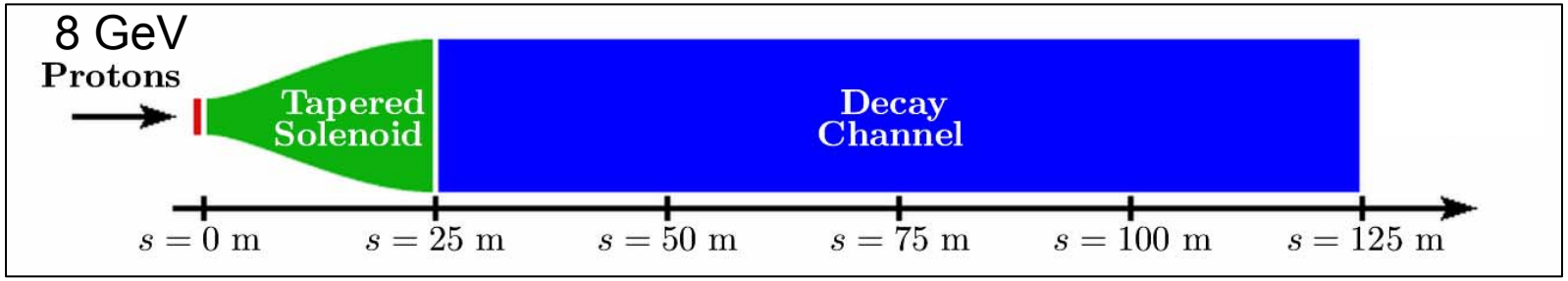
Can we share a muon source among NF, MC and low energy muon programs ?

some food for thought & discussion

INTRODUCTION

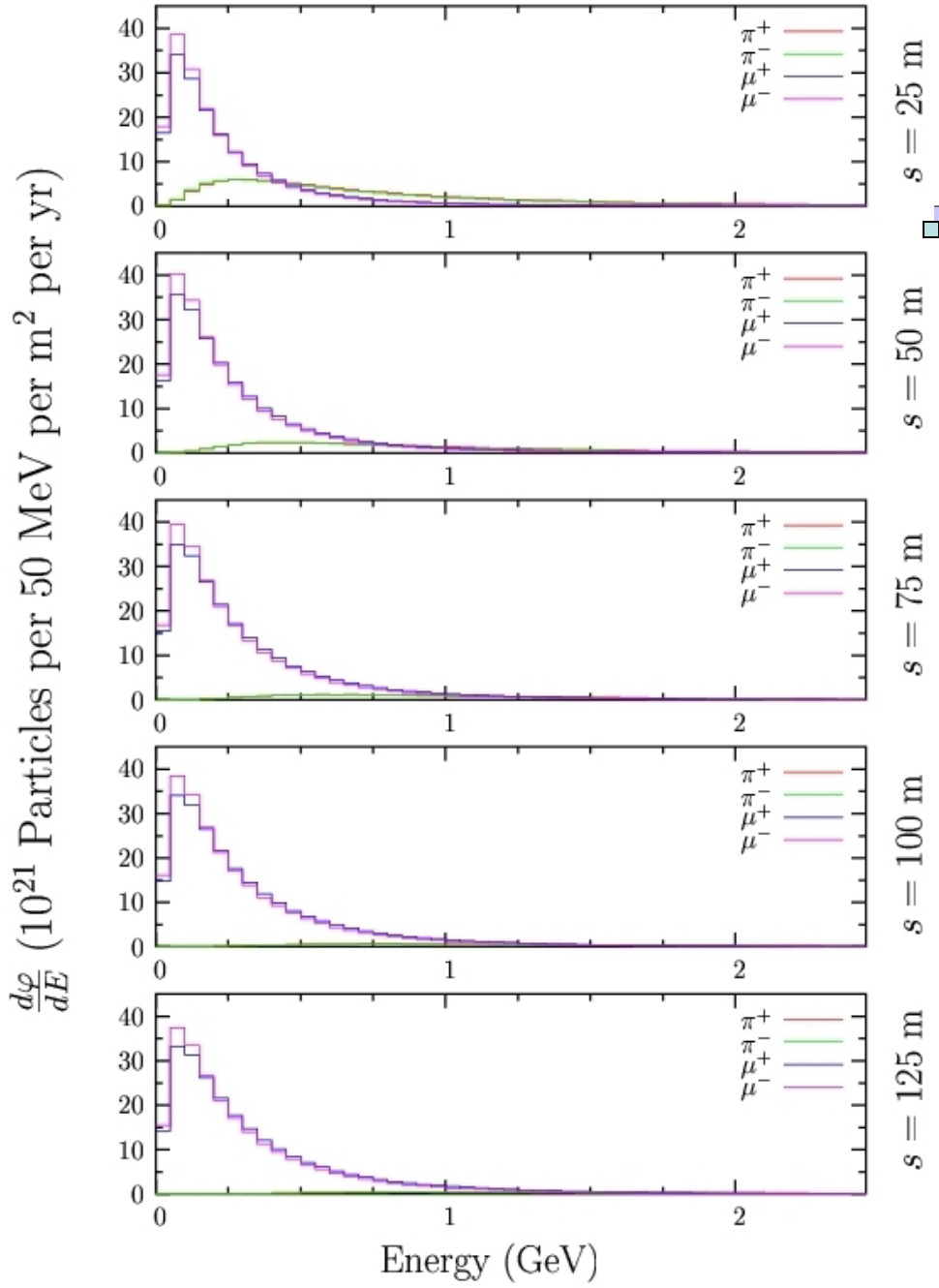
- Muon Colliders & Neutrino Factories both require a front-end based on:
  - High intensity (MW-class) proton source.
  - Target station & decay channel.
  - System that rapidly manipulates the muon beam (bunching, phase rotation and cooling) before acceleration.
- Present NF/MC front-end designs promise O(10^{14}) muons/sec

NF/MC MUON RATES: EXAMPLE



MARS simulations yield 0.2 positive muons/p at end of decay channel …momenta O(100 MeV/c), occupying large longitudinal & transverse phase space.

	$s = 25$ m	$s = 50$ m	$s = 75$ m	$s = 100$ m	$s = 125$ m
μ^+/P	0.16	0.20	0.21	0.21	0.22
μ^-/P	0.16	0.20	0.21	0.21	0.21
π^+/P	0.095	0.051	0.030	0.020	0.014
π^-/P	0.087	0.044	0.025	0.016	0.011



DECAY CHANNEL SPECTRA

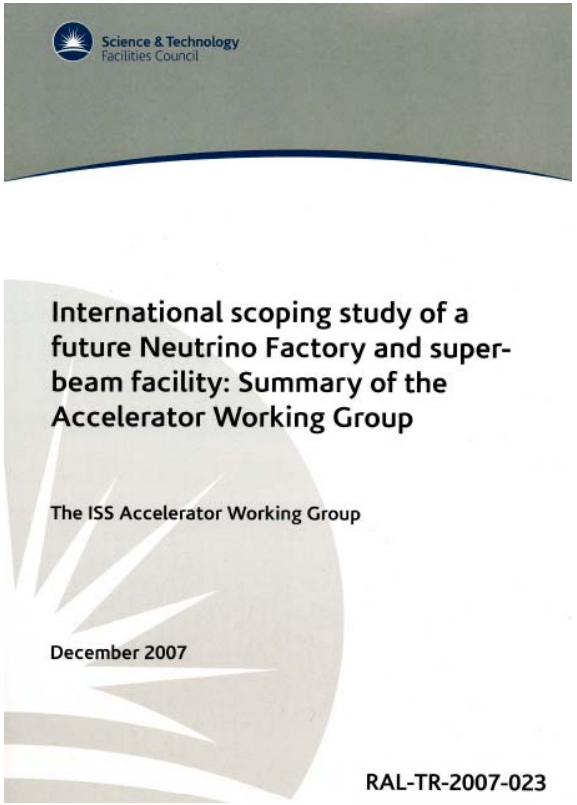
Charged particle fluxes corresponding to 1.6 x 10^{22} POT at 8 GeV

Brice, Geer, Paul & Tayloe
hep-ex/0408135

NF/MC MUON RATES: ISS NF FRONT-END

- At the end of the bunching, phase-rotation & NF cooling channel (ISS Design) calculate 0.07 positive muons per 8 GeV proton (& same number of negative μs).

- For 1MW proton beam, these rates correspond to:
  - ~ 1.5×10^{14} μ^+ per sec at end of decay channel
  - ~ 5×10^{13} μ^+ per sec at end of NF cooling channel



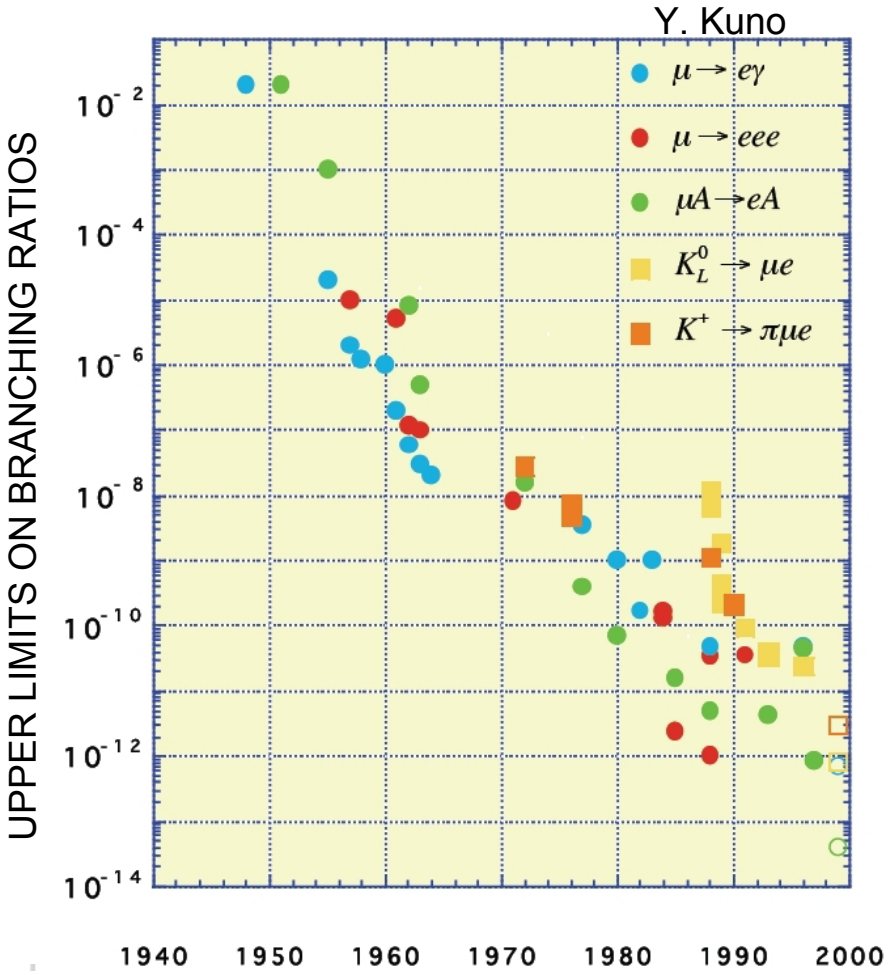
POSSIBLE MUON SOURCE EVOLUTION

- PRESENT CAPABLITY
  - 10^8 muons/sec at PSI
- NEXT STEPS (in next 10 years)
  - Proton sources: O(10KW) – O(100KW)
  - 10^{11} - 10^{12} muons/sec for mu2e/COMET
- NF/MC FRONT-END
  - Proton Source: few MW (typically 4MW)
  - few $\times 10^{14}$ muons/sec

CAN FUTURE MUON EXPERIMENTS USE THE FLUX ?

- Example: Charged LFV
  - LFV sensitivity seems to be increasing at the rate of an order of magnitude / decade.
  - Nth generation expts being proposed now, & (N+1)th generation expts dreamt of.
  - If the trend continues, guess that (N+2)th generation expts would benefit from MC/NF front-end muon source intensity/brightness.
  - A muon source with 10% of the NF/MC intensity would also be very interesting.

Example: Charged Lepton Flavor Violation



LOW ENERGY MUON EXPERIMENTS

Table from NUFACT05

Experiment	Charge	Intensity ($\mu/10^7$sec)	Pulse width (ns)	Pulse interval (μs)	Energy (MeV)	Mom. spread (%)	Polarization n/a	Note
$\mu \rightarrow e\gamma$	+	10^{15}	DC	≤ 1	1	≤ 10	Depol	e comtami. $\leq$ 10-2, beam size cm
$\mu N \rightarrow eN$ (MECO type)	−	10^{21}	10-100	1-1000	≤ 20	≤ 10	n/a	
$\mu N \rightarrow eN$ (PRISM type)	−	10^{20}	10-100	1-1000	≤ 20	3	n/a	π comtami. $\leq$ 10-15, beam size cm
g-2	±	10^{15}	≤ 15	≥ 1000	3100	10^{-2}	Pol ~100%	
edm	±	10^{18}	≤ 50	≥ 1000	200-400	10^{-3}	Pol >50%(NP^2) ❖	$d\mu < 10^{-24}$ e.cm → $NP^2 > 10^{16}$ total
μ lifetime	+	10^{14}	~100	30-100	4	1-10	π beam	
μ lifetime (π)	+	10^{14}	~100	30-100	4	1-10	100%	
Michel parmammeter	+	10^{16}	≤ 0.5	≥ 0.02	30-40	1-3	~100%	
Pol param.	+	10^{16}	≤ 0.5	≥ 0.02	30-40	1-3	Pol	
μ-atoms	−	10^{16}	≤ 100	100-1000	1-4	1-5	n/a	e comtami. $\leq$ 10-2, beam size cm
Life science	−	10^{15}	1	100-1000	1-4	1-5	n/a	beam size mm
μCF	−	10^{19}	1	≥ 1000	≥ 100			
μSR	±	10^9/s	DC	-	4	1-5	~100%	
μSR	±	$10^{10\text{-}20}$/s	0.001	100	4	1-5	~100%	

LOW ENERGY MUON EXPERIMENT NEEDS

- Wide spectrum of potential future muon experiments, with different beam needs
  - Intensities
  - Muon energies
  - Polarization requirements
  - Bunch structures
- In particular, flexibility is desirable for the muon beam bunch structure – suggest a flexible primary proton beam bunch structure is desirable

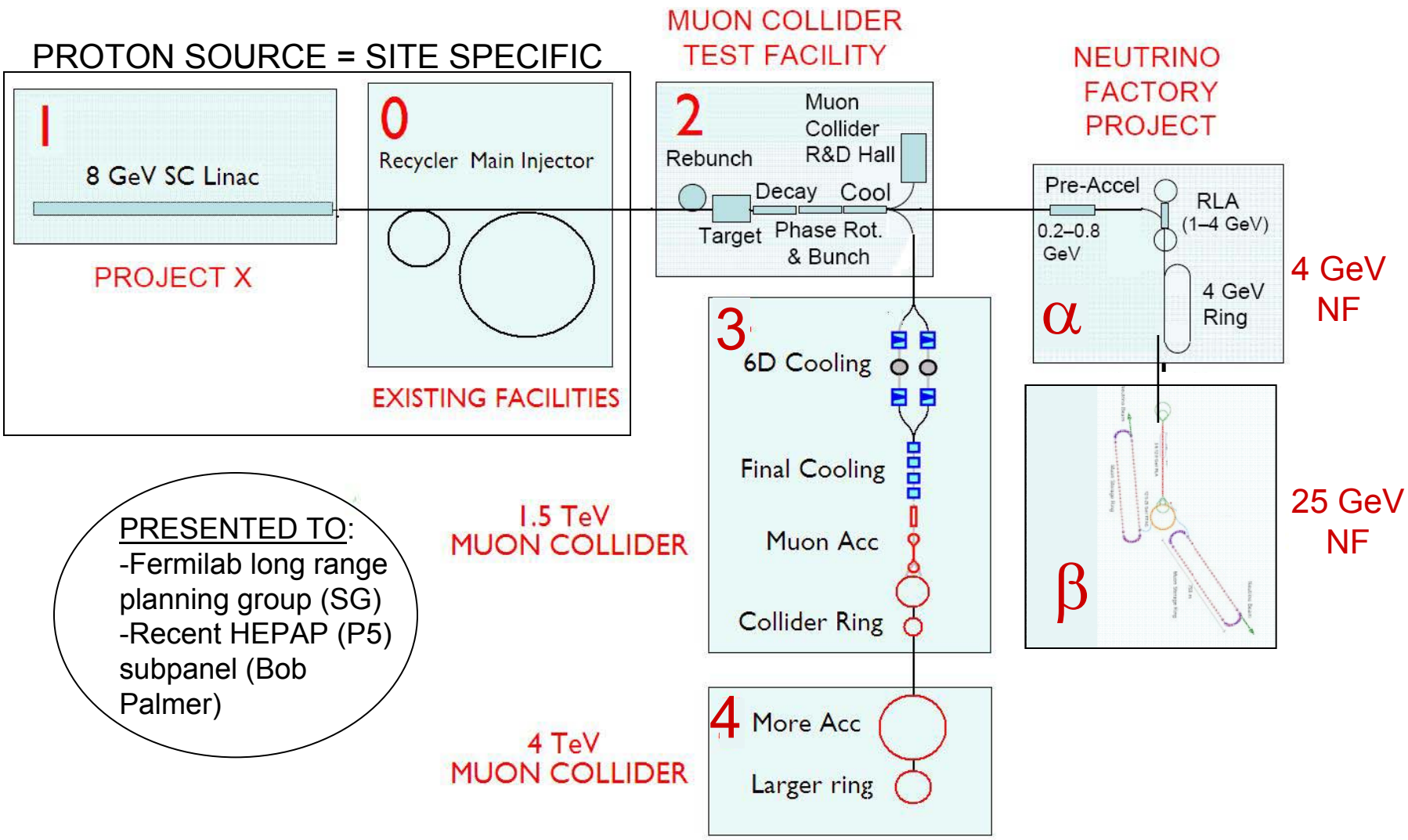
PROTON SOURCE REQUIREMENTS

- NF/MC front ends need
  - – Optimum energy: $5 < E_p < 15$ GeV (Muons/MW falls only slowly for $E_p > 15$ GeV)
  - –Short proton bunches: $\sigma_t < 3$ns
  - –Multi-MW beam powers (typically 4MW)
- Low energy muon experiments have different needs
  - –Example: μ2e/COMET needs $E_p \sim 8$ GeV, $\sigma_t \leq$ ~100ns
- Desired Rep. Rates Vary
  - –ISS NF: 3 or 5 bunches $\times$ 50Hz
  - –MC rep rates still being studied – typically 10 – 100 Hz
  - – μ2e/COMET bunch spacing = O(1μs)
- Can we design a proton source with sufficiently flexible bunch structure to satisfy all these needs?
  - –Two rings for accumulation/rebunching ?

STAGING

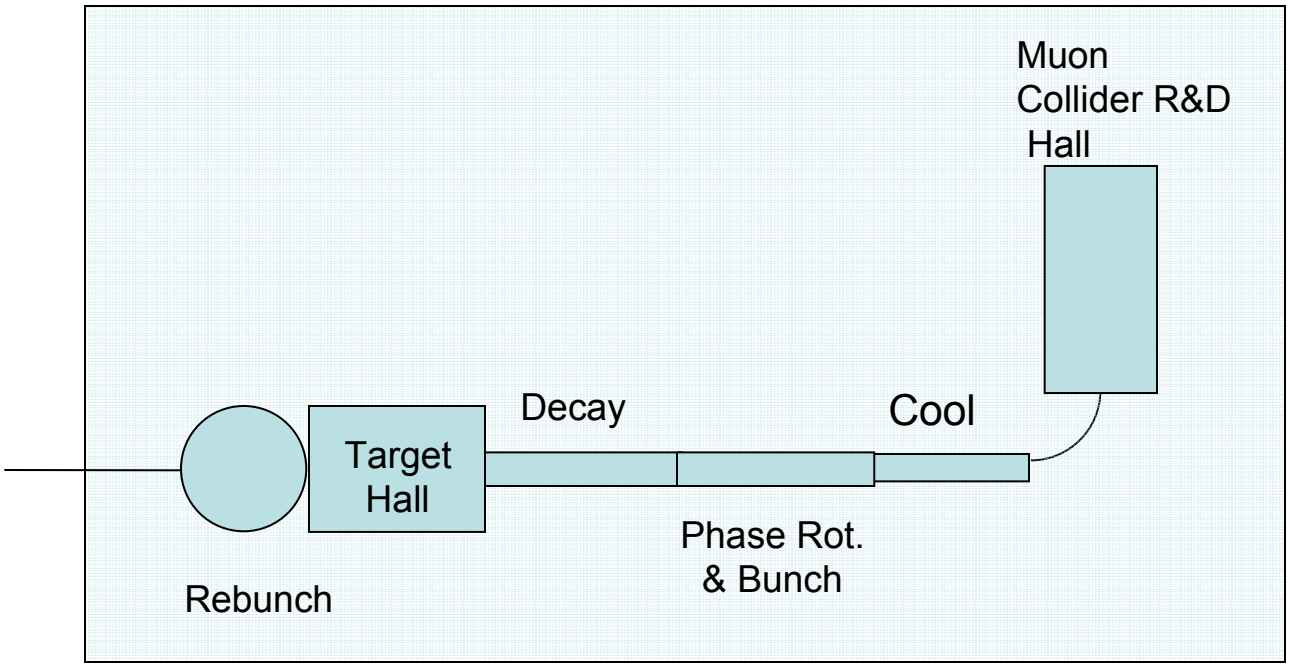
- For illustration, consider a scenario recently developed in the U.S. for the Fermilab long range steering group, and presentations to the recent HEPAP P5 subpanel.
  - This is a Fermilab-based scenario, but the general picture is applicable to any other lab thinking about the path to a MC.
  - The illustrative staging scenario is based on the recent NF International Scoping Study (ISS) baseline design, recent work on a low energy NF, and the latest R&D planning from the U.S. NF and MC Collaboration (NFMCC) and the Fermilab Muon Collider Task Force (MCTF).

ILLUSTRATIVE STAGING SCENARIO



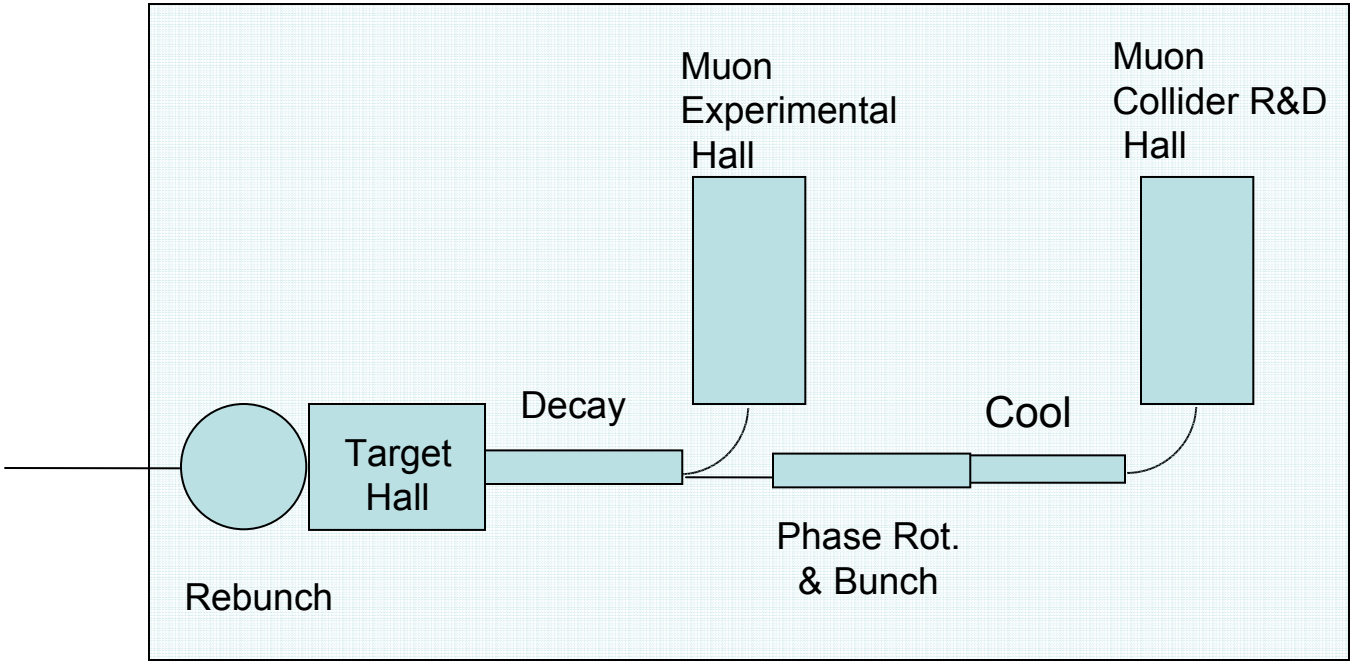
MUON COLLIDER TEST FACILITY

- Illustrative Staging Scenario Step 2:



- However, in general phase rotation & cooling require bunch structures different from low energy muon experiments $\rightarrow$

MUON COLLIDER TEST FACILITY & MUON EXPERIMENTAL HALL



COST CONSIDERATIONS

- A full NF/MC target/decay/phase-rotation/bunching /cooling setup is probably overkill for a test facility

- Need to think about minimal (upgradable?) setup

  –Target station cost dominated by concrete → upgrade path possible from low to high intensity? (full target station + decay channel estimated at 116M$ (FY08) unloaded).

  –Cheaper (upgradable ?) versions of bunching/phase-rotation/cooling channels desirable (full versions estimated 350-420M$ (FY08) unloaded).

  → Is there a cheaper test bunching/phase rotation solution ?

  → Should the cooling channel be included (or perhaps a short channel is the first experiment in the MC R&D hall ?

HOMEWORK ASSIGNMENT

- FOR A MULTI-MW PROTON SOURCE, DESIGN A REBUNCHING SCHEME, TARGET STATION & DECAY CHANNEL THAT:

  – Delivers ~10^{13} muons/sec to a muon experimental hall, with flexible bunch structure.

  –Is as cheap as possible.

  –Is upgradable to a NF/MC-class facility.

SUMMARY

- Can we share a muon source among NF, MC and low energy muon programs ?

- Motivates thinking about:
  - –Flexible proton rebunching scheme
  - –Cost effective solution for staging & the minimal (& possibly upgradable) Muon Collider R&D Test Facility
  - –Requirements for a low energy muon experiment facility delivering ~10^{13} μ/sec

- No definitive answers, but some food for thought