

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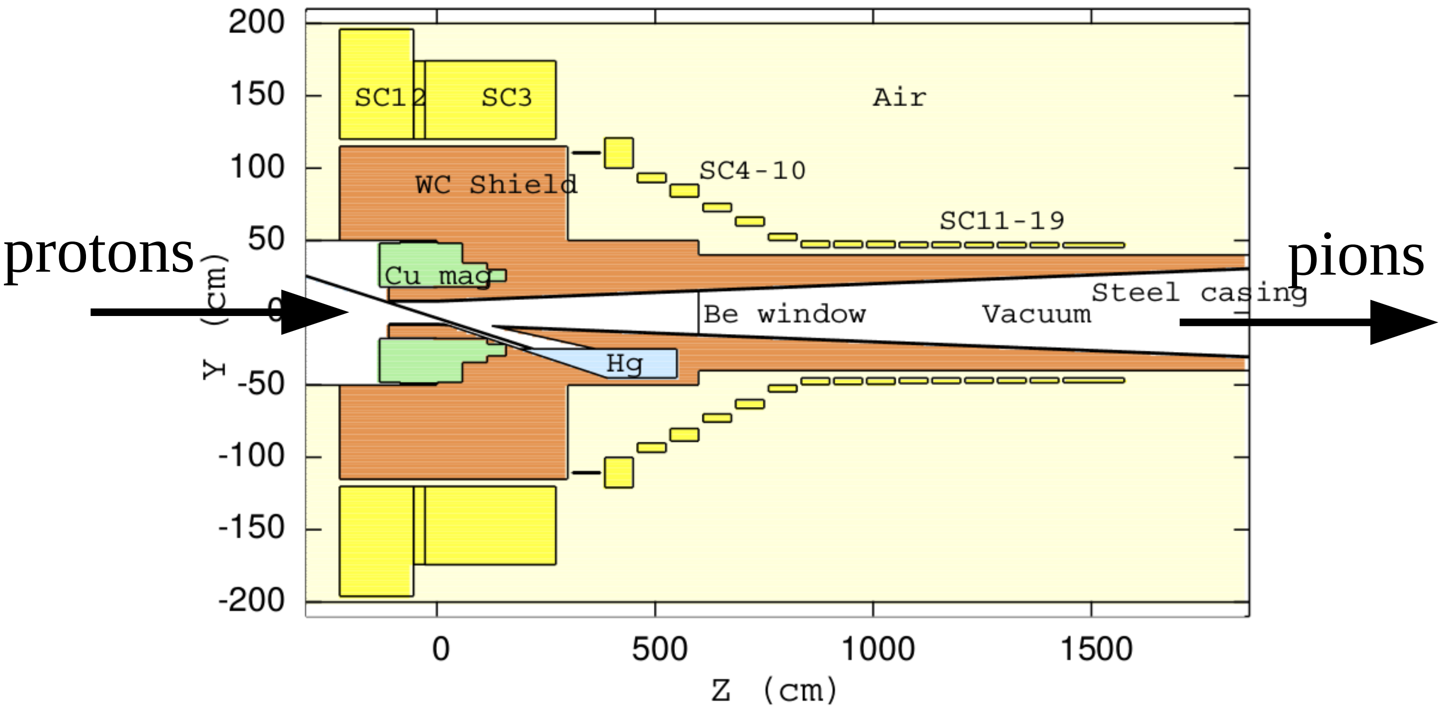
Overview

- Internal target technology can be used for muon production from protons
- May enable high rate pion and muon production with a relatively modest accelerator as source
- May enable high muon yield reducing the requirements on proton-driven muon collider cooling
- Design for muon production from internal target by Yoshi Mori et al
  - Y.Mori et al., "Intense Negative Muon Facility with MERIT ring for Nuclear Transmutation"; Proc, 14th Conf. On Muon Spin Rotation,Relaxation and Resonanc(μSR2017), JPS Conf. Proc. 21, 011063(2018). https://journals.jps.jp/doi/book/10.7566/musr2017
  - Intense Muon Source with Energy Recovery Internal Target (ERIT) Ring Using Deuterium Gas Target, Yoshiharu MORI, Hidefumi OKITA,Yoshihiro ISHI, Yujiro YONEMURA and Hidehiko ARIMA pp.1-9, Vol.77, No.1, September 28, 2017 http://kenkyo.eng.kyushu-u.ac.jp/memoirs-eng/top.php

Proton-based Muon Collider Pion Production

- “Standard” muon collider design takes protons onto a target in high field solenoid



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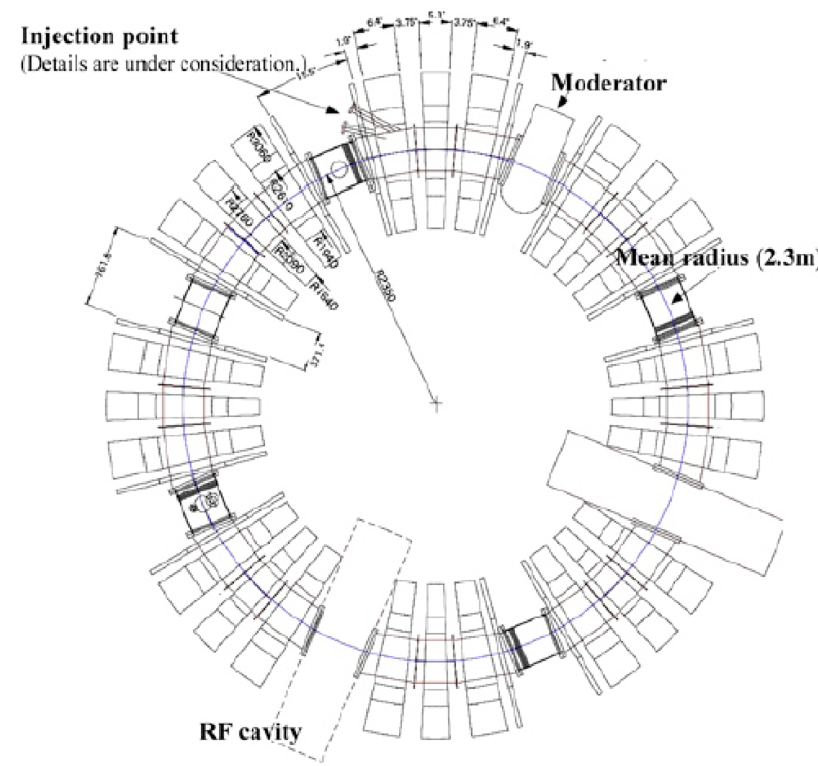
Challenges

- Large secondary radiation yield
- Large momentum spread of pions/muons
- Managed in proton-based muon collider in a number of ways:
  - Local shielding near to target and significant radioactive material handling facility
  - Short proton bunch and phase rotation to control longitudinal phase space
  - Ionization cooling to control transverse phase space
  - High-acceptance solenoidal chicane and absorber to filter beam impurities
- Significant beam cooling to give the required luminosity

Energy Recovery Internal Target (ERIT)

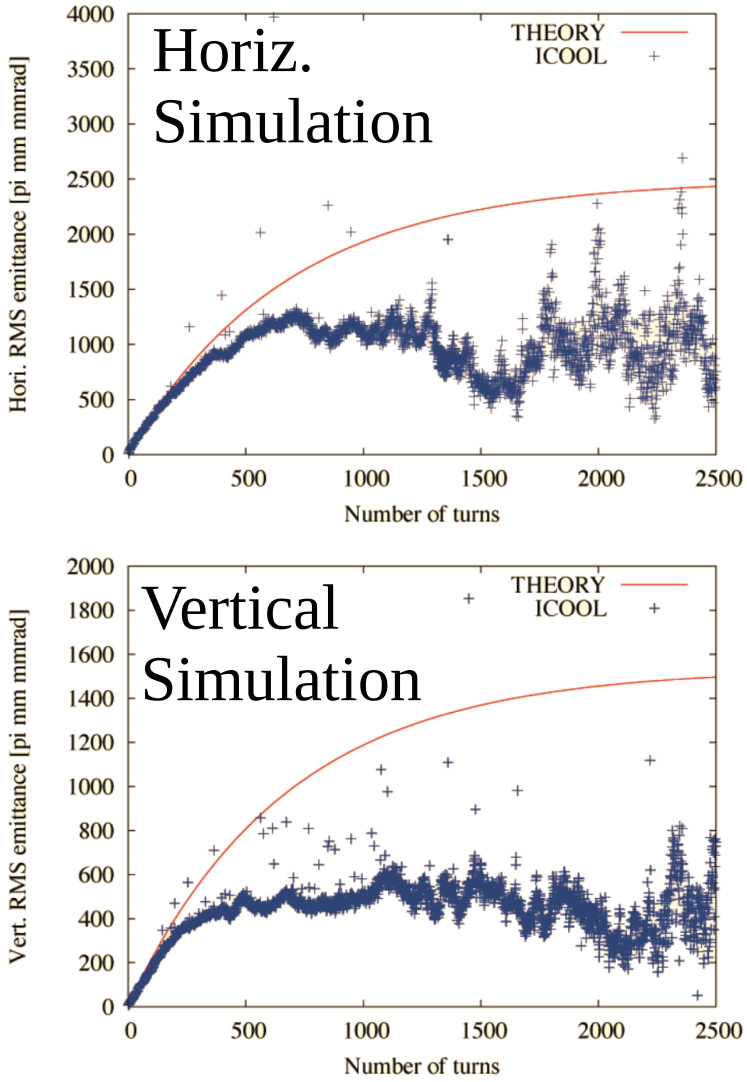
- KURNS ERIT ring (Mori et al)
- Study of neutron production for cancer therapy

Mean Radius [m]	2.35
Number of Sectors	8
Max B Field [T]	0.9
Field Index	1.92
FD Ratio	3
Horizontal Tune	1.74
Vertical Tune	2.22
Horizontal Acceptance [microns]	7000
Vertical Acceptance [microns]	3000
RF Voltage [kV]	200
Harmonic Number	6
RF Frequency [MHz]	3.01



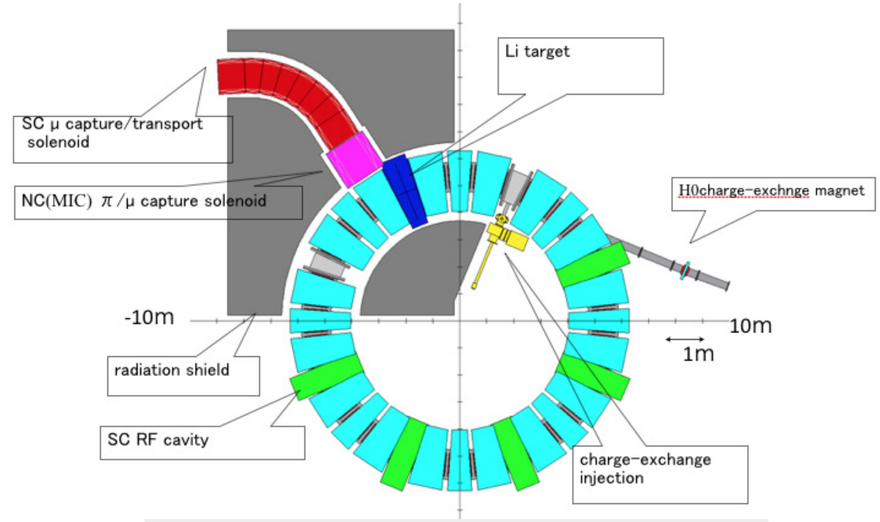
Energy Recovery Internal Target (ERIT)

- Excellent acceptance
- Beam survival ~ several 100 turns
- Limited in the end by vertical aperture
- Demonstrates that **amplification** using energy recovery is possible



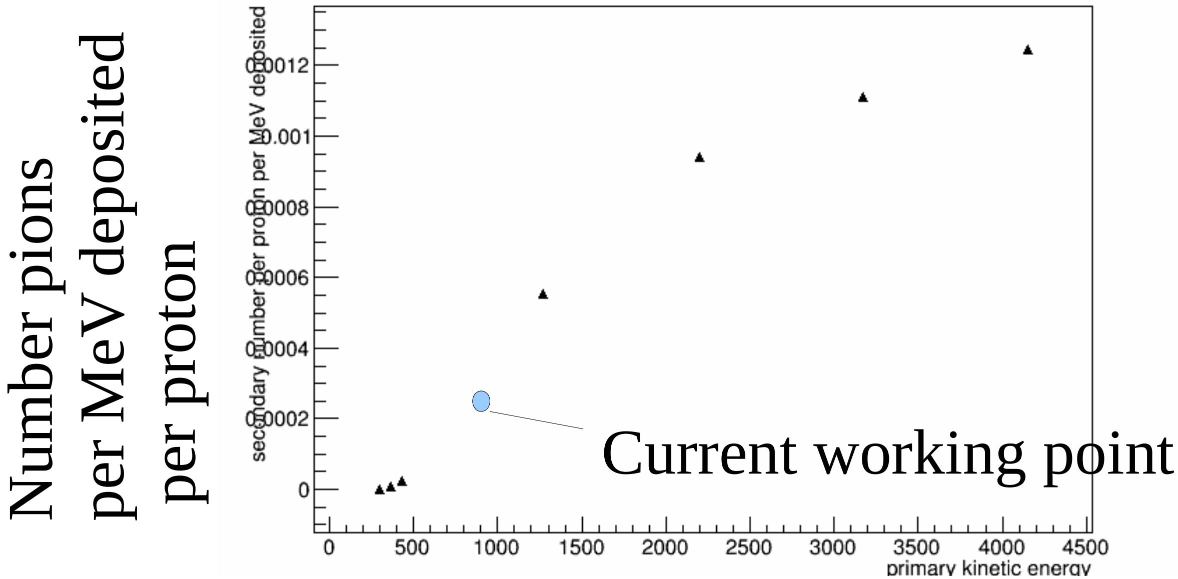
Multiplex Energy Recovery Internal Target (MERIT)

- MERIT muon production concept (Yoshi Mori, KURNS)
- Extend vertical aperture
  - Splitting coils further
  - Modify pole-tip profile
  - Very large DA
- Accelerate to top energy and hold
  - Wedge shaped liquid Li target
  - Serpentine (fixed frequency) acceleration
- Yields very long beam lifetime



Ring configuration	H–FFAG
Energy Range [MeV]	500-800
Magnetic Rigidity [Tm]	3.633-4.877
Lattice	FDF
Average Radius [m]	5.044-5.5
Magnetic Field [T]: F	1.96-2.41
Magnetic Field [T]: D	1.71-2.11
Number of Cells	8
Field Index	2.43
Cell Tune: H	0.212
Cell Tune: V	0.18
Horiz. Beta Function [m]	2.5
Vert. Beta Function [m]	2.8
Dispersion function [m]	1.5

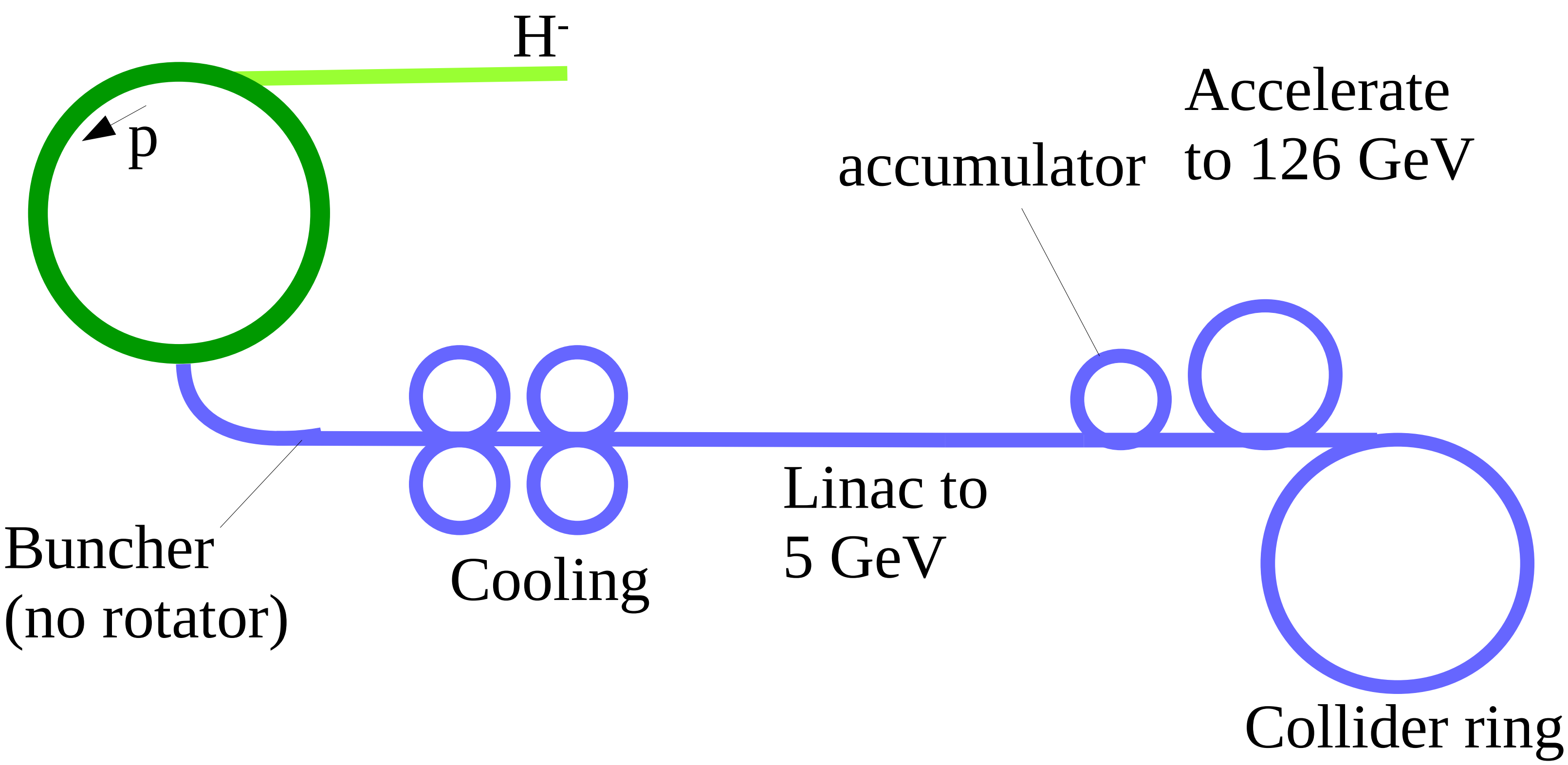
Muon Production



- Get between about 10^{-4} and 10^{-3} pions per proton per MeV deposited on target
  - Baseline has 2 MeV/proton per pass (100 ns)
  - Baseline has approx 10^{12} protons stored

Combining into a Muon Collider

- Scheme as follows



Considerations

- Near IR MERIT ring must be remote handled
  - But existing MC design → high field solenoid near IR
- Buncher and cooling channel must be CW
  - Can't accumulate near capture due to short muon lifetime
  - Can take advantage of longitudinal cooling
- In collider ring muons have 2 ms lifetime
  - 4×10^8 muons per pass
  - 4×10^{13} in 1 ms lifetime @ 100 GeV
  - Can run with 1 kHz rep rate
- Operating proton ring at higher energy has advantages
  - More primary protons (weaker space charge limit)
  - More secondary pions per proton
  - Can get to even higher rates