Muon Dreams

revisited

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BL1A Upgrade Plan

Jess H. Brewer - 03-04 June 2021

Proposal:

Low Energy Muon Source

in front of the Isotope Production Facility

Recapitulating the Obvious:

- Any Upgrade Plan should include the following categories:
  - ☆ Maintenance & Operation of existing facilities and programs.
  - ☆ Construction & Commissioning of finished engineering designs.
  - ☆ Engineering Design of thoroughly evaluated new concepts.
  - ☆ Concept Evaluation: Comparison of scientific potential, technical feasibility and probable cost of competing proposals.

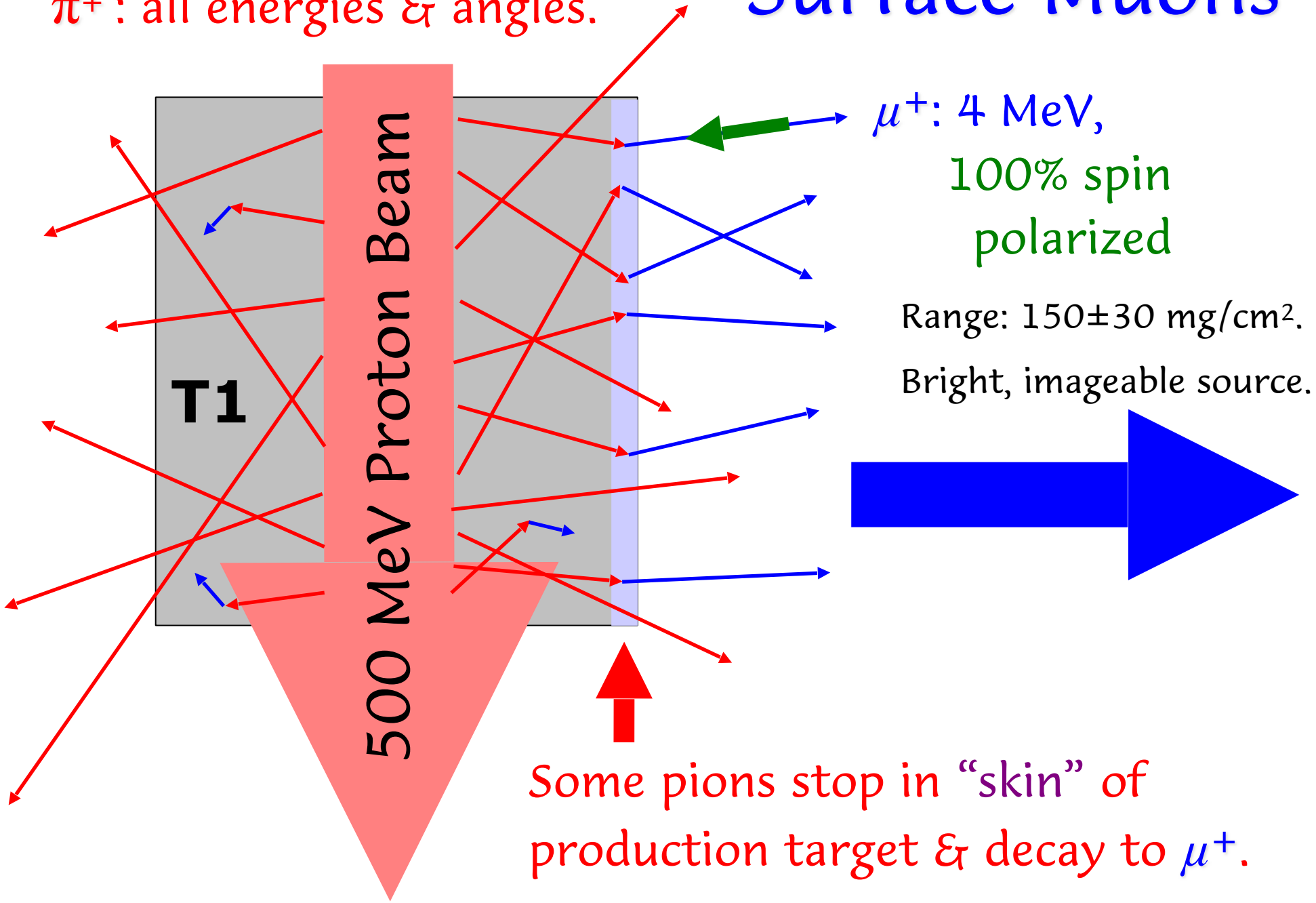
- Guiding Principles:
  - ☆ Do what you're good at. (*e.g.* M20 & M9 upgrades ✓)
  - ☆ Go for the Gold!  (future World's Best)

What We're Good At

- Making Muons - *e.g.*
  - ☆ Surface μ^+ beam invented by U. Arizona group at LBL but developed at TRIUMF (all M*xx* but M11). Now indispensable at all μSR facilities.
  - ☆ Ultra low energy μ^+ beam invented at TRIUMF but developed at PSI because of rates. Now world's most oversubscribed muon channel.
- Using Muons - *e.g.*
  - ☆ Spin Rotators developed & perfected at TRIUMF.
  - ☆ RF-μSR spin echo first achieved at TRIUMF.

Surface Muons

π^+ : all energies & angles.



μ^+: 4 MeV,
100% spin
polarized

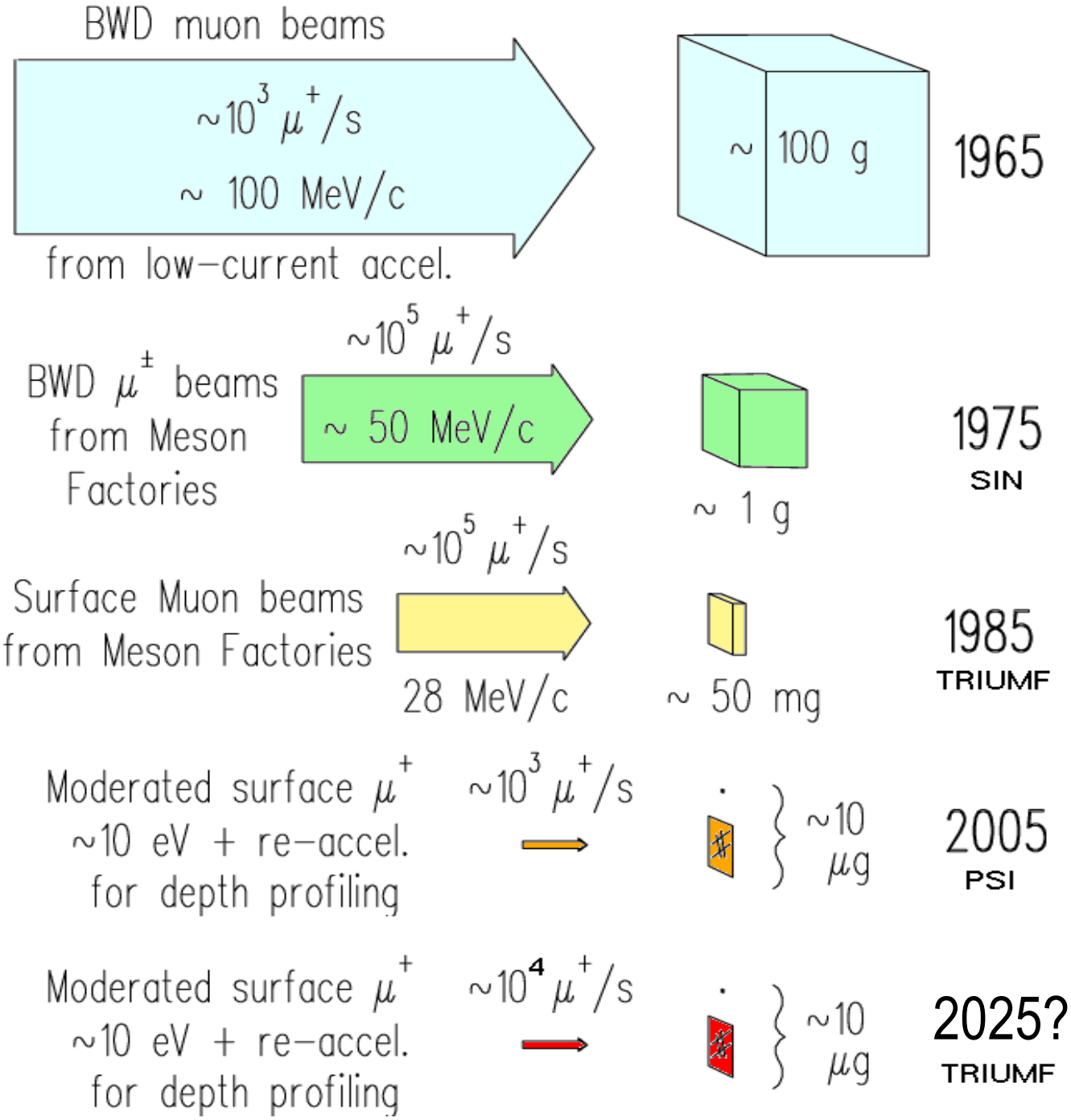
Range: 150±30 mg/cm^2.

Bright, imageable source.

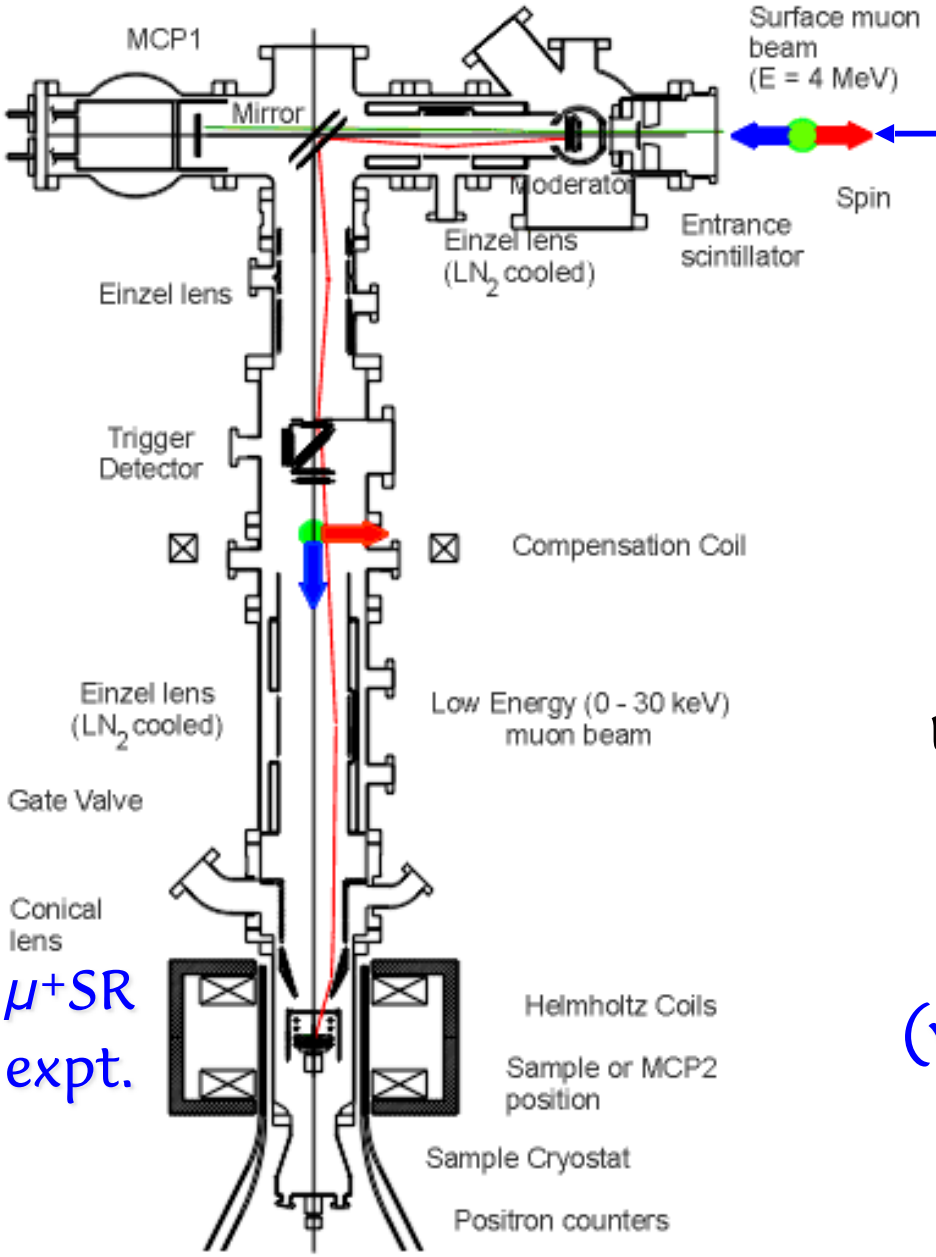
Some pions stop in "skin" of production target & decay to μ^+.

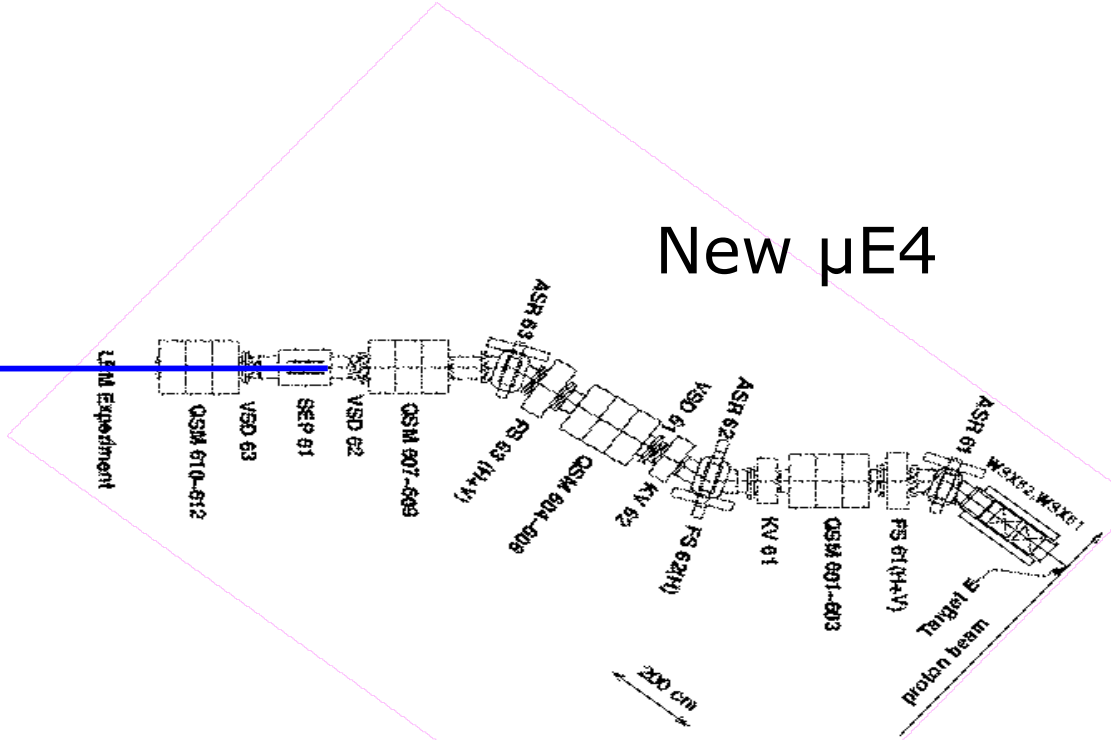
History of μ^+ stopping luminosity:

Enabling μ^+SR



The PSI Apparatus for Low Energy μSR





World's only operating ultra-Low Energy Muon beam facility at PSI:

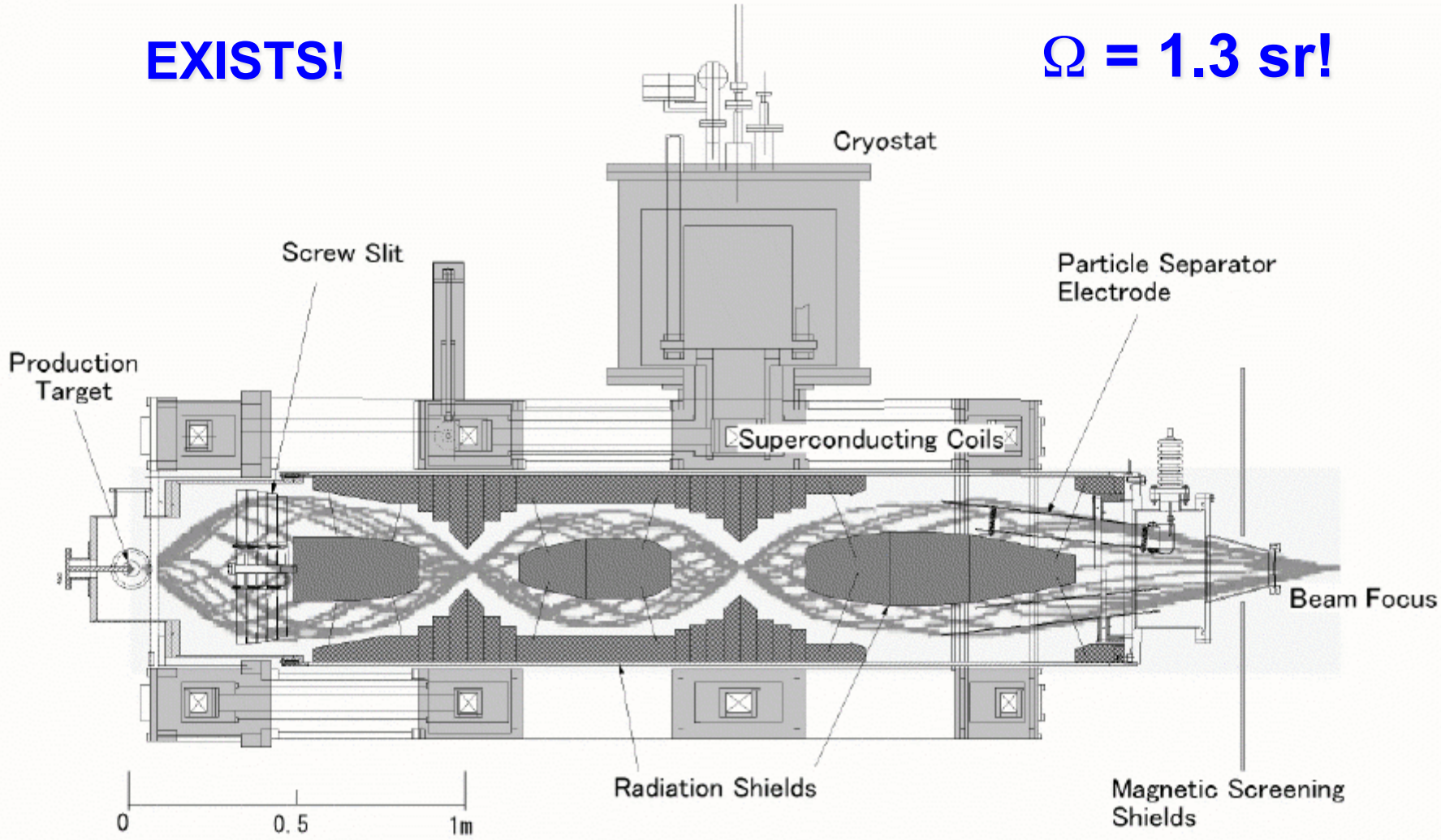
~10^3 μ^+/sec

(vs. TRIUMF's ^{8}Li β-NMR)

Large Solid Angle Axial Focusing Superconducting Surface Muon Channel, Dai Omega

EXISTS!

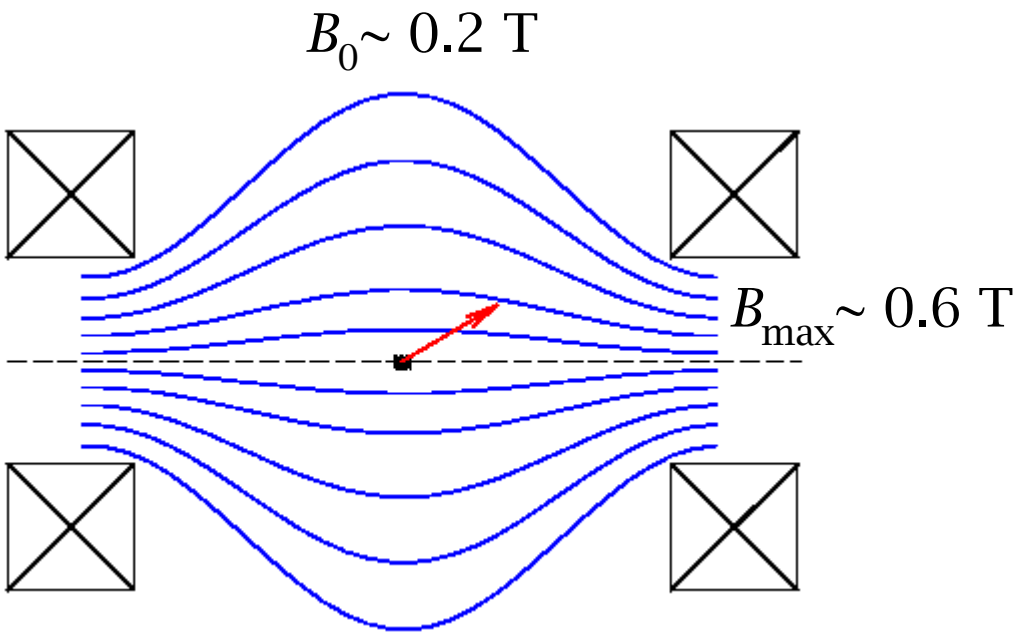
Ω = 1.3 sr!



Another possible design:

Leaky Magnetic Bottle

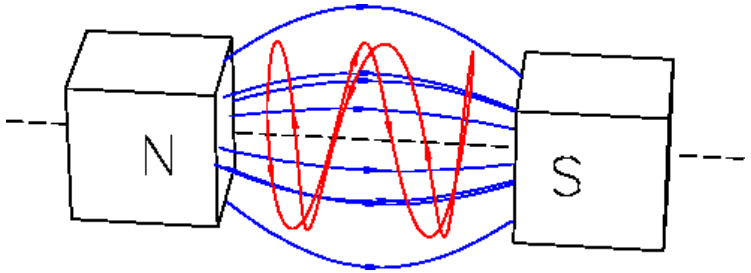
Place production target in a field between two rad-hard coils (proton beam into page).



$\theta_{crit} \sim 35^o \Rightarrow \Omega_{escape} \sim 1.5$ sr

Reflection criterion:

$$\left|\frac{v_{0\parallel}}{v_{0\perp}}\right| = |\cot\theta_0| < \sqrt{\frac{B_{max} - B_0}{B_0}}$$



Low energy **pions** **return** to skin of production target (textured to make every surface both an entrance and an exit surface).

Surface **muons** **escape** if $\theta_0 < \theta_{crit}$ (equivalent to an **acceptance** of 1/4 of entire 2π solid angle).

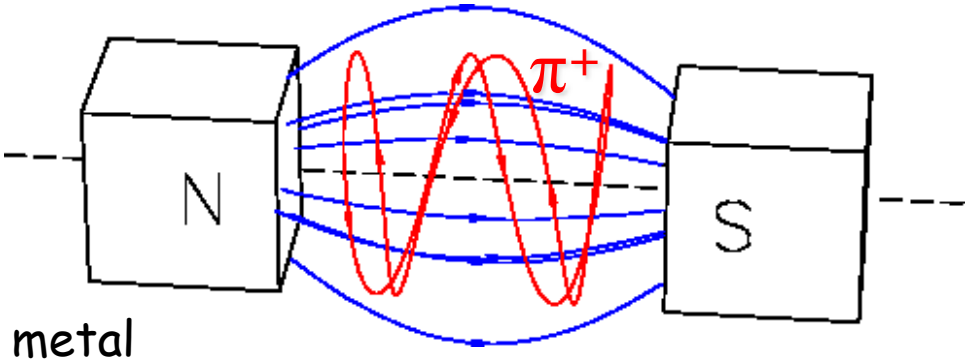
Compare $\Omega \approx 50$ msr for typical surface muon channel: factor of

30

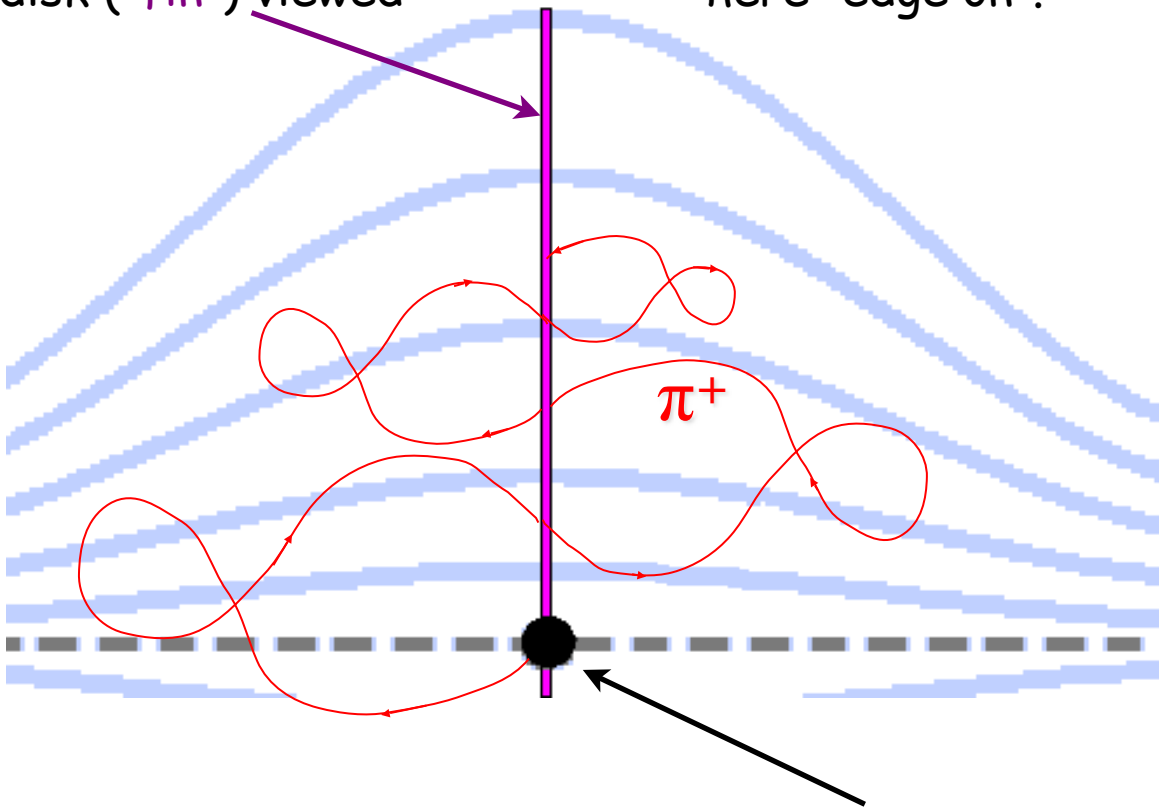
from solid angle alone.

Details of Production Target:

Magnetic Bottle for π^+



Production target thermally coupled to thin metal disk ("fin") viewed here "edge on".



Low energy **pions** **return** to "fin" of production target (every surface is both an entrance and an exit surface). At each pass, the pion loses energy and is scattered.

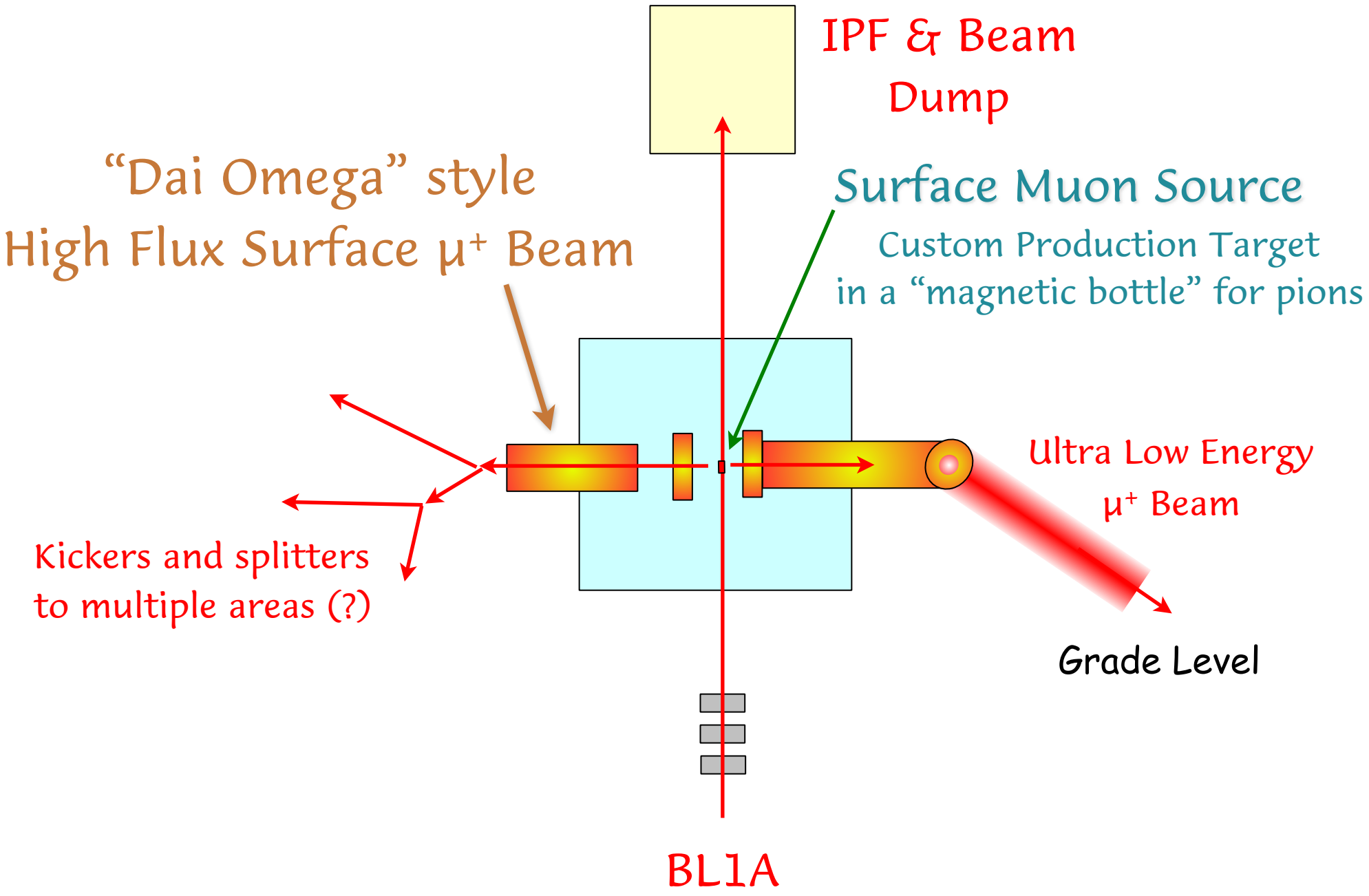
The π^+ spectrum is almost flat near zero energy, so each pass through the "fin" is another chance to stop within the "muon skin". But at each pass, a fraction f of the pions "leak out of the bottle". Thus the "surface enhancement factor" relative to a plain target is

$$\varepsilon = \sum_{n=0}^{\infty} (1 - f)^n = 1/f$$

For $f = 1.5/2\pi$,

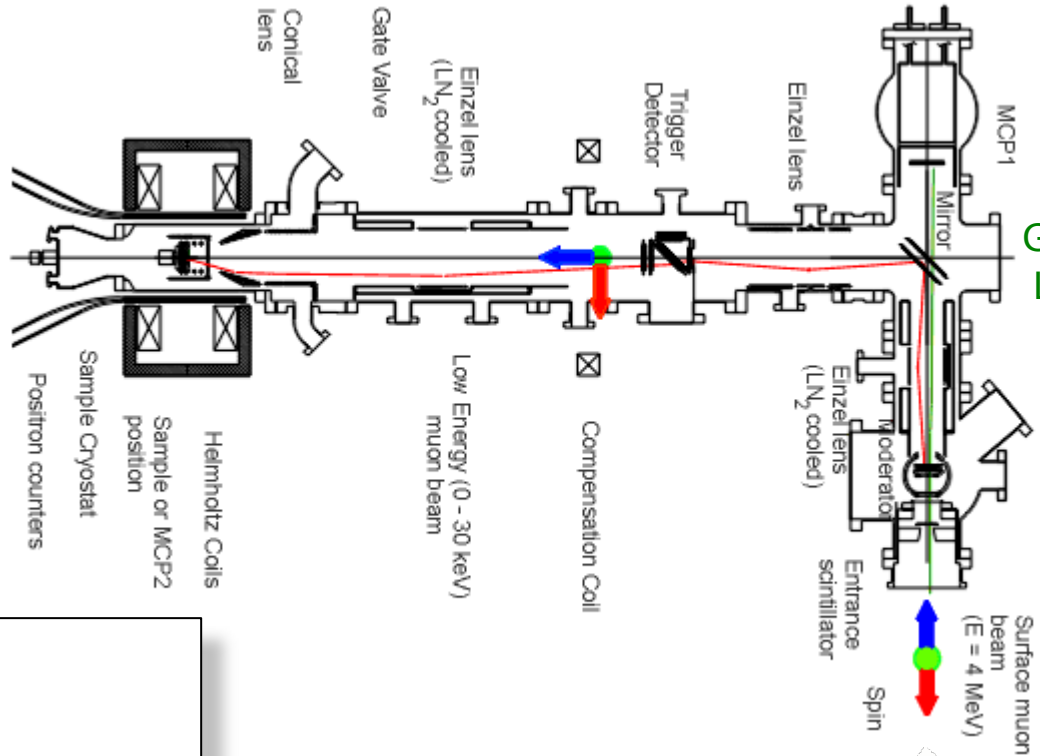
$$\varepsilon = 4.2$$

Location: approximately at present **TNF**



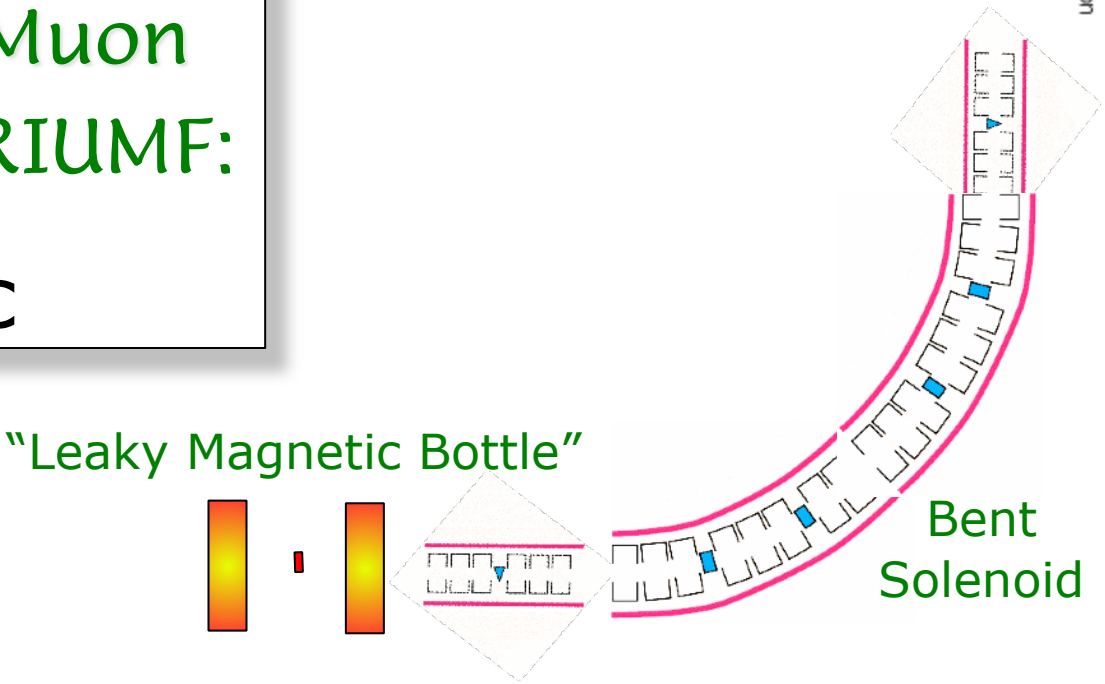
OR . . . re-accelerate
to ~ 500 keV and

focus on **very** small spot.



Proposed
Ultra-Low Energy Muon
beam facility at TRIUMF:

~10⁴ μ^+/sec



New Science Opportunities

- Simply increasing Low Energy Muon intensity from 10^3 to 10^4 μ^+/s is a huge step for LE-μSR.
- Combined with β-NMR, probe thin films, multilayers, magnetic nanostructures, ...
- Muonium in gases; hydrogen isotope chemistry.
- Re-accelerate LEM to ~ 1 MeV ⇒ parallel beam can be focused onto μm-sized spot:

"Scanning μSR Microscope"

The End

... for now

Build it now, or...

Ah'll be back!