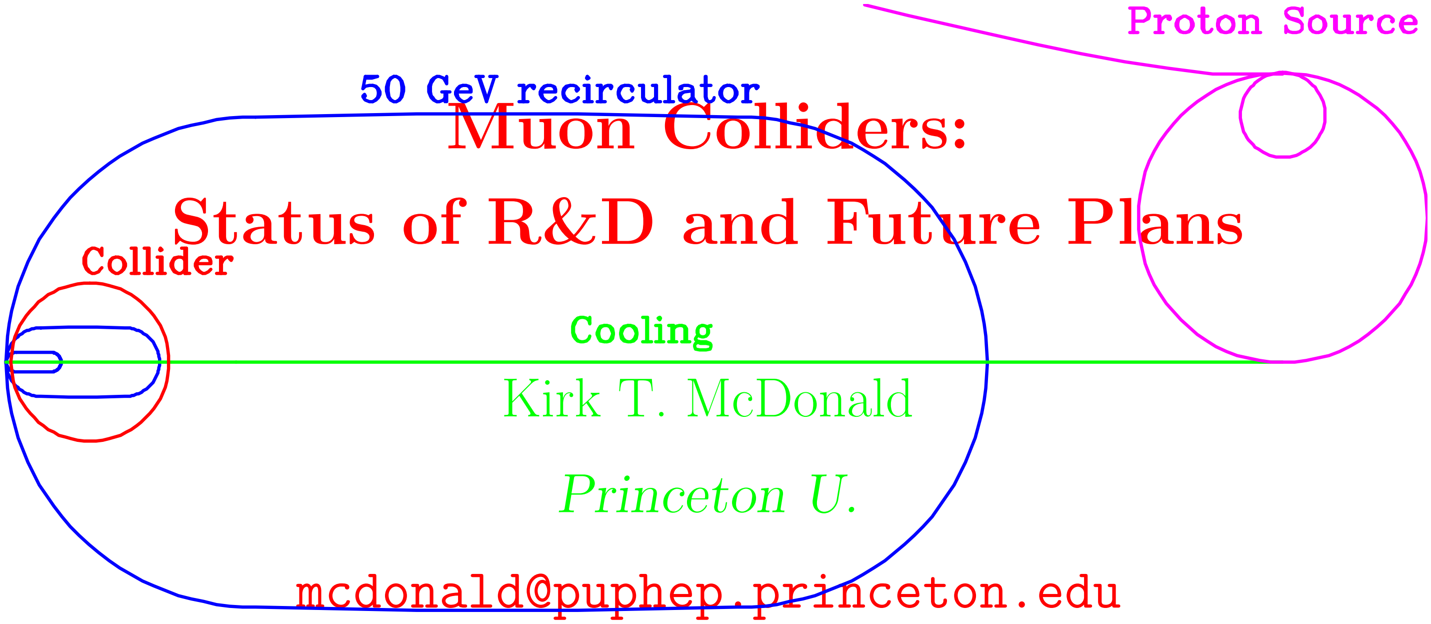

Muon Colliders: Status of R&D and Future Plans

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Muon Collider main page:

`http://www.cap.bnl.gov/mumu/mu_home_page.html`

Muon Collider R&D Status Report:

`http://www.cap.bnl.gov/mumu/status_report.html`

Princeton Muon Collider page:

`http://puhep1.princeton.edu/mumu/`

AIP Conference Proceedings, Vols. 352, 372, 435 & 441

The Y2K Problem for Particle Physics

- Can elementary particle physics prosper for a 2nd century with laboratory experiments based on innovative particle sources?
- Can a full range of new phenomena be investigated:
  - Neutrino mass ⇒ a 2nd 3×3 (or larger?) mixing matrix.
  - Precision studies of Higgs bosons.
  - A rich supersymmetric sector (with manifestations of higher dimensions).
  - ... And more ....
- Will our investment in future accelerators result in more cost-effective technology, that is capable of extension to 10's of TeV of constituent center-of-mass energy?

The Solution...

- A **Muon Collider** is the best option to accomplish the above!

What is a Muon Collider?

An accelerator complex in which

- Muons (both μ^+ and μ^-) are collected from pion decay following a pN interaction.
- Muon phase volume is reduced by 10^6 by ionization cooling.
- The cooled muons are accelerated and then stored in a ring.
- $\mu^+\mu^-$ collisions are observed over the useful muon life of ≈ 1000 turns at any energy.
- Intense neutrino beams and spallation neutron beams are available as byproducts.

Muons decay: $\mu \to e\nu \qquad \Rightarrow$

- Must cool muons quickly (stochastic cooling won't do).
- Detector backgrounds at LHC level.
- Potential personnel hazard from ν interactions.

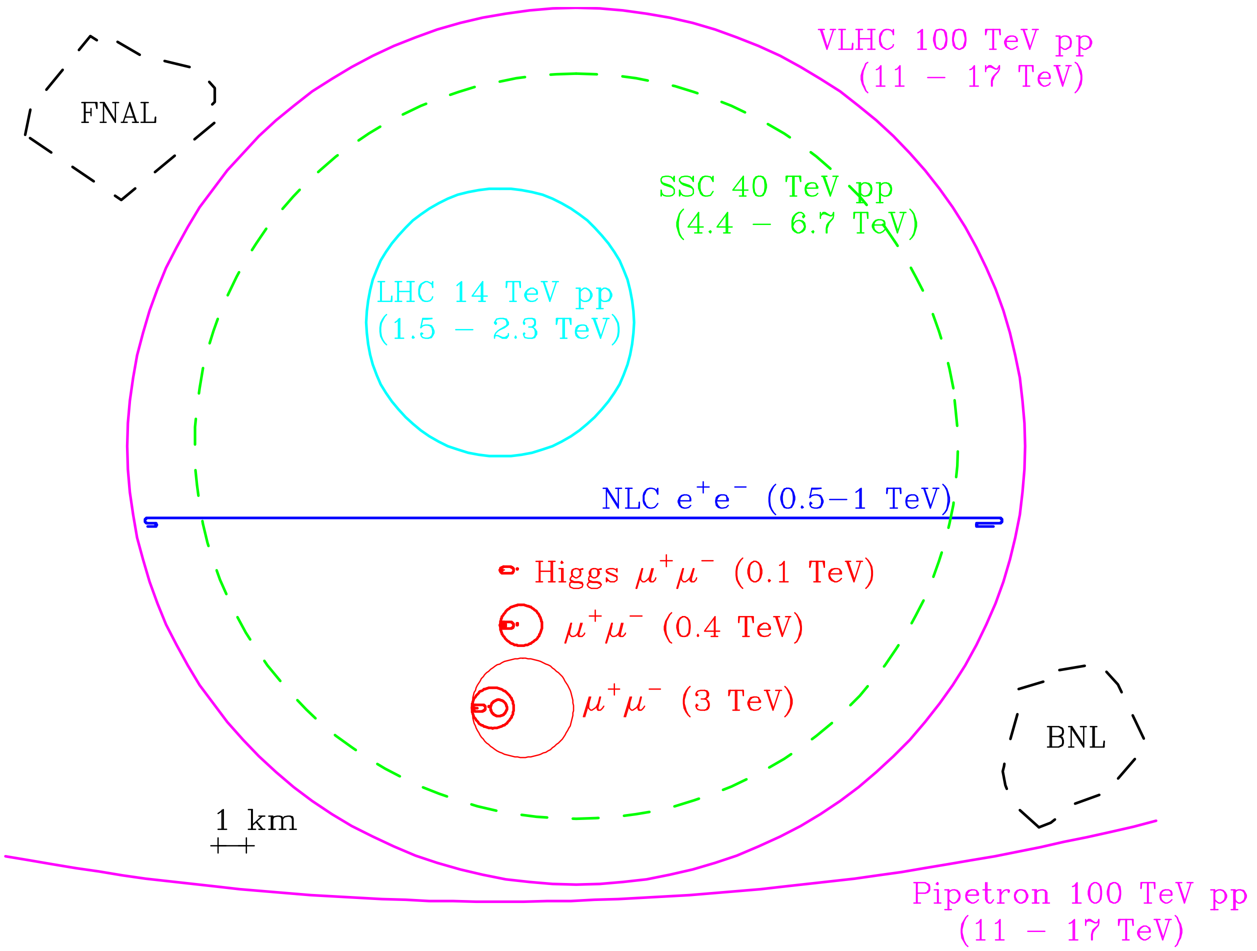
Baseline Parameters

For muon colliders at 3 TeV, 400 GeV (top factory) and 100 GeV (light Higgs factory).

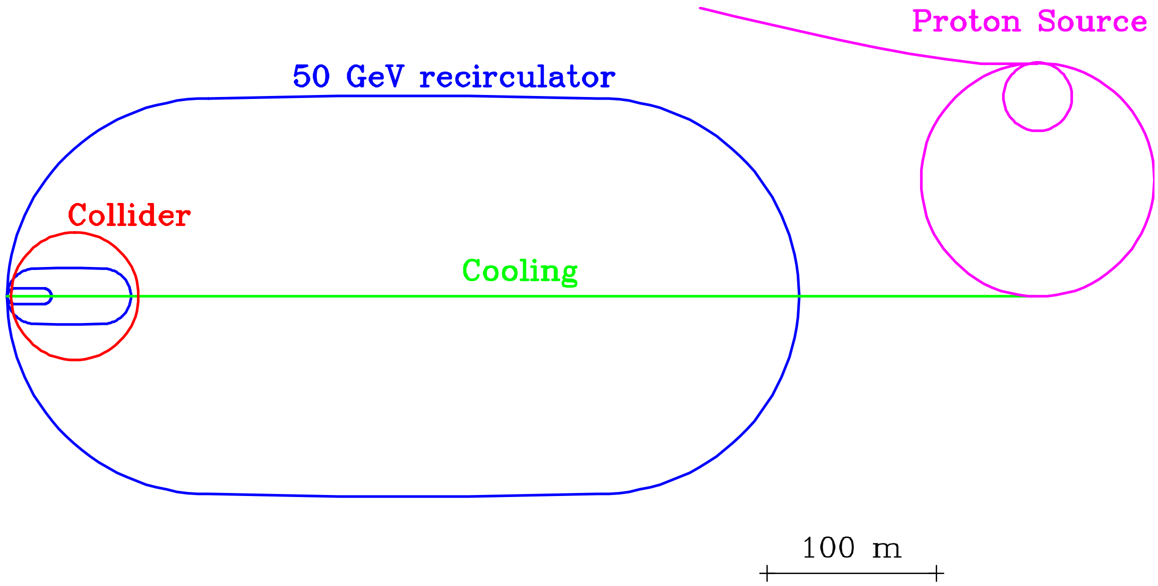
CoM energy (TeV)	3	0.4	0.1
p energy (GeV)	16	16	16
p's/bunch	2.5×10^{13}	2.5×10^{13}	5×10^{13}
Bunches/fill	4	4	2
Rep. rate (Hz)	15	15	15
p power (MW)	4	4	4
μ/bunch	2×10^{12}	2×10^{12}	4×10^{12}
μ power (MW)	28	4	1
Wall power (MW)	204	120	81
Collider circum. (m)	6000	1000	350
Ave. bending field (T)	5.2	4.7	3
Depth (m)	500	100	10
Rms $\Delta P/P$ (%)	0.16	0.14	0.003-0.12
6d ϵ_6 $(\pi\mathrm{m})^3$	1.7×10^{-10}	1.7×10^{-10}	1.7×10^{-10}
Rms ϵ_n (π mm-mrad)	50	50	85- 290
β^* (cm)	0.3	2.6	4.1-14.1
σ_z (cm)	0.3	2.6	4.1-14.1
σ_r spot (μm)	3.2	26	86-294
σ_θ IP (mrad)	1.1	1.0	2.1
Tune shift	0.044	0.044	0.051-0.022
n_{turns} (effective)	785	700	450
Luminosity ($\mathrm{cm}^{-2}\mathrm{s}^{-1}$)	7×10^{34}	10^{33}	10^{31}-1.2×10^{32}
Higgs/year			2-4 $\times 10^3$

Higgs/year assumes a cross section $\sigma = 5 \times 10^4$ fb; a Higgs width $\Gamma = 2.7$ MeV; 1 year $= 10^7$ s.

Footprints



A First Muon Collider to study light-Higgs production:



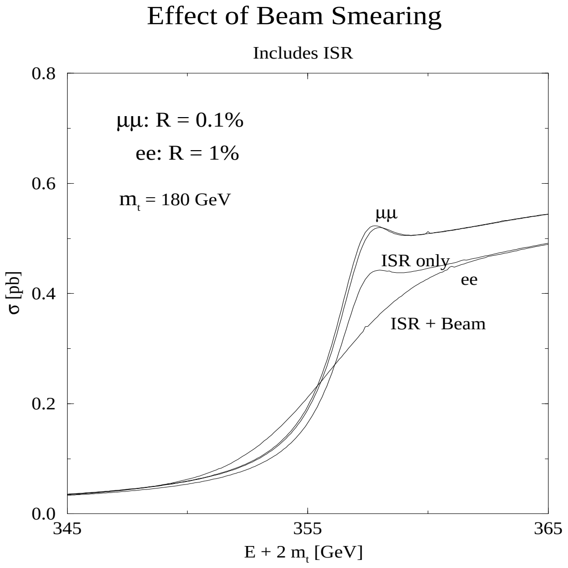
The Case for a Muon Collider

- More affordable than an e^+e^- collider at the TeV (LHC) scale.
- More affordable than either a hadron or an e^+e^- collider for (effective) energies beyond the LHC.
- Precision initial state superior even to e^+e^-.

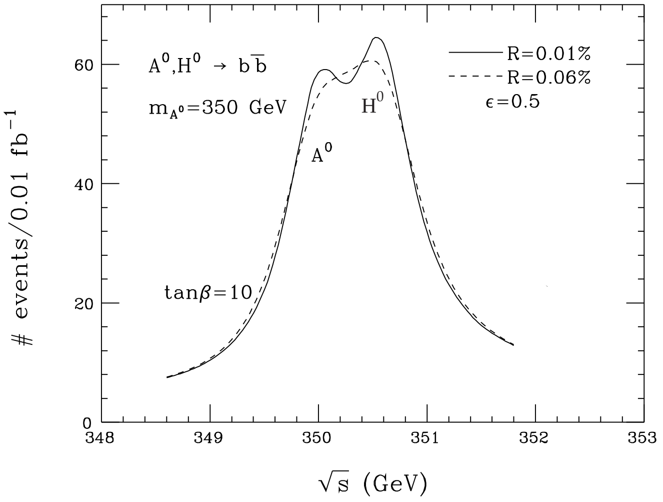
  Muon polarization $\approx 25\%$,

  $\Rightarrow$ Can determine E_{beam} to 10^{-5} via $g-2$ spin precession.

$t\bar{t}$ threshold:



Nearly degenerate A^0 and H^0:



- Initial machine could produce light Higgs via s-channel:

  Higgs coupling to μ is $(m_\mu/m_e)^2 \approx 40,000\times$ that to e.

  Beam energy resolution at a muon collider $< 10^{-5}$,

  $\Rightarrow$ Measure Higgs width.

  Add rings to 3 TeV later.

- Neutrino beams from μ decay about 10^4 hotter than present.

  Initial scenario in a low-energy muon storage ring.

  Study CP violation via CP-conjugate initial states:

$$\mu^+ \to e^+ \overline{\nu}_\mu \nu_e$$

$$\mu^- \to e^- \nu_\mu \overline{\nu}_e$$

HEPAP Subpanel Report on
PLANNING FOR THE FUTURE OF U.S. HIGH-ENERGY PHYSICS

February 1998

Recommendation on R&D for a Muon Collider

The Subpanel recommends that an expanded program of R&D be carried out on a muon collider, involving both simulation and experiments. This R&D program should have central project management, involve both laboratory and university groups, and have the aim of resolving the question of whether this machine is feasible to build and operate for exploring the high-energy frontier. The scale and progress of this R&D program should be subject to additional review in about two years.

CERN-EP/98-03
CERN-SL 98-004 (AP)
CERN-TH/98-33

Options for Future Colliders at CERN

J. Ellis, E. Keil, G. Rolandi

January 23, 1998

6 RECOMMENDATIONS

3. CERN should launch technical studies of $\mu^+\mu^-$ colliders, notably in the areas of the source and beam cooling, and should explore the possibility of locating such machines on or in the neighbourhood of the CERN site.

6. These studies should be carried out in collaborations with other laboratories, since most technical problems do not depend on the site. CERN's goal in these collaborations should be to contribute to the global pool of technologies for future collider options. It should confirm its reputation as a valuable and reliable partner in the international collaborations that will form to develop