Muon Collaboration

Steve Geer
MUTAC
June 2000

MUCOOL
Overview and Plans

- Mission
- History & accomplishments
- Lessons from design studies
- Component development
- Towards a beam test
- Organization
- Summary

MUCOOL COLLABORATION

ANL: A. Hassanein, K.–J. Kim, J. Norem, C. Wang
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Princeton University: C. Lu, K. McDonald, E. Prebys
University of California, Berkeley: J. Wurtele
University of California, Los Angeles: D. Cline, Y. Fukui, K. Lee, Y. Pischalnikov
University of Chicago: M. Oreglia, K.–J. Kim, Y. Wah
University of Illinois, Urbana: D. Errede
University of Mississippi: L. Cremaldi, D. Summers

MUCOOL contact people underlined

MUCOOL MISSION

To develop, prototype, and bench test all of the critical components needed for a muon cooling channel, and ultimately to build and beam test short sections of a cooling channel.

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Cooling Channel

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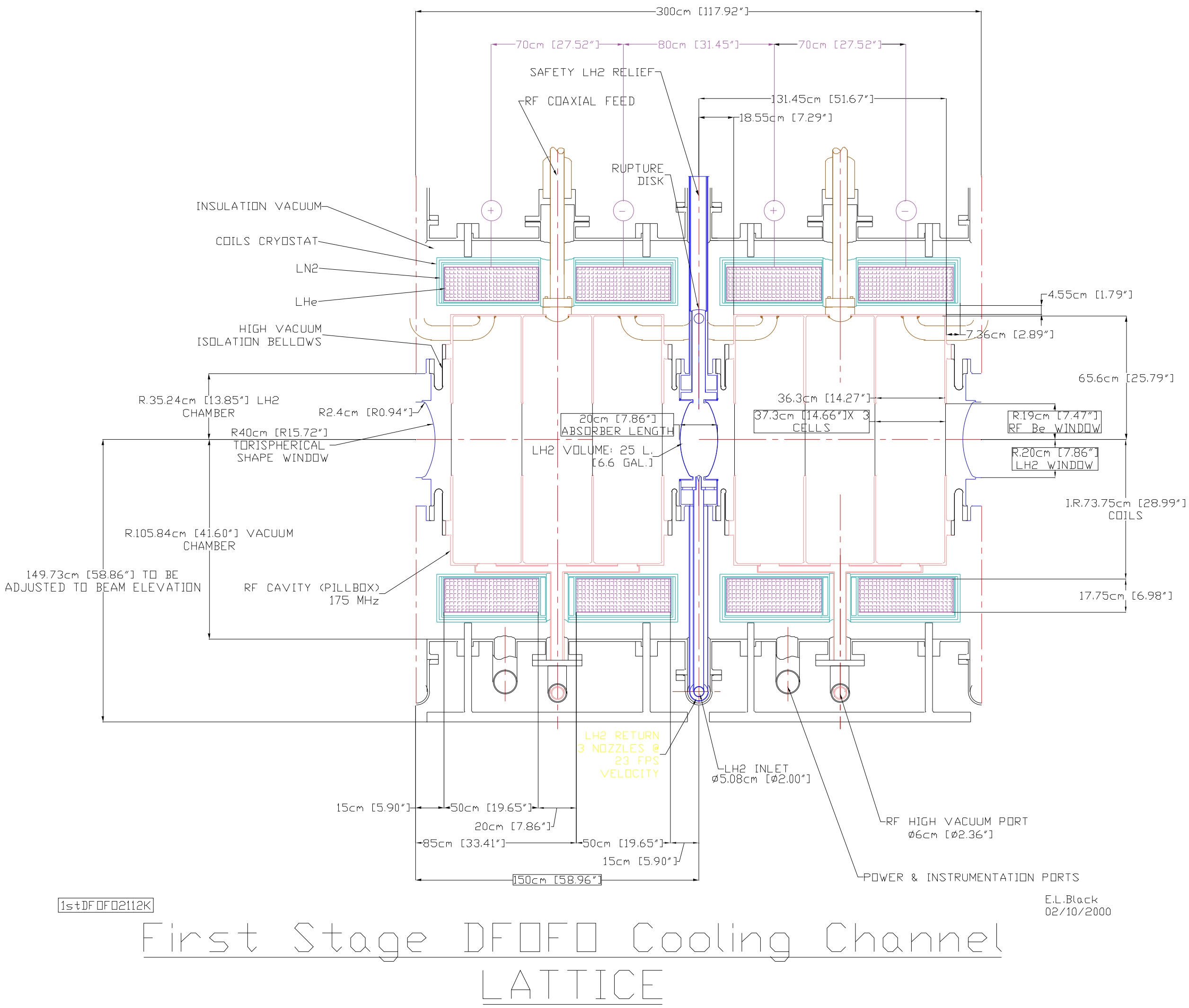

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The Challenge

A cooling channel can be thought of as a LINAC filled with material.

The challenge is to:

1. **Design a cost effective channel that both cools the beam & keeps it captured in longitudinal phase–space.**
2. **Develop the very high gradient cavities, Liq. H2 absorbers, & solenoids required by the design.**
3. **Make cost–effective test of a cooling section.**

MUCOOL History – 1

- May 1997: MUCOOL born.
- August 1997: MUCOOL R&D program presented to Gilman panel.
- April 1998: Proposal for late cooling channel component development & beam test submitted. First DOE funds –> $600K used for RF R&D.
- FY99: Additional DOE funds ($1.2M) –> RF R&D plus cooling channel engineering studies.
- FY00: DOE funds ($1.8M) –> RF, LH2, engineering studies, instrumentation development.

Hardware Accomplishments
805 Mhz RF Highlights

Need highest gradients achievable –> 2 cavity designs: (1) open cell, (2) with Be windows.

Made Al model of open cell cavity, measured properties, & started constructing Cu cavity for high power test.

Tested small Be foils in RF gun –> OK.

Measured mechanical properties of Be windows when heated at LN_2 temperatures

Built prototype Cu cavity with Be windows, measured properties.

Almost completed a high power test facility at Fermilab (Lab G)

Built & tested 5T solenoid so cavities can be tested in appropriate field at Lab G

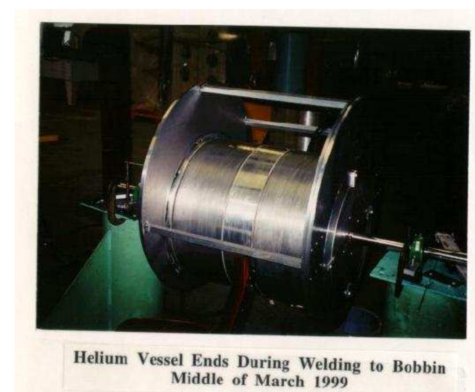
805 Mhz cavity development to be completed in FY01

Will learn about trying to get highest gradients in cavity, cavities with Be windows, & making high gradient cavity tests in magnetic field.


Be window


Open cell cavity: Al model


X–ray cavern at Lab G



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Hardware Accomplishments
Instrumentation Highlights

Low pressure TPC (Princeton)

Test chamber –> drift velocity & longitudinal diffusion coeff. Measured at low pressures.

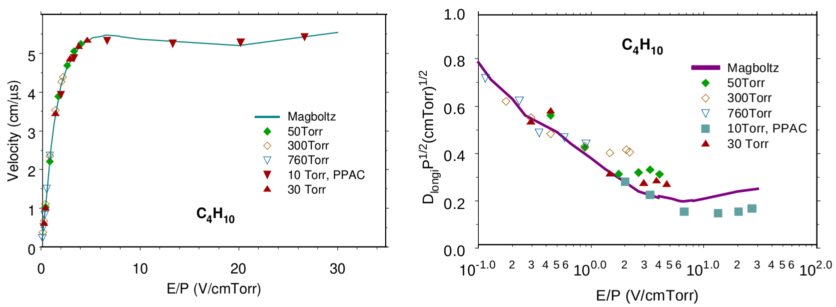
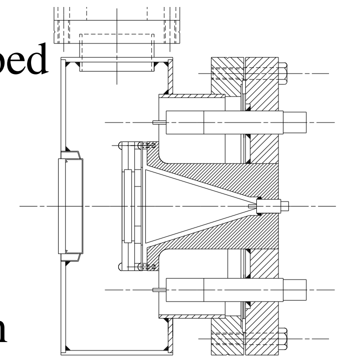


Figure 9. Longitudinal diffusion coefficient and drift velocity of iso-butane.

Fast timing (FNAL, UCLA)

Sci–Fiber detector prototyped & tested –> 100 ps

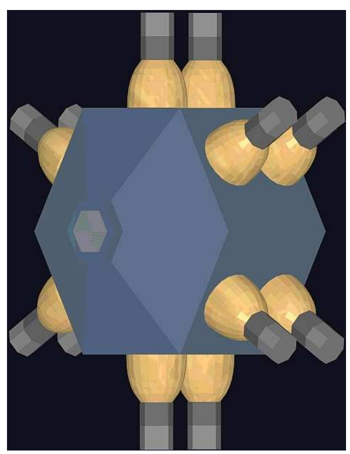
Fast cherenkov device designed & being prototyped –> 10–30 ps resolution.
All parts acquired.
Primary data acquisition tested–> 3 ps resolution.
Secondary data acquisition (TDC) ready in fall.



Particle ID (Mississippi)

Need to reject incoming pions and electrons

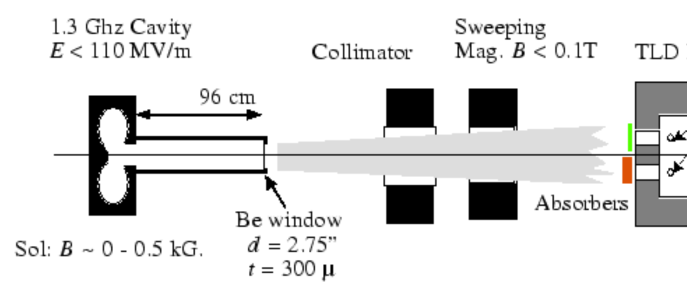
Threshold cherenkov devices designed for range of beam momenta.



X–Ray flux: (ANL)

Measured X–ray flux downstream of 1.3 GHz cavity with surface field of 130 MV/m –> $10^7\,\gamma/cm^2/sec$ at ~100KV.

Plan to measure at 805 Mhz in Lab G and see if fast (secondary emission, Faraday cup) detectors can operate close to cavity



MUCOOL History – 2

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- Summer 1999: Collaboration changes primary focus from Muon Colliders to Neutrino Factories, & hence MUCOOL changes focus from Late Cooling –> Early Cooling. BIG CHANGE !

RF: 805 MHz –> 175/200 MHz

Solenoids: 15T –> ~3T

Apertures: r(LH2) = 5 cm –> >10 cm

Task – 1

Design a cost effective channel that both cools the beam & keeps it captured in longitudinal phase–space.

- Design –> iterative effort between theory/ simulation group & MUCOOL engineering.
- Design pursued recently in the context of the 6 months study Oct 99 – March 00.
- Rapid progress possible because of the tools developed over the previous 2 years (ICOOL, DPGEANT, engineering feedback) & the experience accumulated in cooling channel design.

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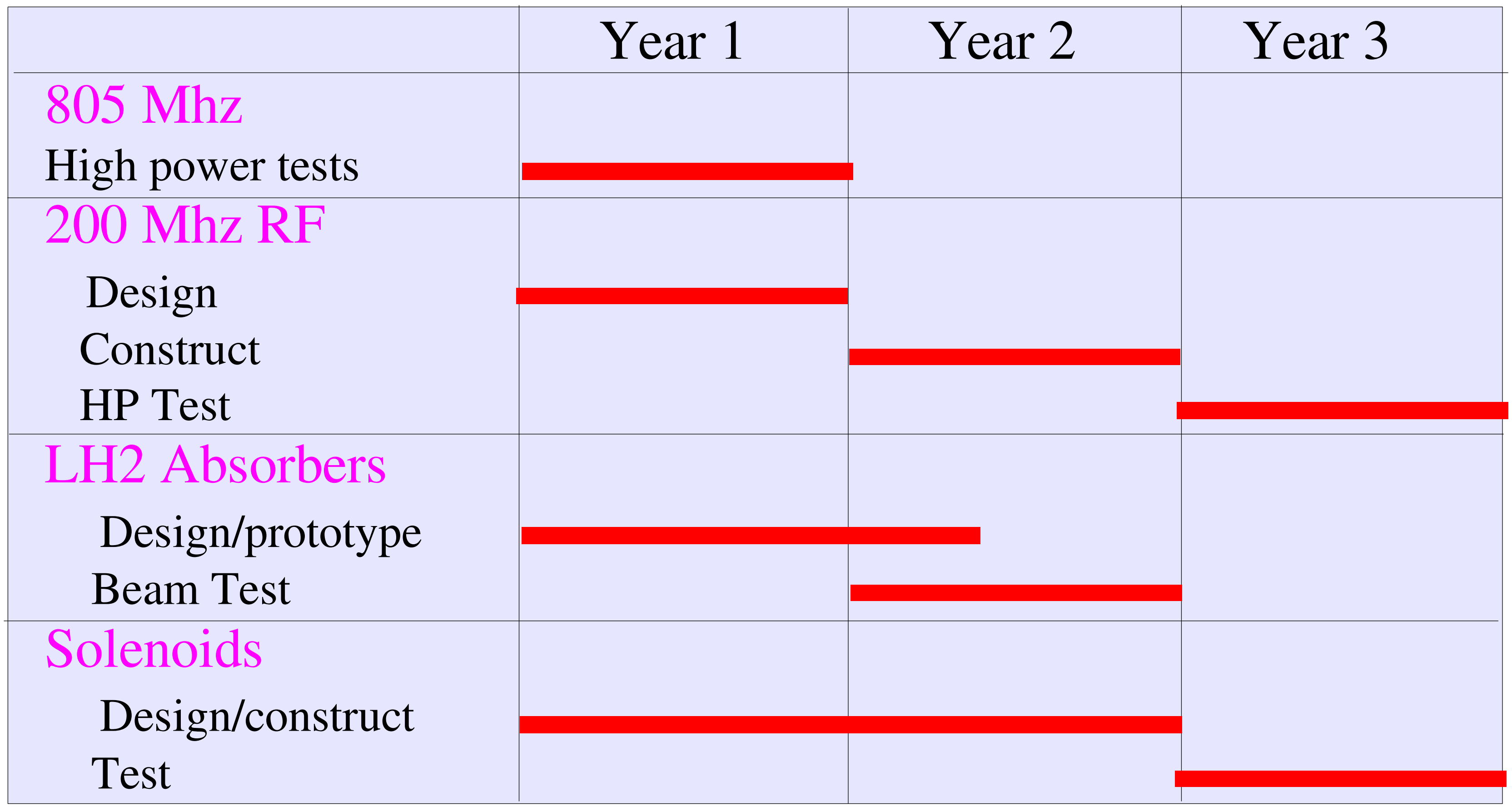
Lessons from Design Studies

1. Need highest gradient RF –> R&D –> J. Corlett talk
2. Need LH2 absorbers with thin windows to minimize scattering –> R&D –> M.A. Cummings talk
3. Solenoids (for 6 months study design) very expensive –> design issue (R&D issue ?) –> J. Miller talk
4. Cooling performance depends critically on what's upstream & therefore cooling channel must be designed together with rest of front end. Don't yet have an optimal (cost effective) cooling channel / front end, although progress since the 6 month study is encouraging –> J. Wurtele, J. Monroe talks. Need vigorous continuation of theory/simulation & engineering design studies.

Task – 2

Develop the high gradient cavities, Liq. H_2 absorbers, solenoids required by the design.

- Technology driven schedule –> it will take about 3 years to develop the cooling channel components:



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Task – 2

Develop the high gradient cavities, Liq. H_2 absorbers, solenoids required by the design.

- High gradient 200 Mhz RF cavities

  Continued cavity design crucial for overall simulation/design effort

  Will need a 200 Mhz high power test setup (LAB G ?) at beginning of year 3.

- LH2 absorbers

  To be pursued by members (IIT, NIU, UIUC) of a consortium of Illinois universities + Fermilab. Anticipate state funding for development of absorbers.

  We will need a LH2 assembly/test area at Fermilab within a few months.

- Solenoids

  Goal would be to have a set of solenoids end of year 3 –> high power cavity test within solenoid field –> concerned about getting adequate support from Labs to meet anything like this schedule. NHMFL role – NSF funding ?

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Task – 3

Make a cost–effective test of a cooling section.

Method:

- Find a cost–effective practical cooling channel design
- Study the channel sensitivity to scattering uncertainties, alignment, field quality, etc. Identify performance issues (systems issues) that need to be tested in a beam & the required measurement precisions
- Specify the required beam and cooling channel (how many sections ?) needed for the test
- Design & propose cooling test

Note: Beam testing a cooling section is a large scale endeavor and might benefit from international participation ... being explored.

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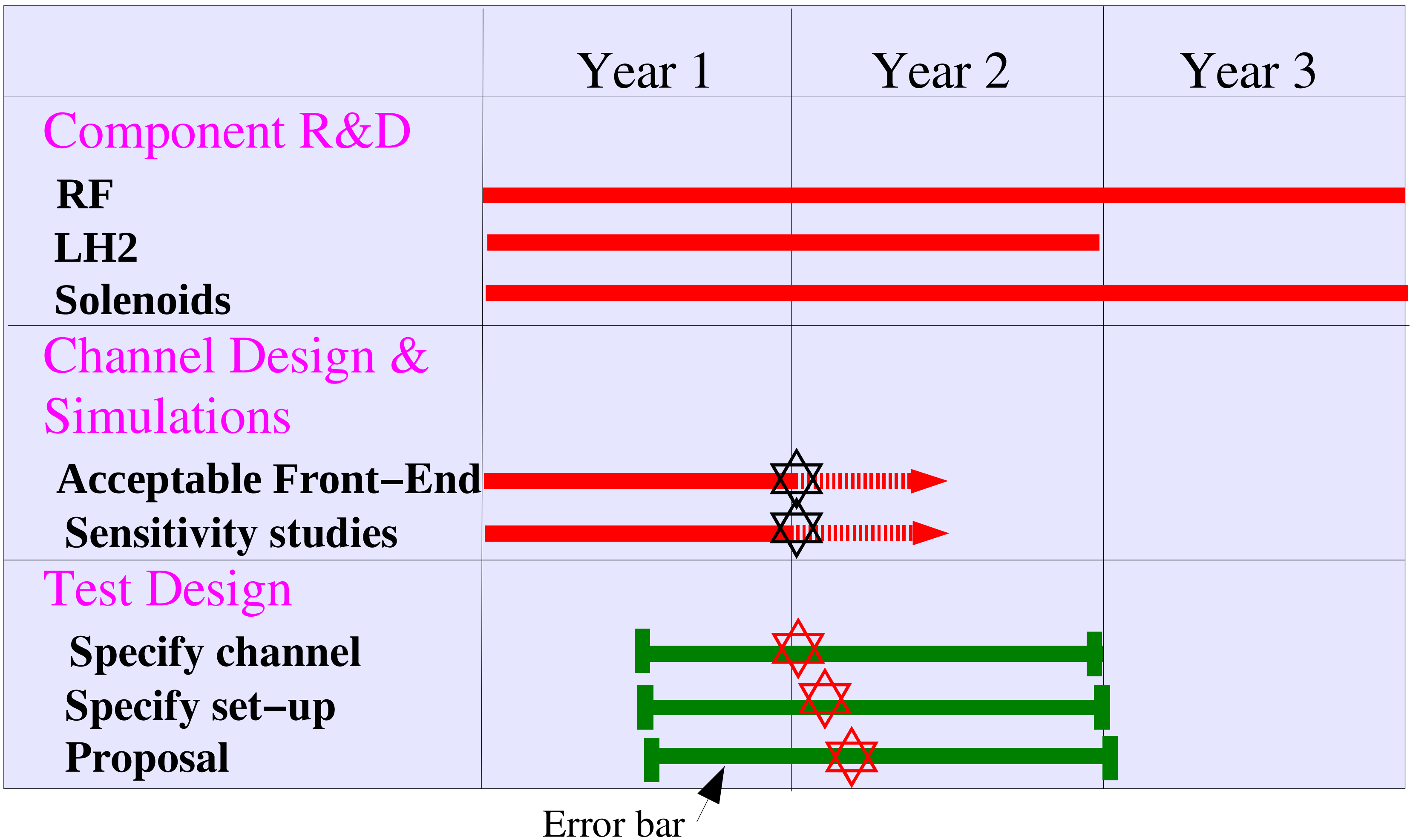
Getting to a Beam Test Proposal

Technology driven schedule

The required beam test eventually needed to demonstrate operation of a cooling channel will be a large scale effort–> support from DOE &/or NSF. The experiment might be international in scope ... being explored.



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Scattering/straggling Experiment ?

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If the uncertainty on the cooling channel performance turns out to be sensitive to the uncertainties on scattering/straggling in LH_2, Be, Al, ... then we may need an experiment to precisely measure scattering/straggling. However:

Previous scattering measurements –> uncertainties on the shape of the scattering (Pt) distribution at few % level:

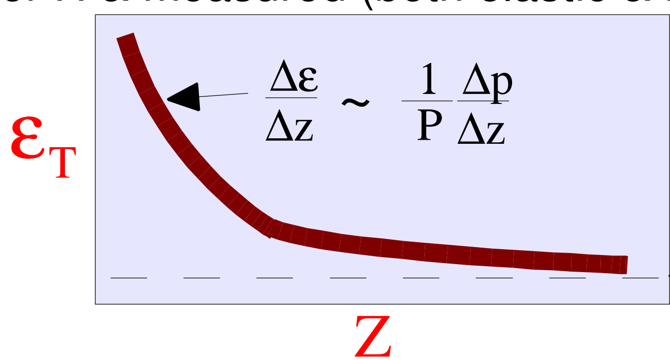
Bernstein & Panofsky: PR102, 522 (1956): $X_0(LH_2)$ measured to +–3% (X_0 depends on atomic form factor)

Shen et al: PRD20, 1584 (1979)

Target	Z	θ(exp)/θ(Moliere)
H	1	0.993+–0.008
Be	4	1.018+–0.037
C	6	1.026 +–0.040
Al	13	1.008+–0.027
Cu	29	0.991+–0.027

Agreement with theory with a precision of a few %

Implementation of Moliere theory in Monte Carlo programs –> model dependence of at most a few %. Don't have to rely on Thomas–Fermi model: Atomic form factors calculated for H & measured (both elastic & inelastic) for other materials by x–ray crystallography



Analytical calculations –> few % change in the shape of the scattering distribution results in a few % change in the "equilibrium emittance"

New experiment being conducted at TRIUMF to measure scattering of low energy muons.

No clear motivation at this time for an additional scattering measurement, but further simulations may uncover areas of sensitivity we are not yet aware of.

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Cooling Channel Instrumentation

The cooling channel will require instrumentation.

New topic ... need to specify requirements and understand instrumentation options.

Plan to have workshop in Fall to focus on the instrumentation requirements for the cooling channel, and formulate the R&D needed –> expect this to become a new sub–topic within MUCOOL.

MUCOOL Organization

Spokesperson: Steve Geer

Simulation coordinator: Jonathan Wurtele *)

RF coordinators: John Corlett, Norbert Holtkamp

LH_2 R&D coordinator: Dan Kaplan

Solenoid coordinator: To be decided **)

Instrumentation coordinator: To be decided ***)

*) Overall Muon Collaboration theory/simulation co–ordinator
**) Fate of HMFL proposal for support from NSF important input
***) New topic, needs initial workshop to clarify ideas first

Weekly working meetings
Bi–Annual MUCOOL collaboration meetings

Web page:
http://www.fnal.gov/projects/muon_collider/cool/cool.html

Technical note database (MUCOOL Notes ... now adopted as Muon Collab. Notes database) –> 70 cooling specific notes.

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Institutional Involvement

ANL: **Instrumentation, cooling theory**
BNL: **RF, cooling simulations, cooling test design**
FNAL: **RF, cooling simulations, LH2 absorber**
Illinois Institute of Technology: **Cooling simulations, LH2 absorber**
Indiana University: **Emittance exchange, cooling simulations & test design**
LBNL: **RF, cooling theory & simulations, solenoids**
NHMFL, Florida: **Solenoids**
Northern Illinois University: **LH2 absorber**
Northwestern University: **Instrumentation**
Princeton University: **Cooling test design, instrumentation**
University of California, Berkeley: **Cooling theory & simulations**
University of California, Los Angeles: **Cooling simulations, instrumentation**
University of Chicago: **Cooling theory, instrumentation**
University of Illinois, Urbana: **LH2 absorber, cooling simulations**
University of Mississippi: **RF, instrumentation**

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- Enthusiatic team in place with responsible persons designated for component development
- We have an aggressive cooling channel design simulation effort in place with engineering feedback for RF, solenoids, absorbers, & integration.
- RF
  We have set up infrastructure in Lab G for high power tests
  5T solenoid constructed & tested for Lab G
  Will have an open cell cavity for high power tests soon
  We have made exploratory designs for 200 Mhz cavities
  Ready to pursue 200 Mhz cavity development
- Absorbers
  We have two designs for LH2 absorbers
  Illinois Universities consortium set up –> expected state support
  Plan to construct & test prototypes
- We are studying the best way to do a beam test of the hardware

MUCOOL Summary

- Progress on channel design, RF, instrumentation, LH_2 designs, ...
- Late –> Early cooling channel was a big change for MUCOOL, but we have developed a technologically driven plan for component development –> 3 years (but this will take a significant increase in resources, particularly for the 200 Mhz RF development).
- In particular we would like support:
  - To complete the 805 Mhz cavity R&D in FY01
  - For a continued strong cooling channel simulation effort with engineering design support for cavities (FNAL) , solenoids (NHMFL), and channel integration (FNAL).
  - To prepare and operate a LH_2 assembly/test area at FNAL
  - To begin high gradient 200 Mhz cavity development & prepare for 200 Mhz high–power tests in 2 years } Hoping for FY01 support from FNAL but this seems hard

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Technologically limited plan versus reality

- Technologically driven plan –> 3 years to develop components
- Requires significant increase in support starting in FY01 (factor of ~2.3) –> see Mike Zisman talk
- We had hoped for a corresponding increase in support from Fermilab to enable 200 Mhz RF, LH2 absorber, and solenoids development to proceed rapidly.
- Recent guidelines from Fermilab management –> flat funding –>
  - Complete 805 Mhz R&D
  - Support LH2 absorber development
  - Support strong simulation group (adequate engineering support for this is also needed)
- Support for the 200 Mhz RF development and the solenoids is a concern at this point