MUON ACCELERATION GROUP

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BNL 12/20/13

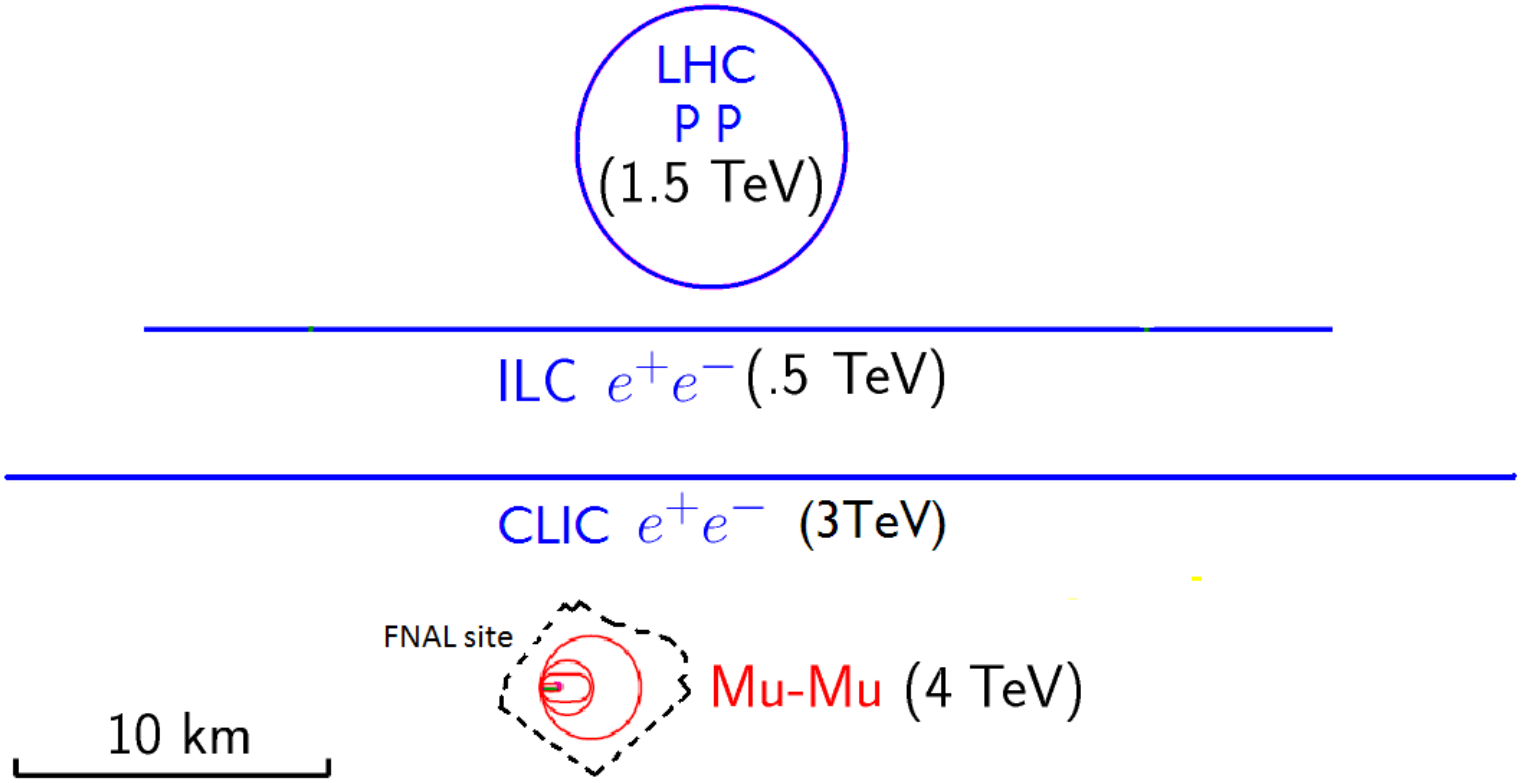
- Why?
  - Small
  - Less wall power
- Sub-systems and what we are doing
  - Target
  - Phase Rotation
  - Ionization Cooling
  - Acceleration
- Conclusion

Why a Muon Collider ?

- Electron Linear Colliders
  - synchrotron radiation ($\propto \gamma^4$) forces Linear Colliders to be linear
  - electrons intersect once and are thrown away
  - beamstrahlung causes huge energy variation
    (70% of Luminosity has dE $>$ 1% at 3 TeV)

- Muon Collider
  - Acceleration can be in rings, using much less rf
  - Collisions can be in rings
    $\approx$ 1000 collisions before decay
    allowing larger emittances and spot sizes
    and requiring less beam power
  - Beamstrahlung now negligible dE/E $\approx$ 0.1 %

Relative sizes



- Muon Colliders much smaller
- Use less wall power

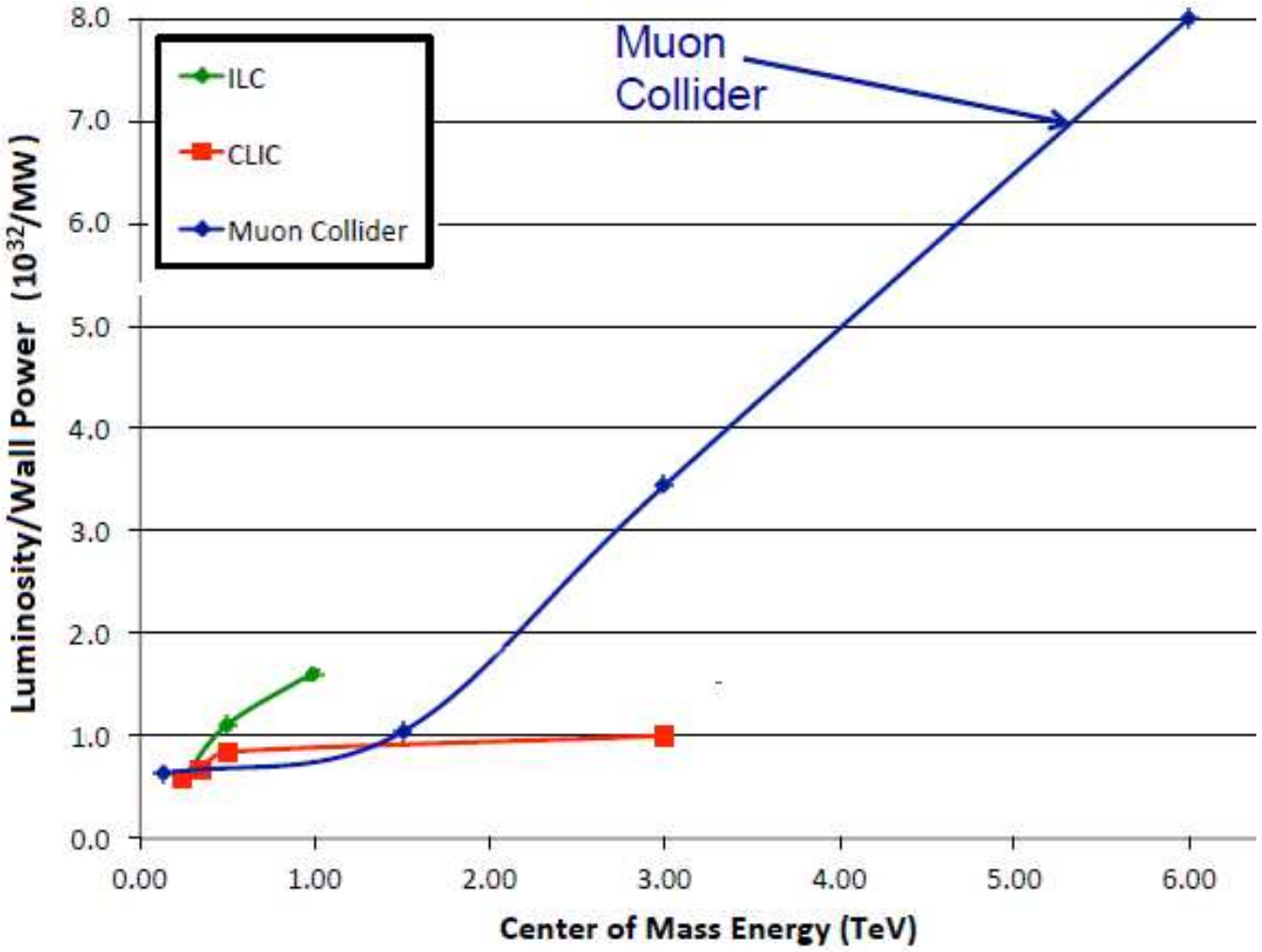
  e.g. Compare with electron positron CLIC at 3 TeV

Compare 3 TeV $\mu^+\mu^-$ with 3 TeV e^+e^- CLIC

		$\mu^+\mu^-$	e^+e^-
Luminosity/IP (E within 1%)	10^{34} cm^{-2}s^{-1}	4	2
IPs = Detectors		2	1
β^* at IP $= \sigma_z$	mm	5	0.09
rms bunch height σ_y	μm	3	0.001
Total lepton Power	MW	11.5	28
Wall power	MW	$\approx$ 230	570
Lepton power/Wall power	%	20.0	20.3

- Spot sizes and tolerances much easier than CLIC's
- $\mu^+\mu^-$ luminosity/detector twice CLIC's (for dE/E $<$ 1%) $\times$ 2 detectors
- Lepton and Wall Power $\approx$ 1/3 CLIC's
- Because muons interact $\approx$ 1000 times, but electrons only once

Luminosity/Wall power vs Energies

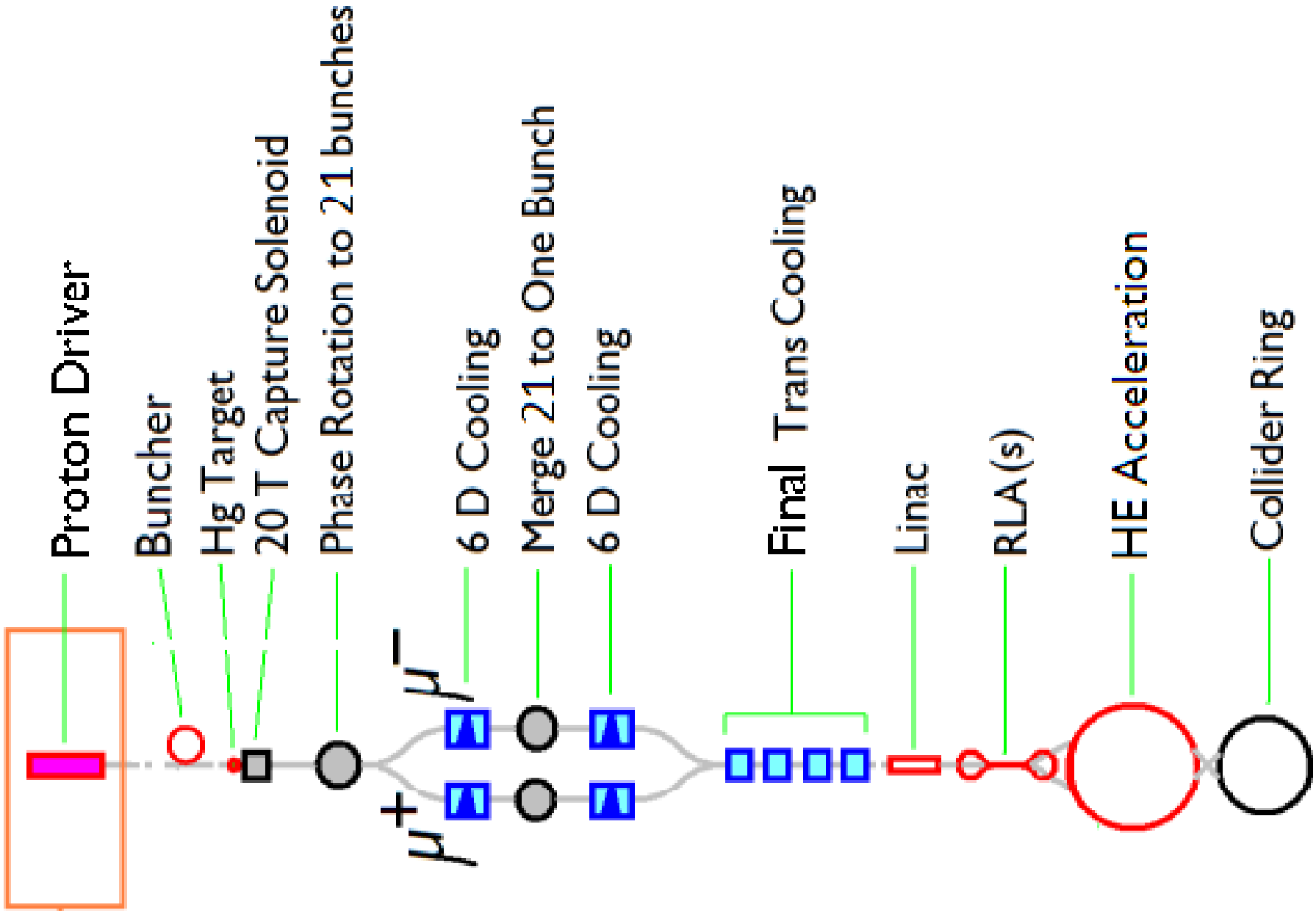


- 1.5 and 3 TeV: Designs 6 TeV: Extrapolation
- In addition Muon Collider has 2, istead of 1, detector

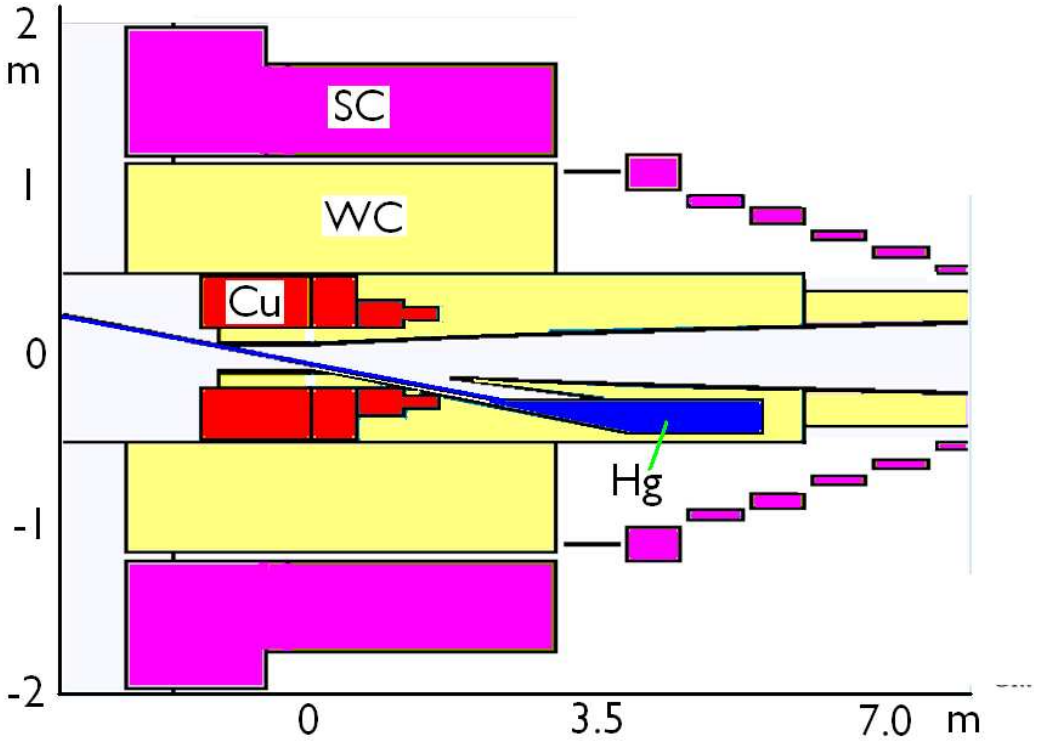
Muon Acceleration Program

- National Program
- Managed by FNAL
- Director Mark Palmer (not a relation)
- Significant role by BNL
  - Muon Acclerator Group (under Ilan)
  - Magnet Division
  - Instrumentation Division

Schematic


Proton Driver
Buncher
Hg Target
20 T Capture Solenoid
Phase Rotation to 21 bunches
6 D Cooling
Merge 21 to One Bunch
6 D Cooling
Final Trans Cooling
Linac
RLA(s)
HE Acceleration
Collider Ring
μ^-
μ^+

Target and 15-20 T Capture Solenoid

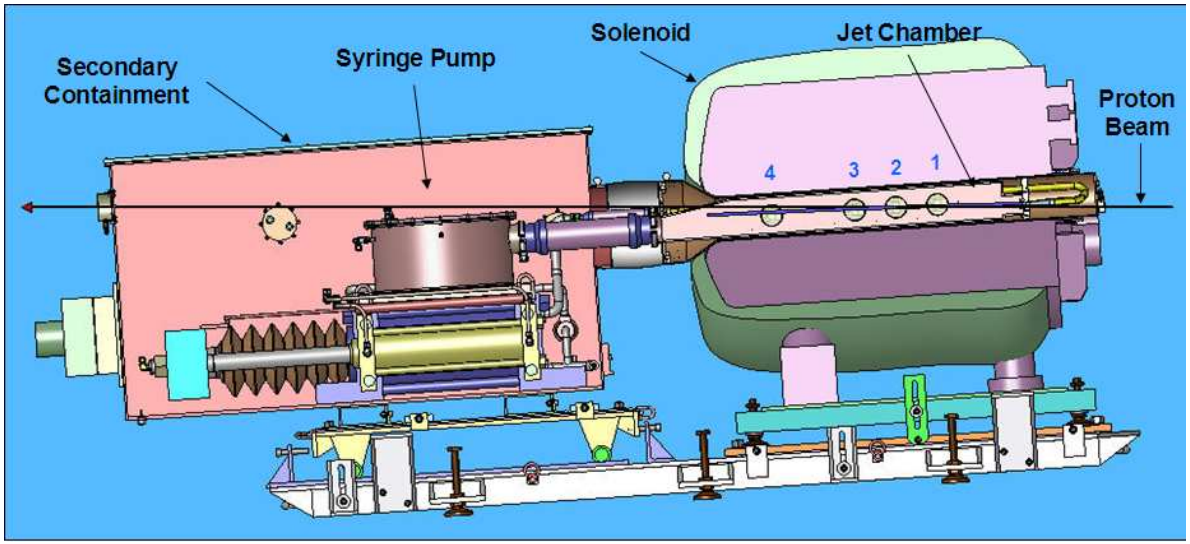


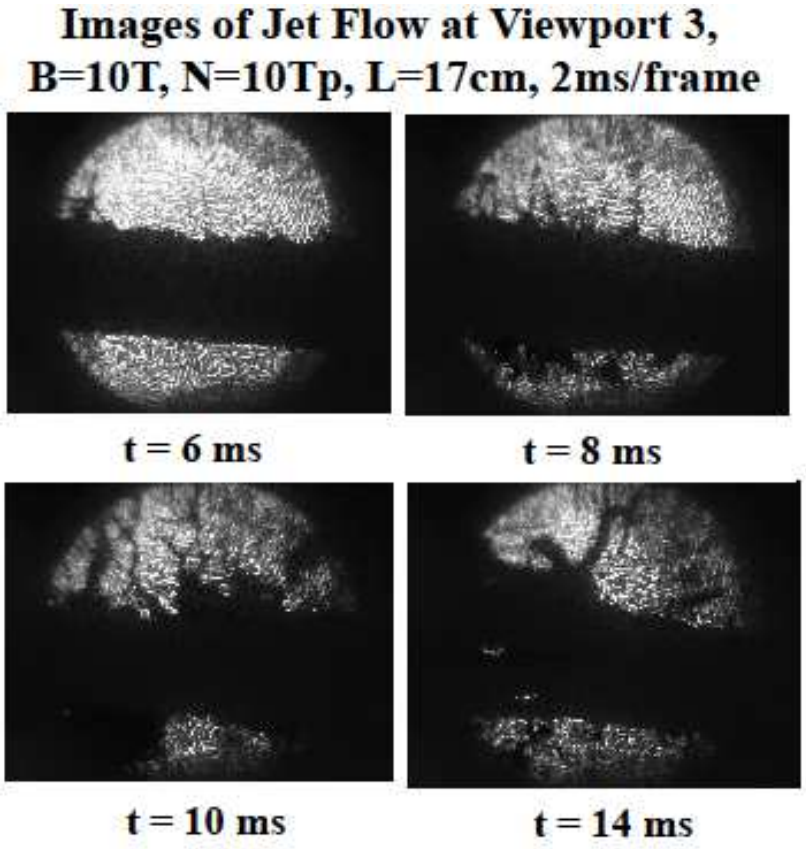
- Copper coil gives 6 T, (uses 15 MW of wall power)
- 14 T Super-conducting solenoid, tapering to 3 T
- Tungsten Carbide in water shielding

Design: HAROLD KIRK
Optimization: HISHAM SAYED (post Doc)

Liquid metal (eg mercury) jet target

MERIT Experiment at CERN



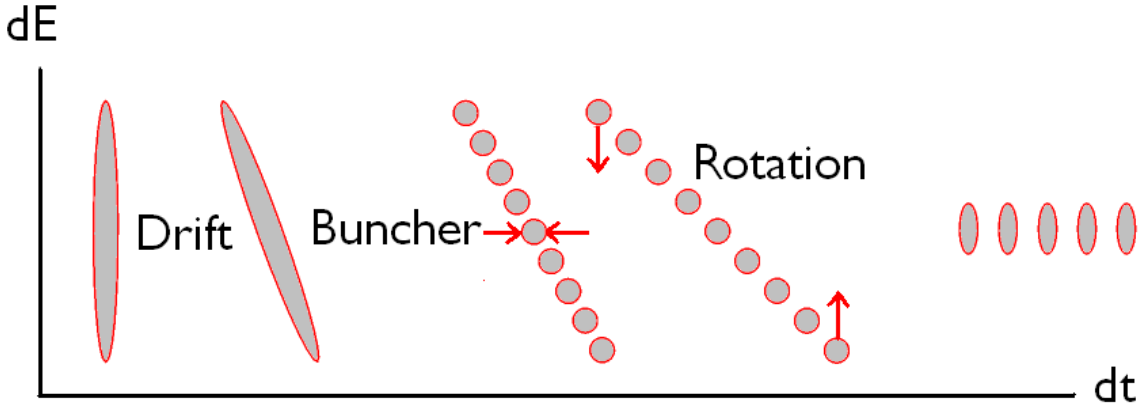


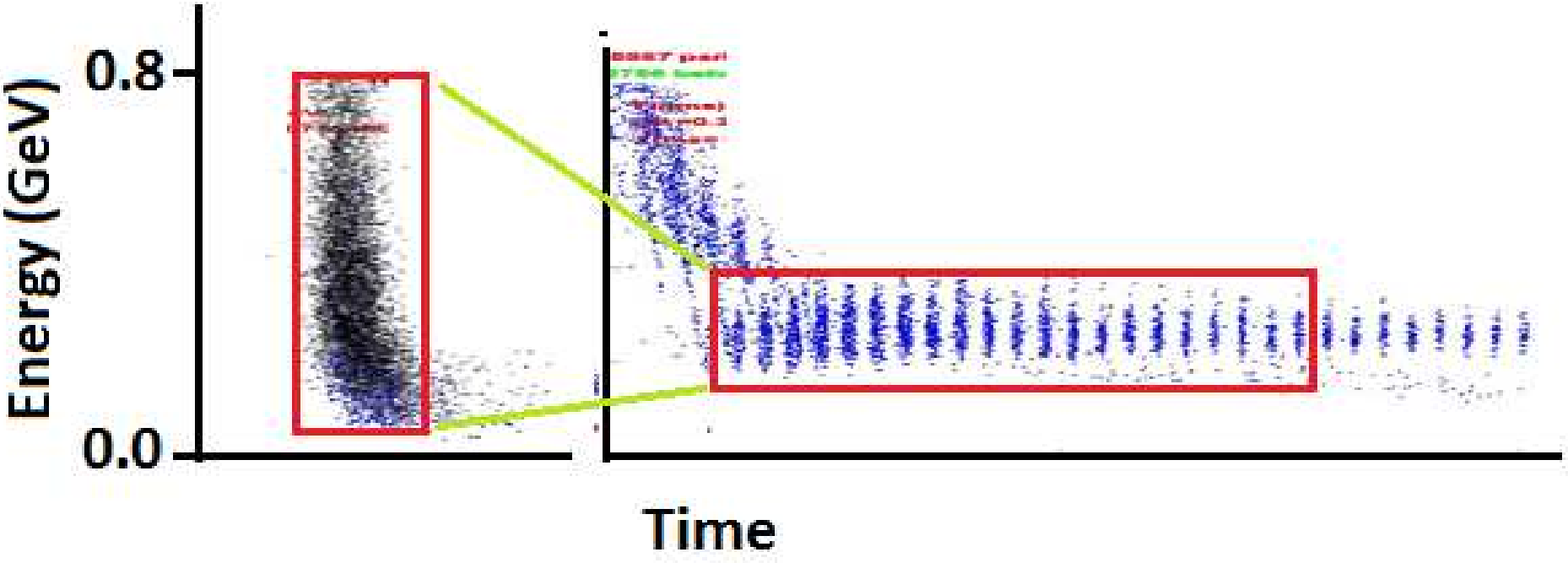
- 15 T pulsed magnet
- Up to 30 Tp
- Splash velocities were moderate
- Density persists for 100 micro sec

Leadership: HAROLD KIRK

Optics: Instrumentation Division

Phase Rotation→Multiple bunches

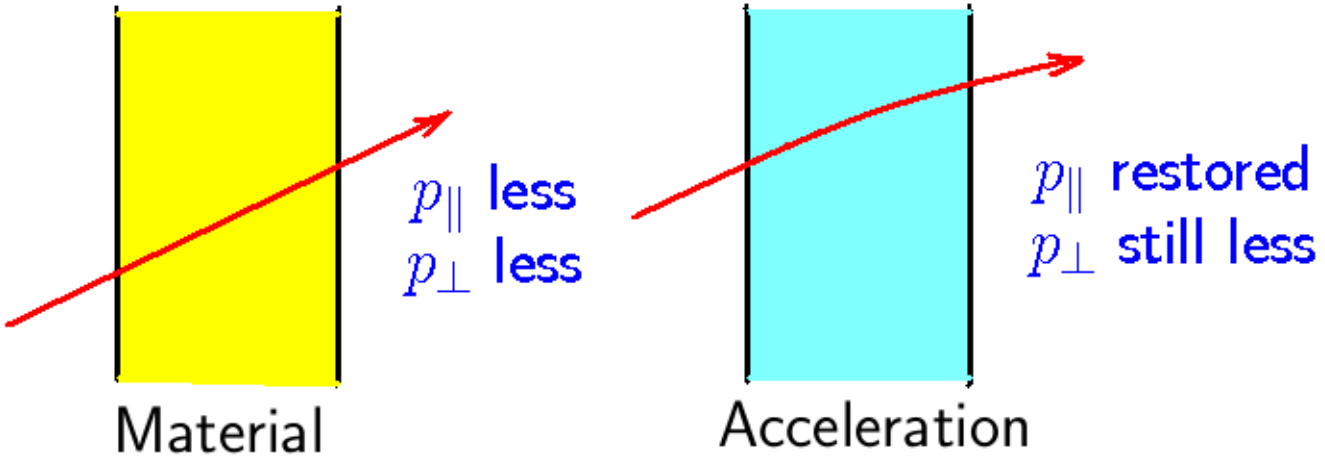


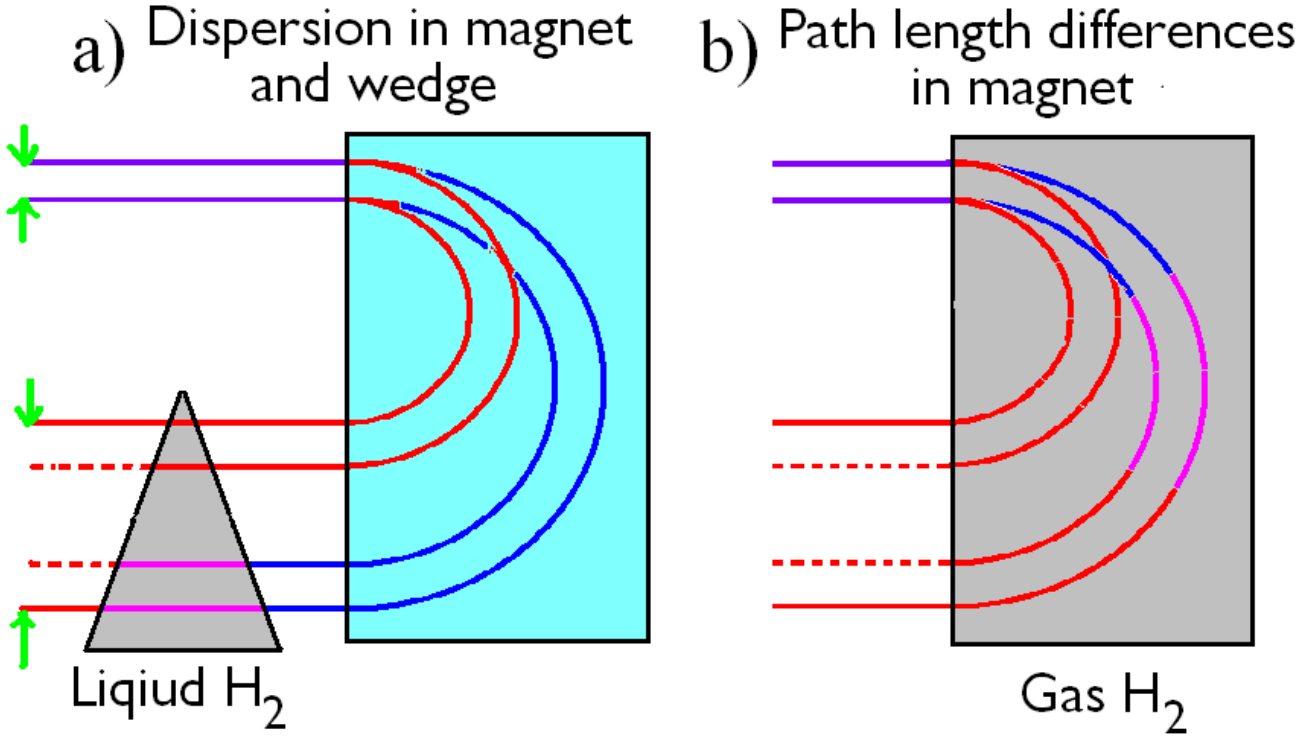


Front End leadership: DIKTYS STRATAKIS

Optimization: HISHAM SAYED

Ionization Cooling

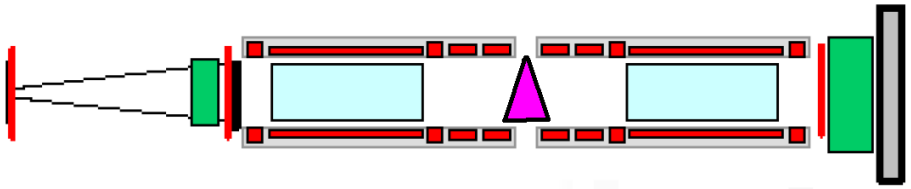




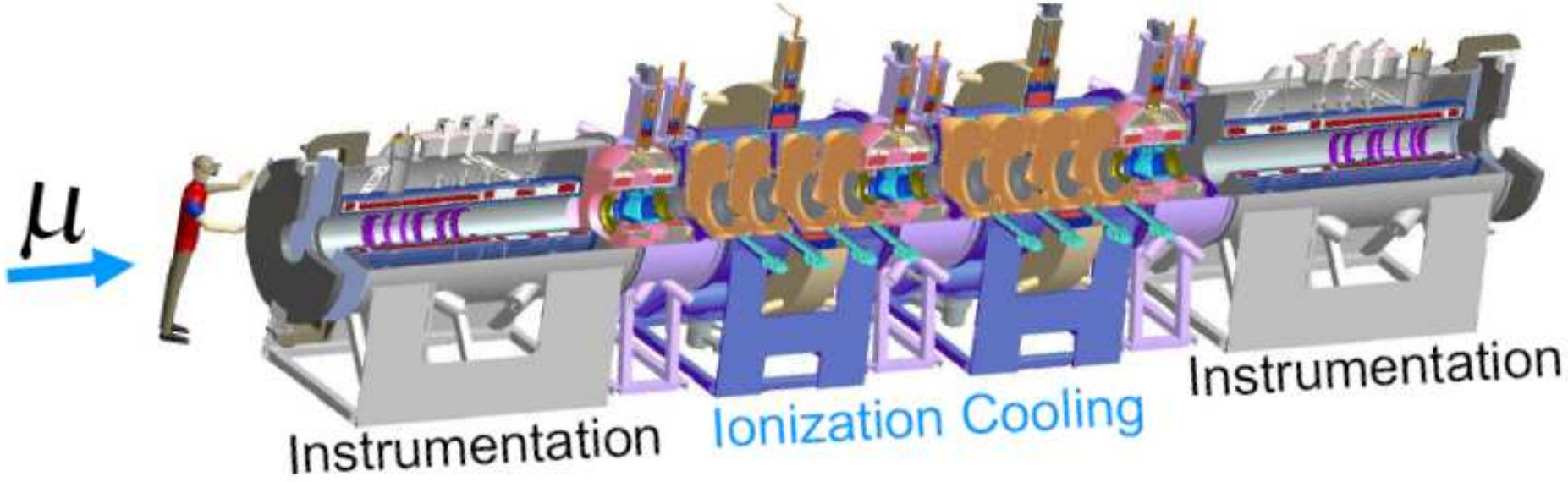
Muon Ionization Cooling Experiment (MICE)

International collaboration at RAL, US, UK, Japan (Blondel)

- Early Experiment to demonstrate Emittance Exchange
  - Cooling in all dimensions
  - But no re-acceleration

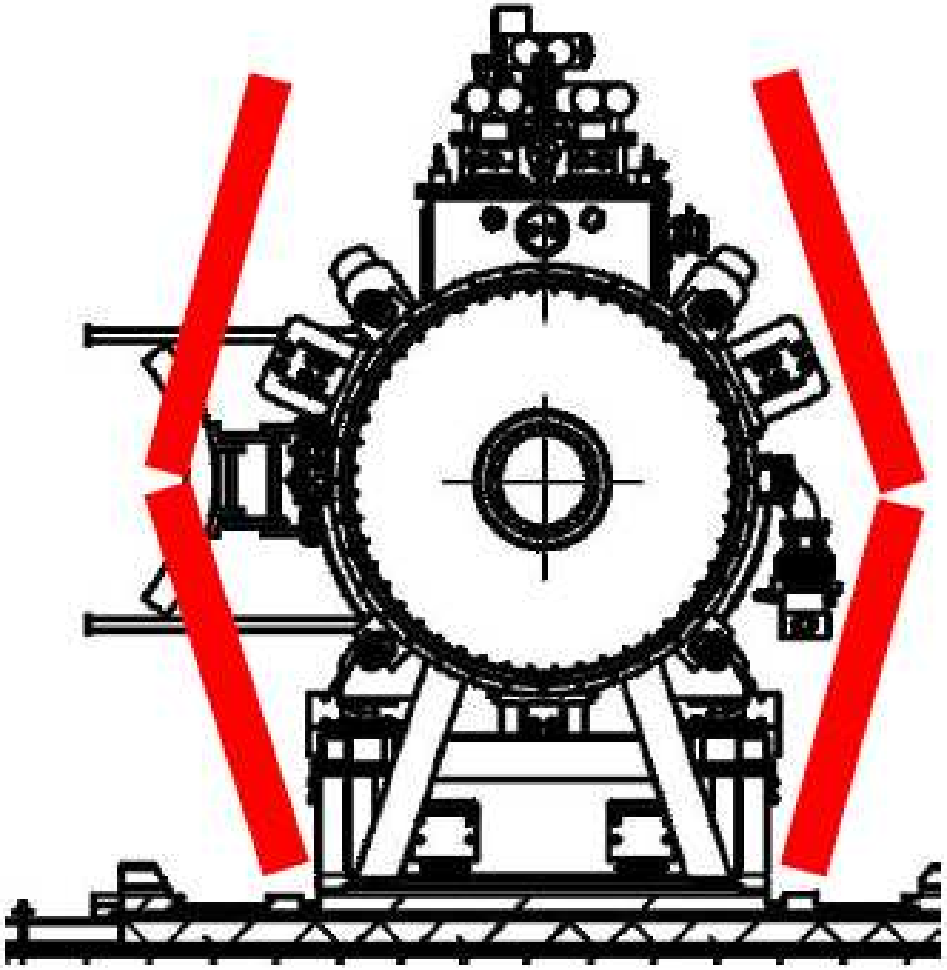


- Will then demonstrate transverse cooling in liquid hydrogen, including rf re-acceleration



- Problem with stray field

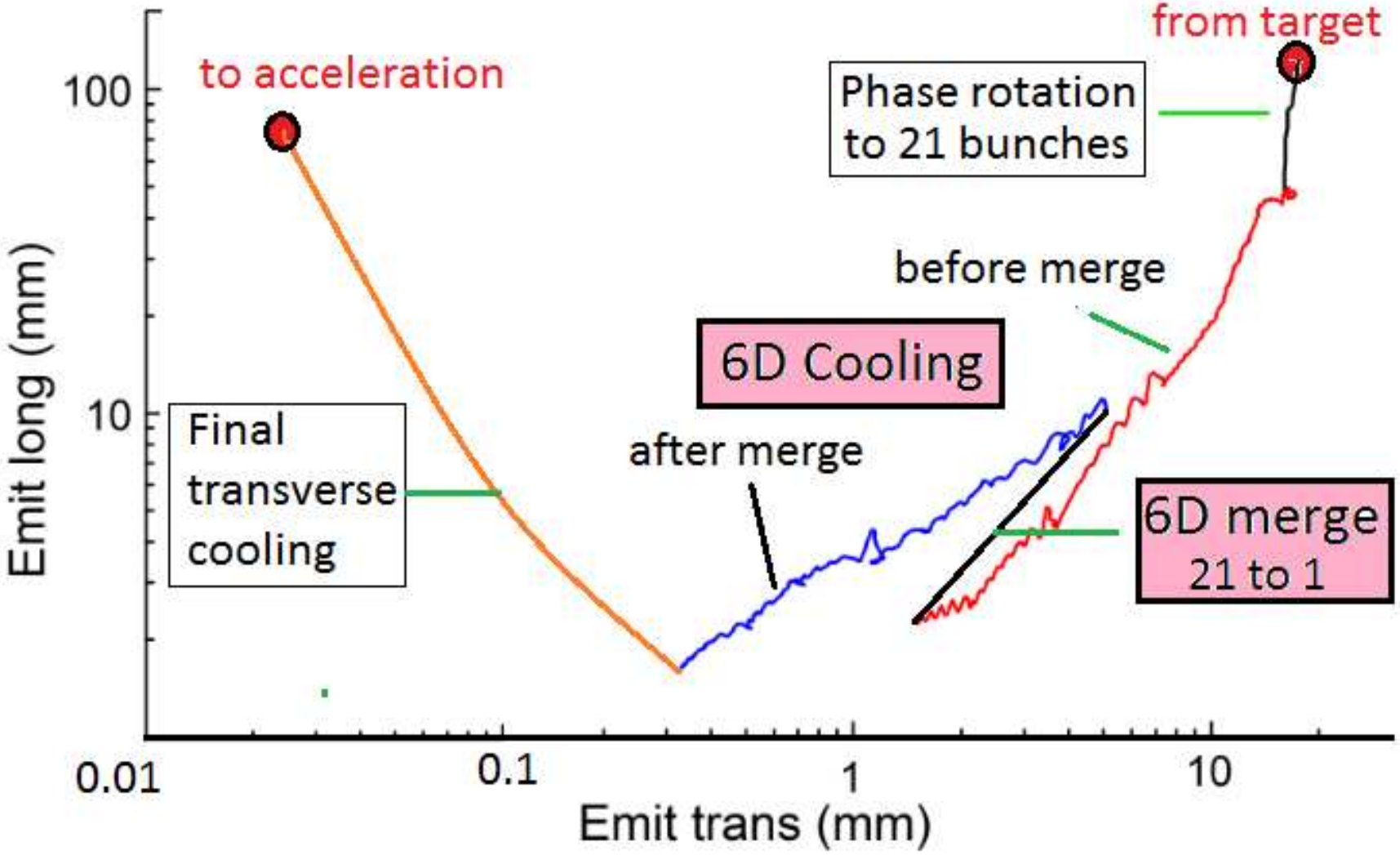
Partial Return yoke



H Witte. Step IV & VI: Local Flux Return.
MICE CM 34, October 2012.

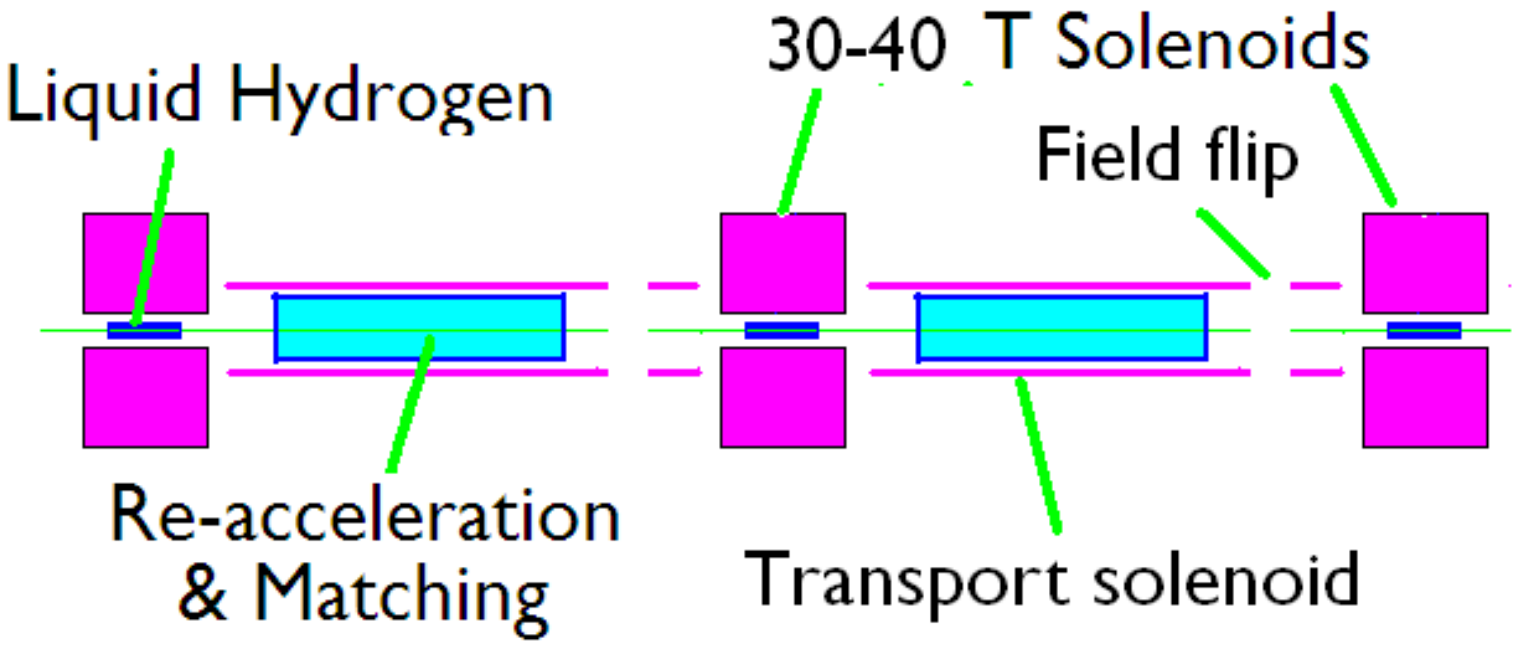
Design, Simulation, and Management: HOLGER WITTE

Emittance Evolution



Simulation theory and simulation software: SCOTT BERG
Design and Optimization of 6D cooling: DIKTYS STRATAKIS
Design of 6D merge: BOB PALMER, Yu Bao (UCR)

Final Transverse Cooling



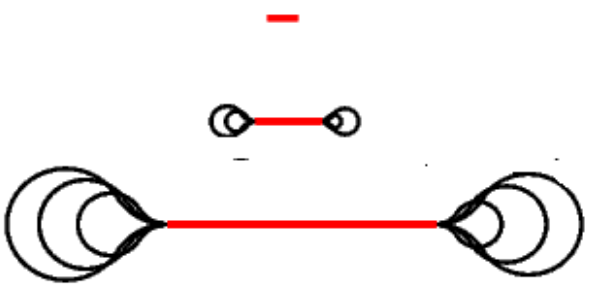
- Cooling in hydrogen simulated for all 13 stages
- Matching and re-acceleration only simulated between last stages

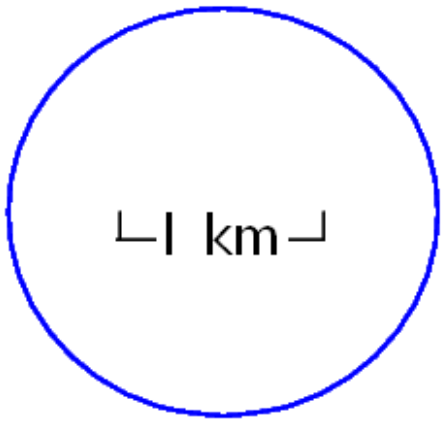
Start on matching simulation: HISHAM SAYED
Magnet experiment: RAMESH GUPTA (magnet division)
Magnet design: BOB PALMER, HOLGER WITTE

Acceleration

Must be fast:

Linacs, recirculating linacs (RLA) and pulsed synchrotrons (RCS)





	E GEV		passes	Lengths
1)	.4-1.5	Linac		L(linac)= 68 m
2)	1.5-12.5	RLA	n=4.5	L(linac)= 306 m
3)	12.5-100	RLA	n=6.5	L(linac)= 1250 m
4)	100-400	RCS	n=23	Circ = 6283 m
5)	400-750	RCS	n=27	Circ = 6283 m

both RCS pulsed at 15 Hz

Design: SCOTT BERG

Pulsed dipole magnets: HOLGER WITTE

CONCLUSION

- It has long been argued that a detailed study of 'New Physics' requires a lepton collider with appropriate energy. From the Luminosity/Power plot one can conclude that

  - If 'New Physics' < 1 TeV, then the ILC would be appropriate
  - If 'New Physics' is at 1 to 2 TeV, then CLIC is appropriate
  - But if 'New Physics' > 2 TeV then a Muon Collider appears to be the only way to achieve needed luminosity with reasonable wall power consumption.

- The Muon Accelerator Group, as part of a National MAP Program, is playing a major role in the effort to determine if a Muon Collider is feasible