VERY LARGE MU-P COLLIDER

VLHC (b. 2026)

VLMC (b. 2028)

VL mu-p collider (b. 2030)

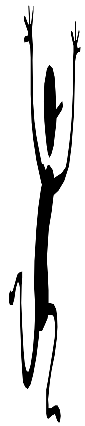
Bruce King

bking@bnl.gov

TOPICS

- INTRODUCTION & MOTIVATION
- NEUTRINO RADIATION => ISOLATED SITE
- TECHNICAL ISSUES FOR VLMCs
- MUON ACCELERATION AS 1/2-ENERGY PROTON INJECTOR
- 140 TeV MU-P COLLIDER

LONG-TERM POTENTIAL GAINS FROM A 3rd PROJECTILE



Electrons
are too light

Discovery reach
of a few TeV ?

Protons are composite
& strongly interacting

Discovery reach of
some 10's of TeV ?

⇨

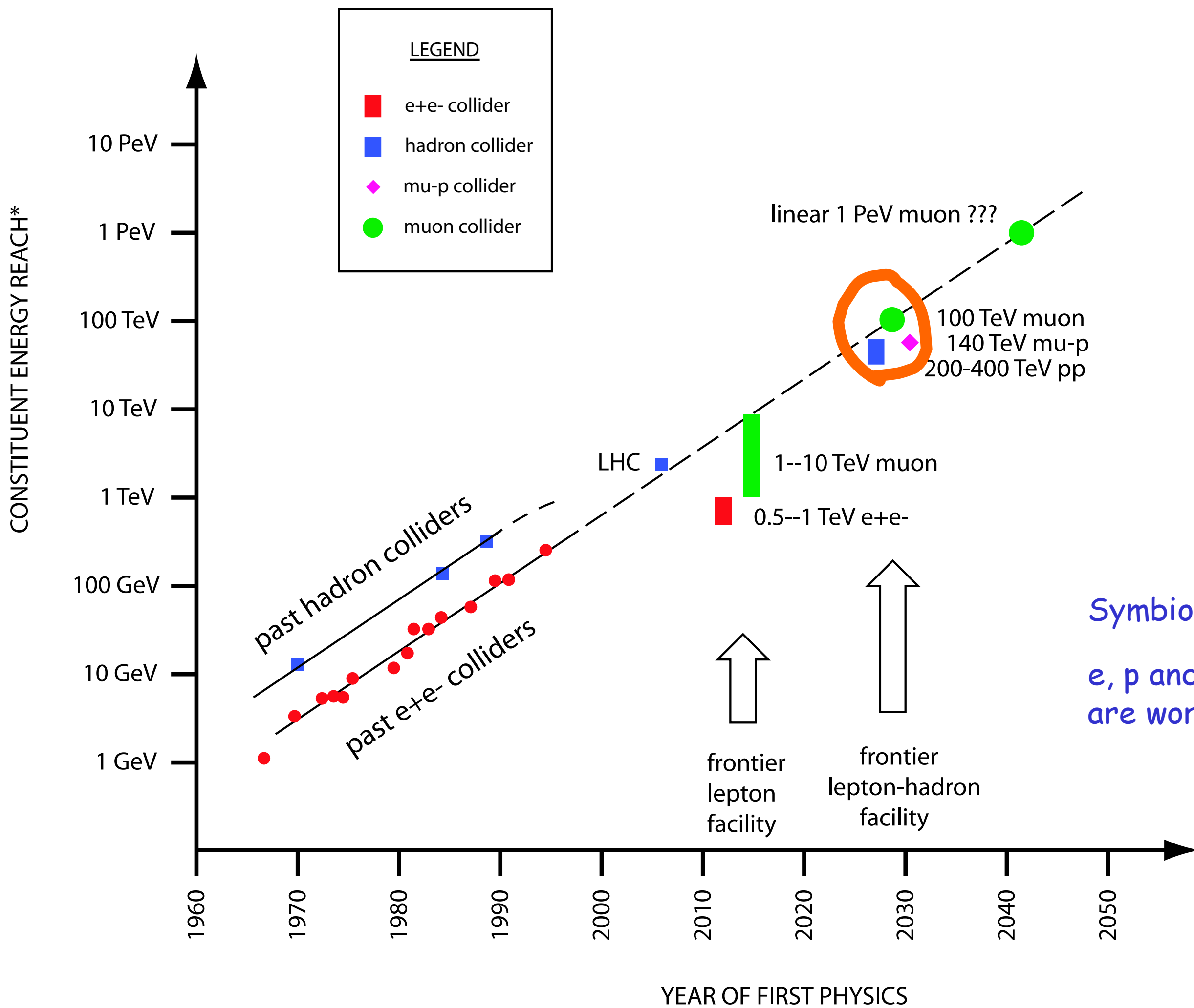
Add Muons,
though unstable

Discovery reach of
~100 TeV (circular)?
~1 PeV (linear)???

$m_\mu \sim 206 \times m_e$
$\mu \rightarrow e\nu\nu$
$\tau_\mu = 2.2\ \mu s$

Can then contemplate an eventual facility combining a) highest energy-scale p-p collider (VLHC), b) highest energy-scale circular muon collider (VLMC) and c) highest energy-scale circular lepton-hadron collider.

THERE ARE PLAUSIBLE PATHS TO A VL mu-p FACILITY ...



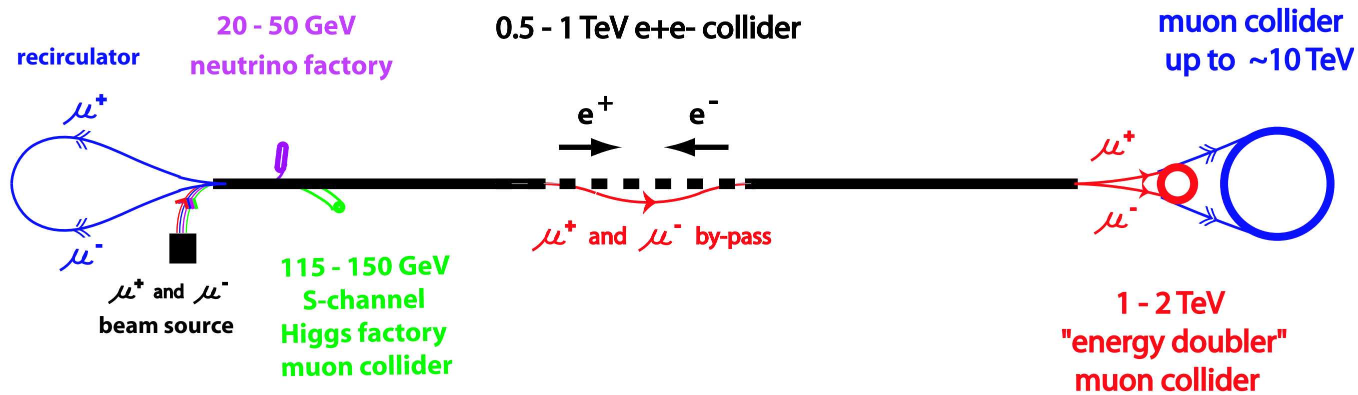
Symbiotic!

e, p and μ technologies are working together

* assume constituent energy reach for hadrons = 1/6 x CoM energy

A POTENTIAL STEPPING STONE: LINEAR e^+e^- COLLIDER + MUON COLLIDER

First discussed by D. Neuffer, H. Edwards & D. Finley in Proc. Snowmass'96



(M1+M3 joint session, Tuesday am, 17 July)

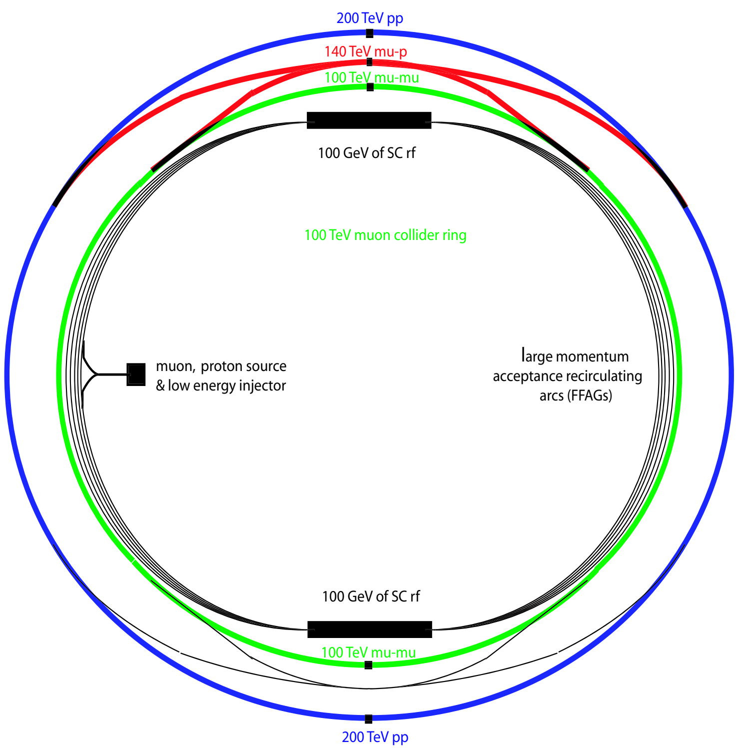
PLAUSIBLE NEW FRONTIER LAB.: VLHC + VLMC

Neutrino radiation => new, very isolated lab. for high luminosity Very Large Muon Collider (VLMC).

On balance, technical difficulties not much worse than for lower energy muon colliders.

(slightly less cooling needed; recent 30 TeV final focus design by Raimondi)

Schematic Layout showing Acceleration,
Muon Collider, Proton Collider & mu-p Collider



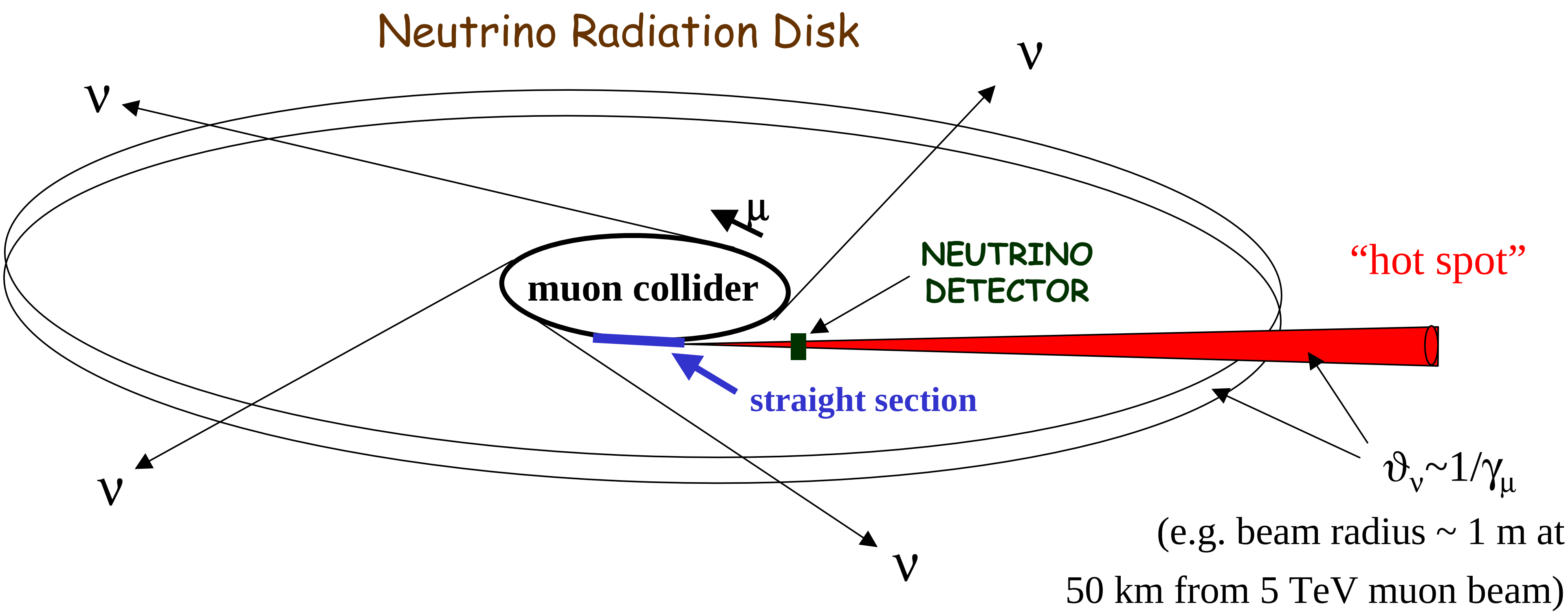
VLMC + VLHC symbiosis

- ✓ common magnet R&D
- ✓ same tunnel, or side-by-side
- ✓ common acceleration to ~50 TeV/beam
  - ➢ full energy for muon collider
  - ➢ ~½ energy for hadron collider
- ✓ mu-p collisions at E_{CoM} ~ 140 TeV

(SEE STRAW-MAN VLMC
PARAMETER SET @ 100 TeV)

NEUTRINO RADIATION => ISOLATED SITE

NEUTRINO RADIATION

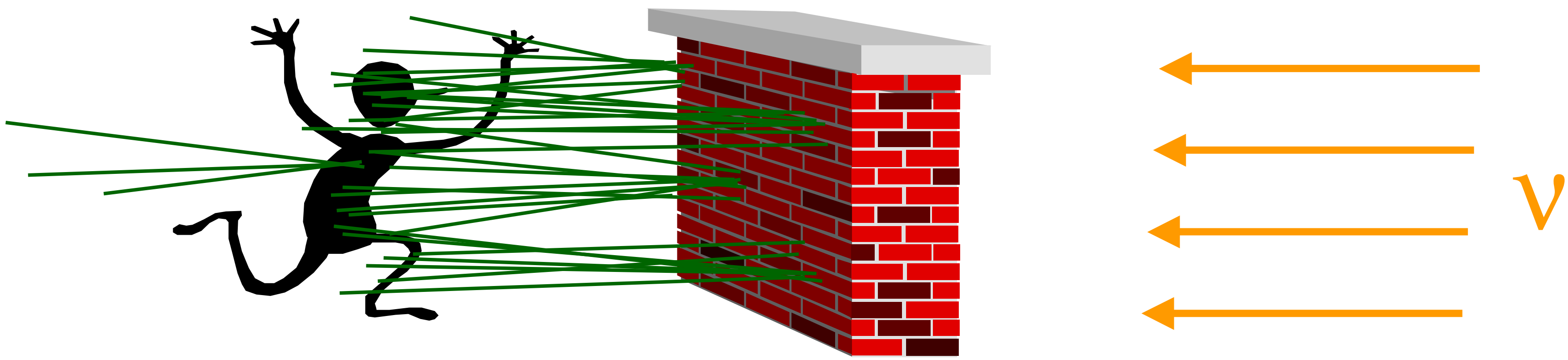


Extra Physics + extra hazards

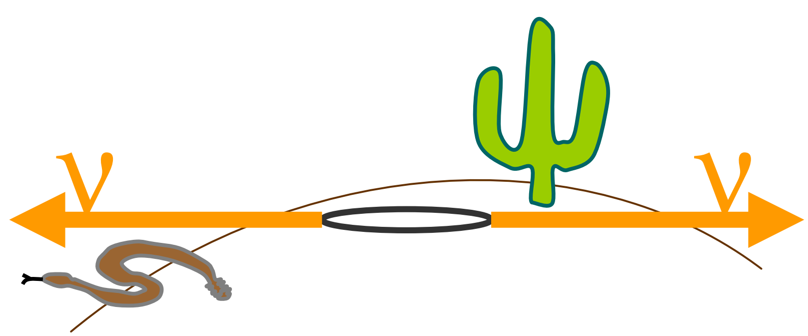
*ref. B.J. King, " Potential Hazards from Neutrino Radiation at Muon Colliders", **physics/9908017**; B.J. King, "Neutrino Radiation Challenges and Proposed Solutions for Many-TeV Muon Colliders", Proc. HEMC'99, **hep-ex/0005006**.

THE OFF-SITE RADIATION CONCERN

The hazard is charged particles from neutrino interactions in the surroundings ...



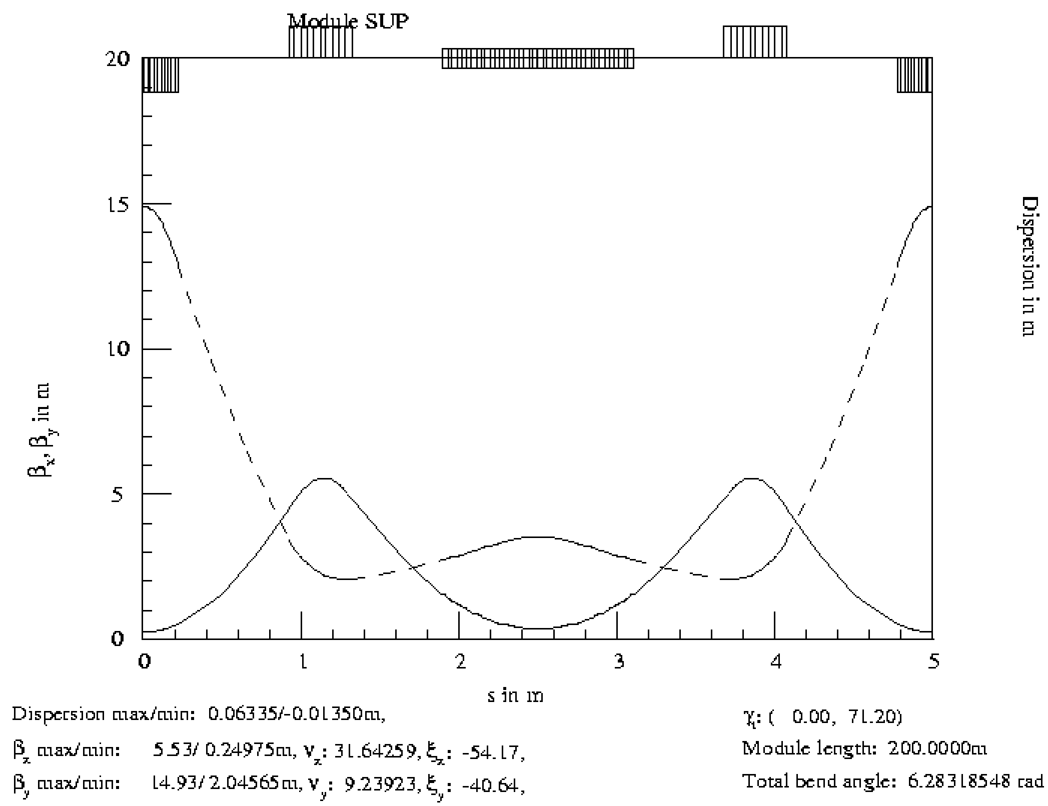
The predicted dose rises sharply with collider energy. A VLMC will need to be located at a very isolated site, e.g. a neutral site such as the Australian outback, and operated using a Global Accelerator Network.



TECHNICAL ISSUES FOR VLMCs

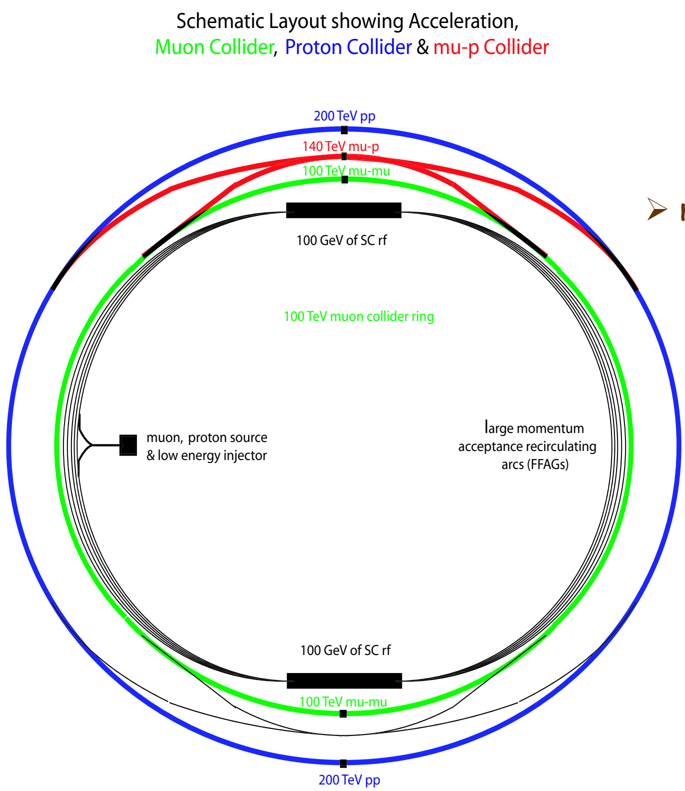
ACCELERATION IN FFAGs

Acceleration will be the main cost driver for VLMCs. Cost reduction => acceleration in (e.g.) FFAG lattices. (Lattices of SC+fast-ramping magnets are also under consideration - Summers, Palmer.)



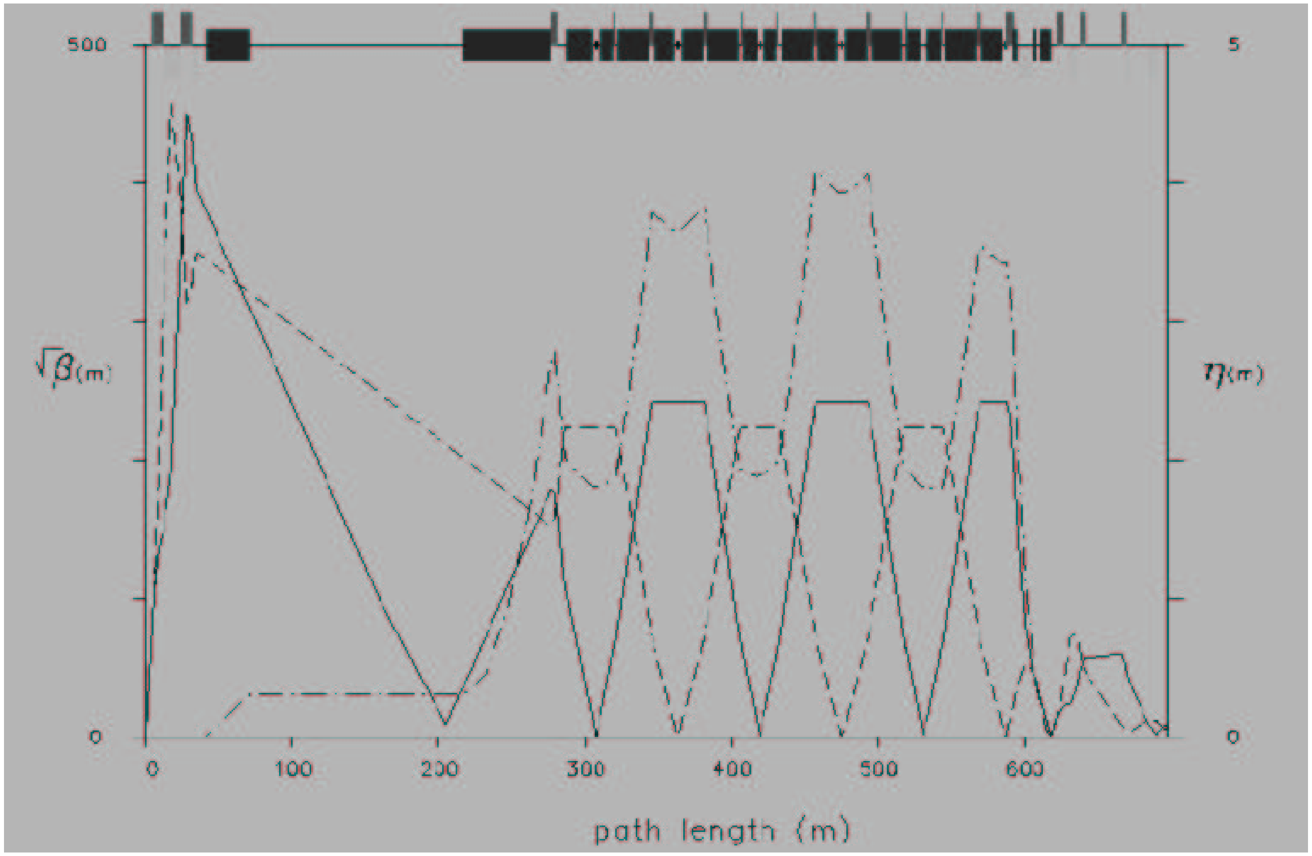
The figure shows a module of an FFAG lattice for 10->20 GeV by Trbojevic (+ Courant & Garren). Trbojevic expects such FFAG lattices to work well at very high energies (work in progress - we will know soon).

VLMC ACCELERATION STRATEGY



- ~200 GeV/turn of SC rf cavities, matched to beam for high efficiency
  - 50 TeV/200 GeV => 250 passes
  - Padamsee calculated 53% (10 TeV) or 33% (100 TeV) efficiencies for HEMC'99 parameters
- multiple recirculating arcs of FFAGs, each providing a factor of 2+ in energy
  - all arcs have same transit time => matched to rf
  - 1000 ~ 2^{10} => 10 FFAG arcs, or less
  - fractional decay loss for 100 GeV -> 50 TeV/beam ~ e^{-1} => need 1.9e12 -> 0.7e12 muons (OK)

COLLIDER RING



The design of the final focus is a major challenge for energy frontier muon colliders.

The figure shows an existing 4 TeV final focus design by Johnstone & Garren (beta*=3 mm). Impressive new 30 TeV ff now exists (Raimondi, beta*=4.8 mm)

MAGNET REQUIREMENTS

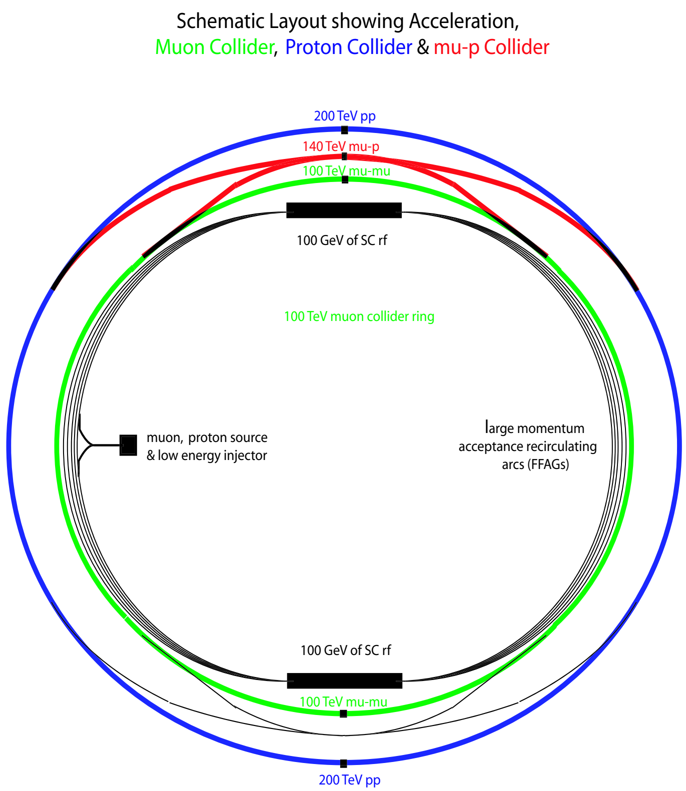
- similar to VLHC: collider ring magnets are only 1/2 the field and may be single aperture, but the final FFAG ring will require stronger magnets than this

- crucial to remove all heat from decays (~40 MW) and synch. rad. (~40 MW) at room temperature => need mid-plane with no cryostat or other solution

- much room for common R&D

USING MUON ACCELERATION AS 1/2-ENERGY INJECTOR TO VLHC

1/2-ENERGY VLHC INJECTOR



- accelerate trains of proton bunches with same total charge as muon bunch train (7×10^{11}) => matched to rf with no extra work

c.f. VLHC stage II total charge ~ 3.1×10^{14}
=> 440 trains/sign

- smaller bunch charges => don't expect stability problems

- do enough trains to fill one proton ring, then reverse FFAG magnets so can inject into ring with opposite sense

Total fill time ~

(440 trains/sign x ~1 sec/train x 2 signs) +
600 sec. to reverse magnet polarity

~ 1500 sec << few hours coast time => OK

VERY LARGE MU-P COLLIDER ISSUES

VERY LARGE MU-P COLLIDER CHALLENGES

- will need mu & p path lengths exactly same

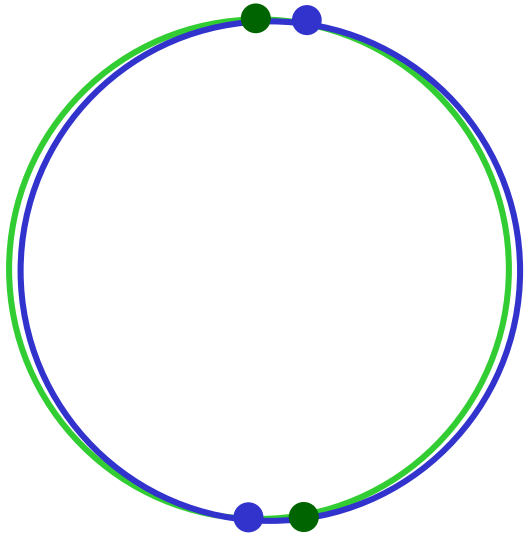
- detector design challenging

- better to use bigger proton bunches - matched to muon bunches. Can this be done?

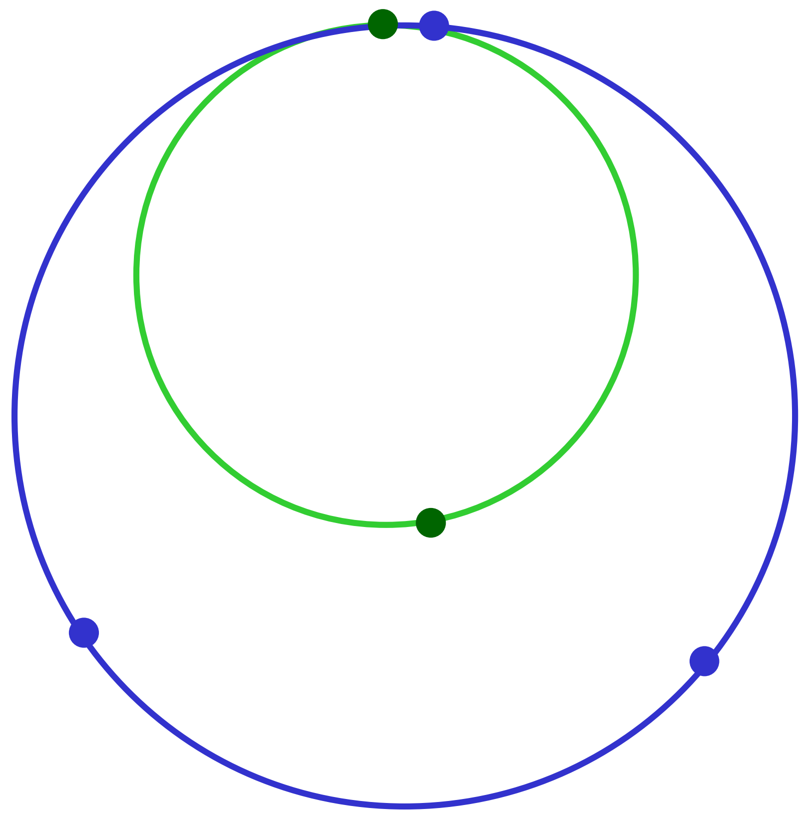
OTHER: emittance, history of studies ...

BEAM MATCHING FOR LUMINOSITY

Want few large bunches and a simple ratio of ring sizes:



$C_\mu = C_p = 200$ km

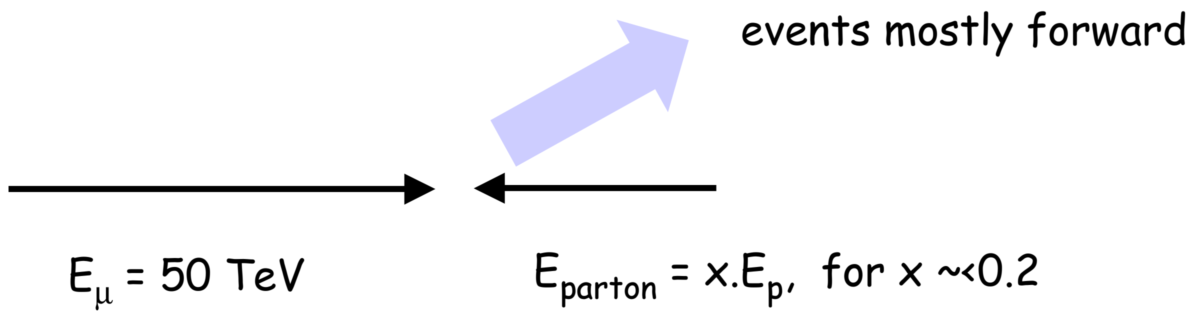


$C_\mu = 200$ km, $C_p = 300$ km

N.B. this is very different proton parameters than for a p-p collider. Will it work?

DETECTOR ISSUES

Mu-p detectors difficult due to combination of (i) muon decay backgrounds imply tungsten mask covering up to 20 degrees from beam direction, and (ii) partons from proton "overpowered" by high energy muon, so events are in forward direction for muon.



Possible solutions:

- work on mask design to reduce angular coverage
- design with more asymmetric beam energies, e.g. (E_μ = 50 TeV, E_p = 200 TeV) or (E_μ = 25 TeV, E_p = 100 TeV)

CONCLUSIONS

- the idea looks promising at first glance
- what are the accelerator issues?