THE MOLLER PROJECT AT JEFFERSON LABORATORY

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A GLOBAL STRATEGY

Direct and Indirect Searches for Physics Beyond the Standard Model

Compelling arguments for "New Dynamics" at the TeV Scale

A comprehensive search for clues requires:

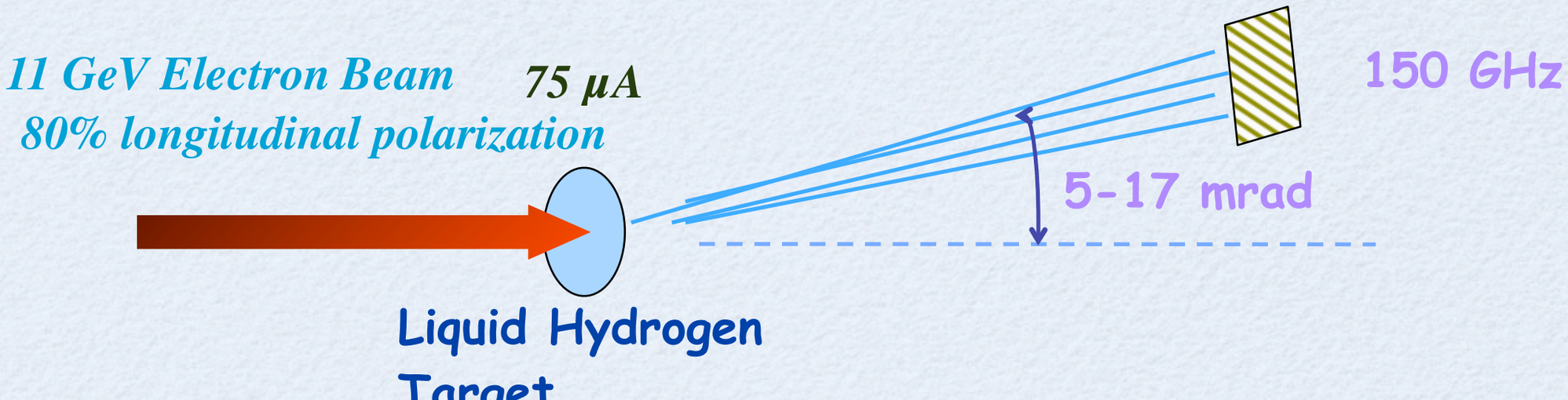
Large Hadron Collider *as well as* **Lower Energy: $Q^2 << M_Z^2$**

***Nuclear/Atomic* systems address several topics; complement the LHC:**

- ***Neutrino Masses and Mixing***
  - *$0\nu\beta\beta$ decay, reactor θ_{13}, long baseline experiments*
- ***Rare or Forbidden Processes***
  - *EDMs, other CP & T-Violation, Charged Lepton Flavor Violation*
- ***Dark Matter Searches***
- ***Precision Electroweak Measurements***
  - *weak neutral currents at low energy, muon g-2, weak decays*

MOLLER AT JLAB

Measurement of Lepton-Lepton Electroweak Reaction



$$A_{PV} = \frac{\sigma_{\uparrow} - \sigma_{\downarrow}}{\sigma_{\uparrow} + \sigma_{\downarrow}} = -A_{LR}$$

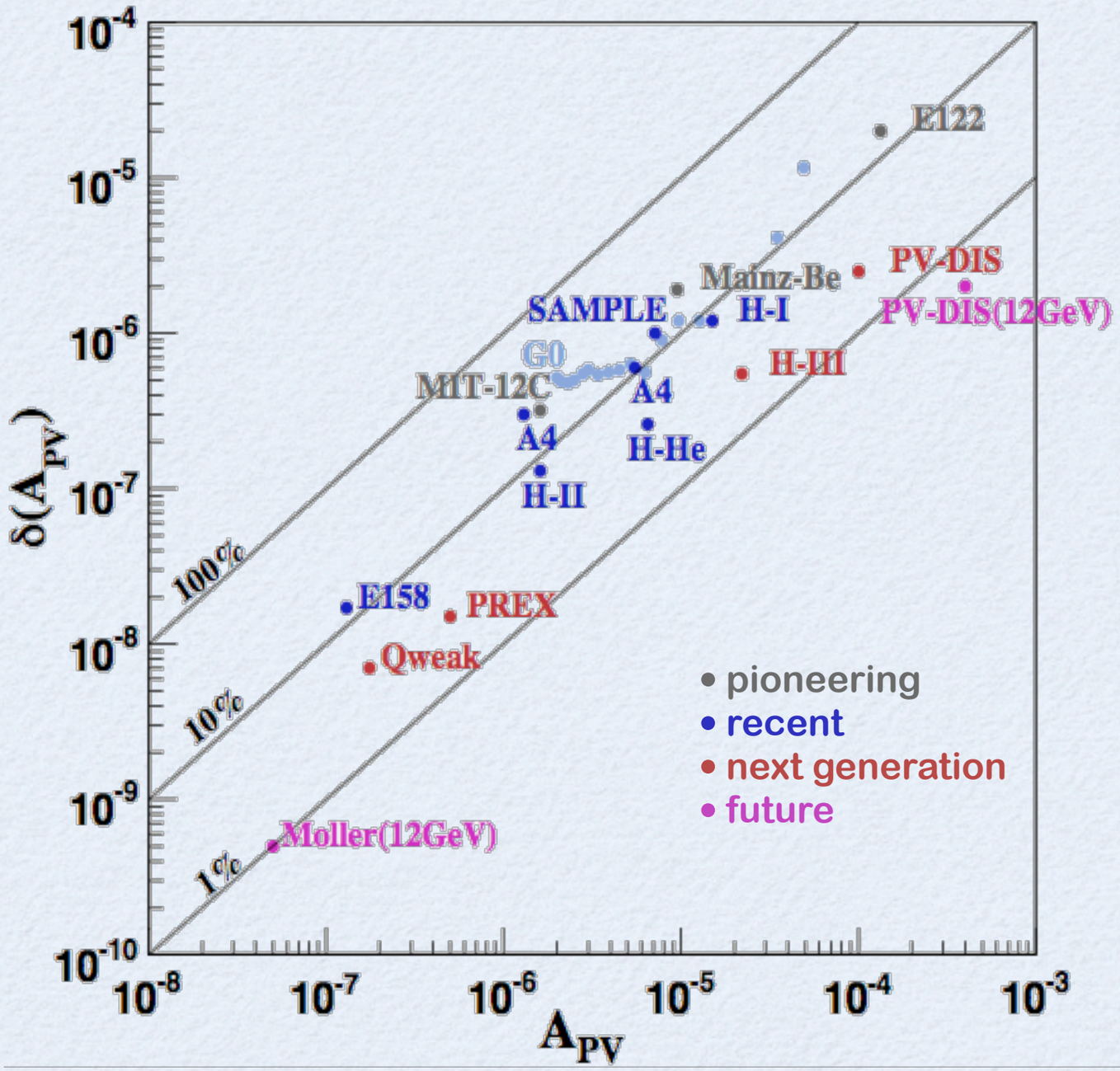
A_{PV} = 35.6 ppb → *38 weeks* → $\delta(A_{PV})$ = 0.73 ppb

Compositeness length scale probed: 4×10^{-21} m

Equivalent to the reach of a several TeV electron linear collider

PROGRESS OVER 3 DECADES

Parity-violating electron scattering has become a precision tool

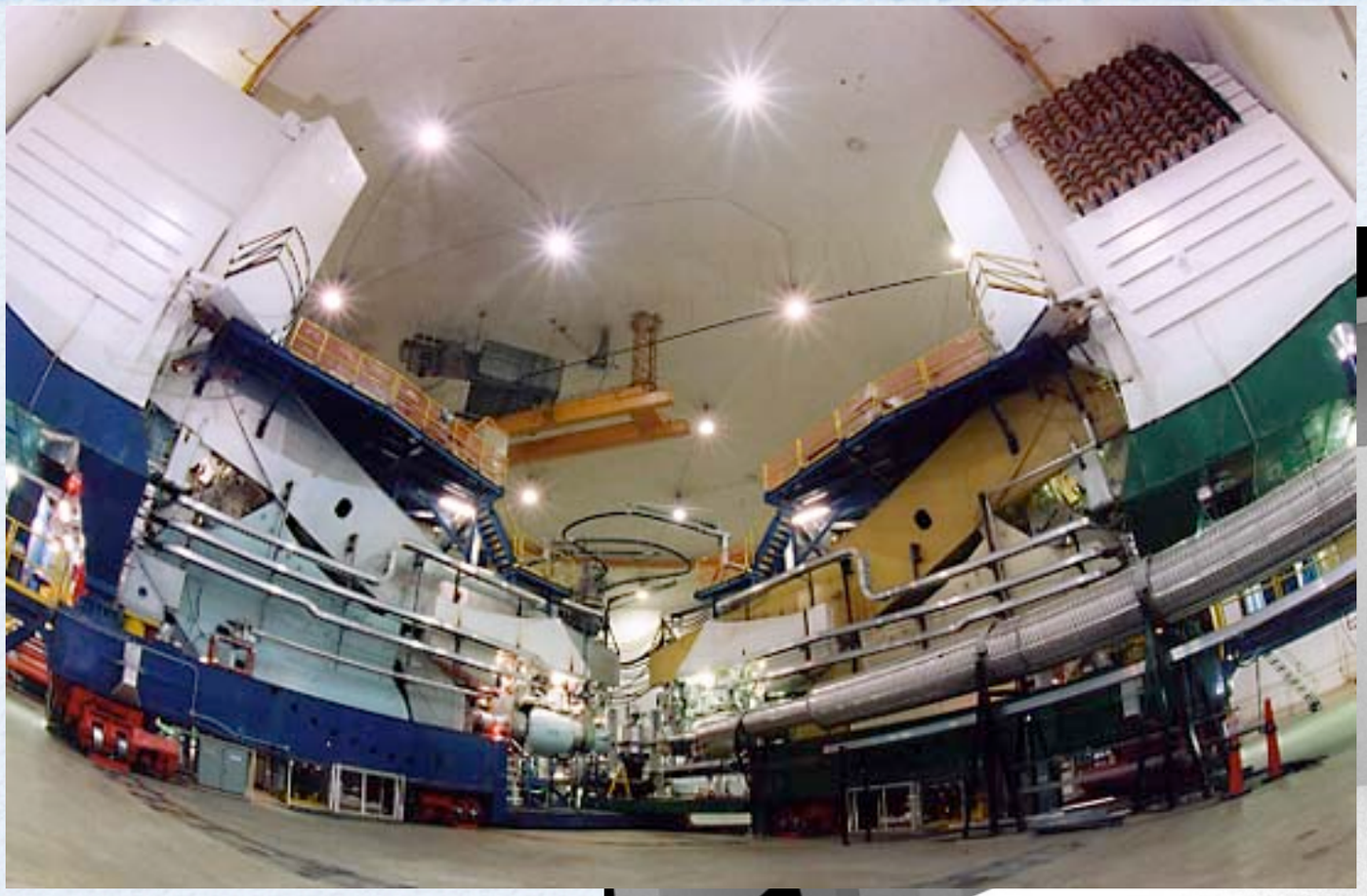


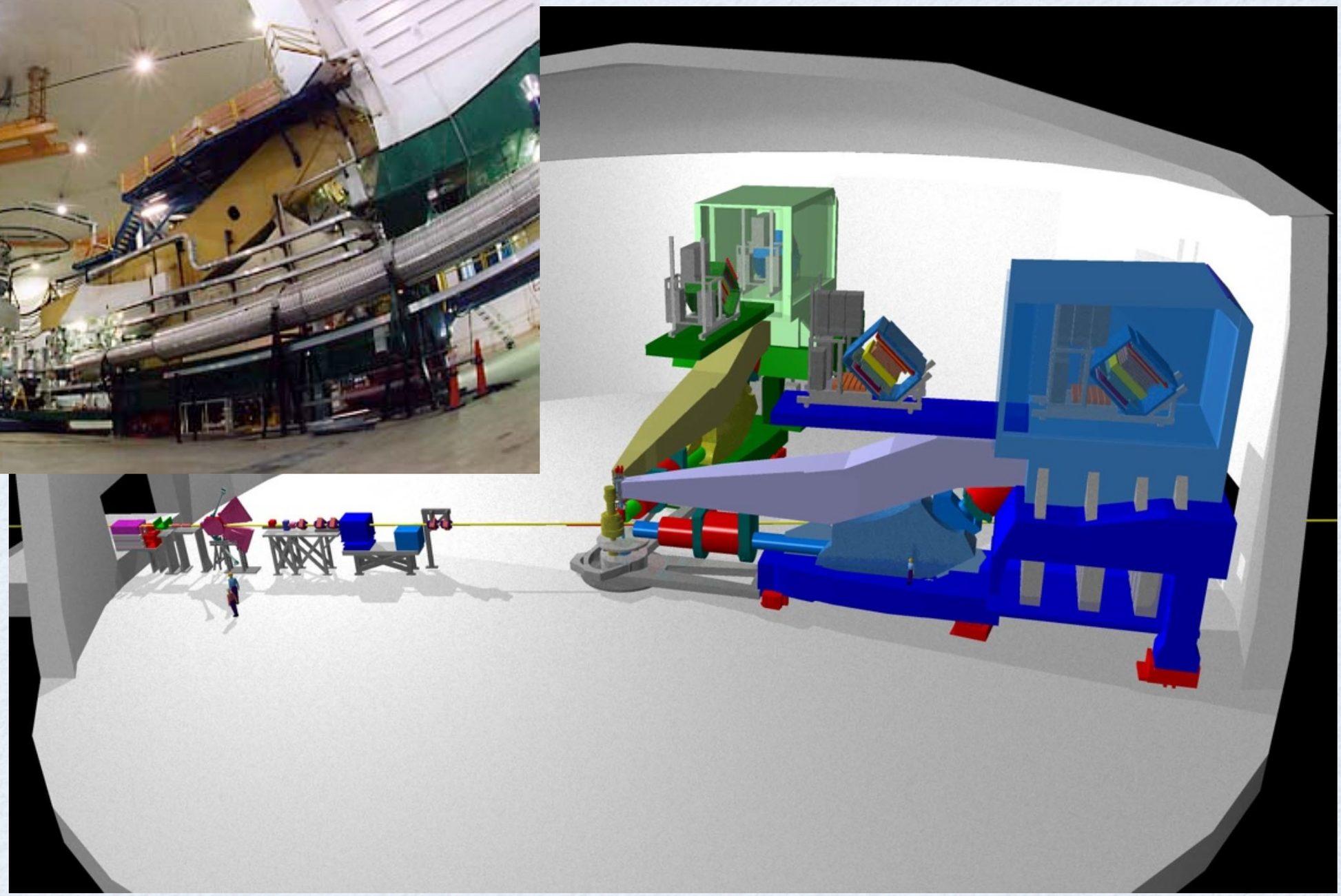
Steady progress in technology towards:

- ***part per billion systematic control***
- ***1% systematic control***
- ***Major developments in***
  - ***photocathodes (I & P)***
  - ***polarimetry***
  - ***high power cryotargets***
  - ***nanometer beam stability***
  - ***precision beam diagnostics***
  - ***low noise electronics***
  - ***radiation hard detectors***

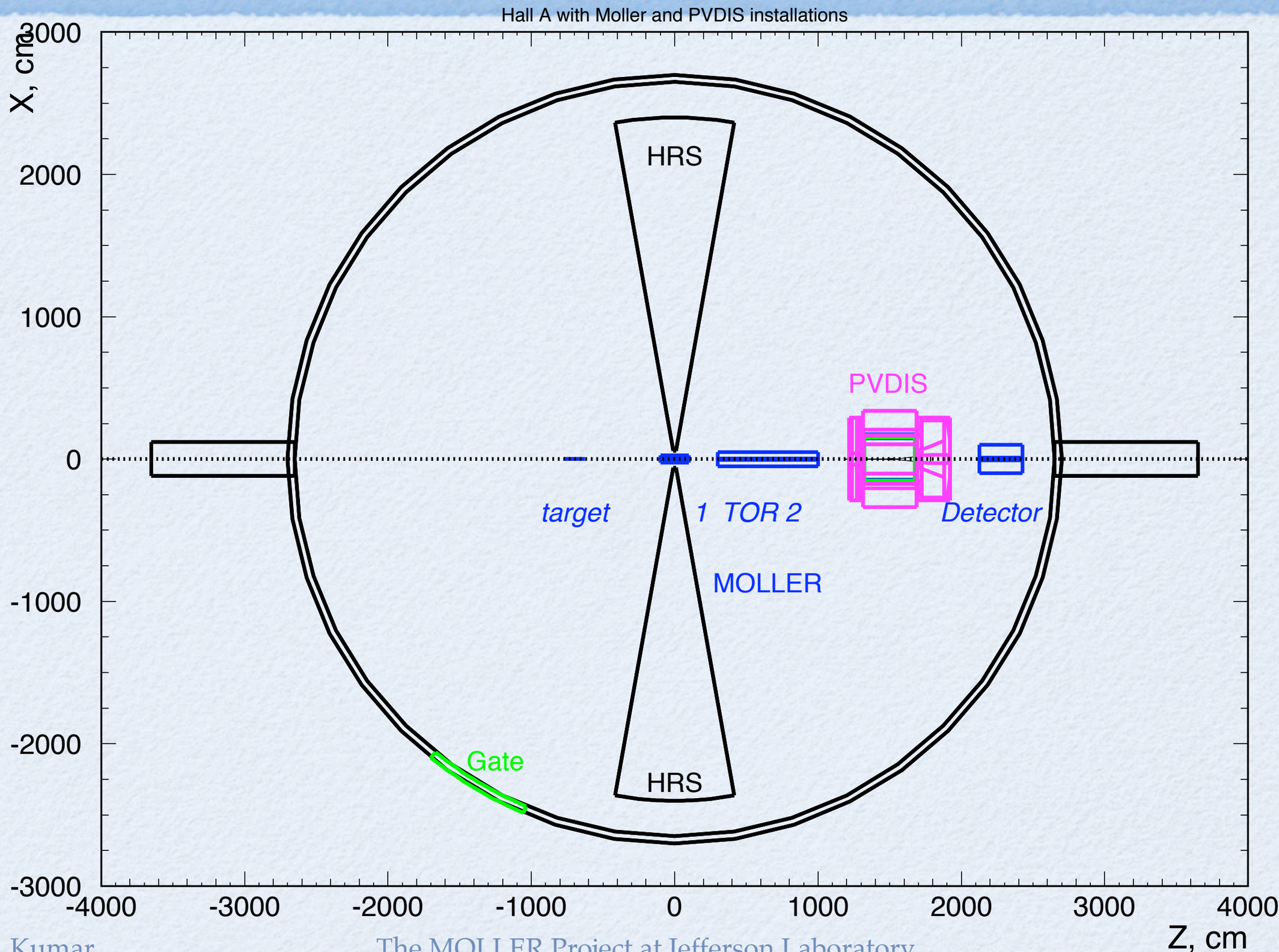
EXPERIMENTAL LAYOUT

HALL A AT JLAB

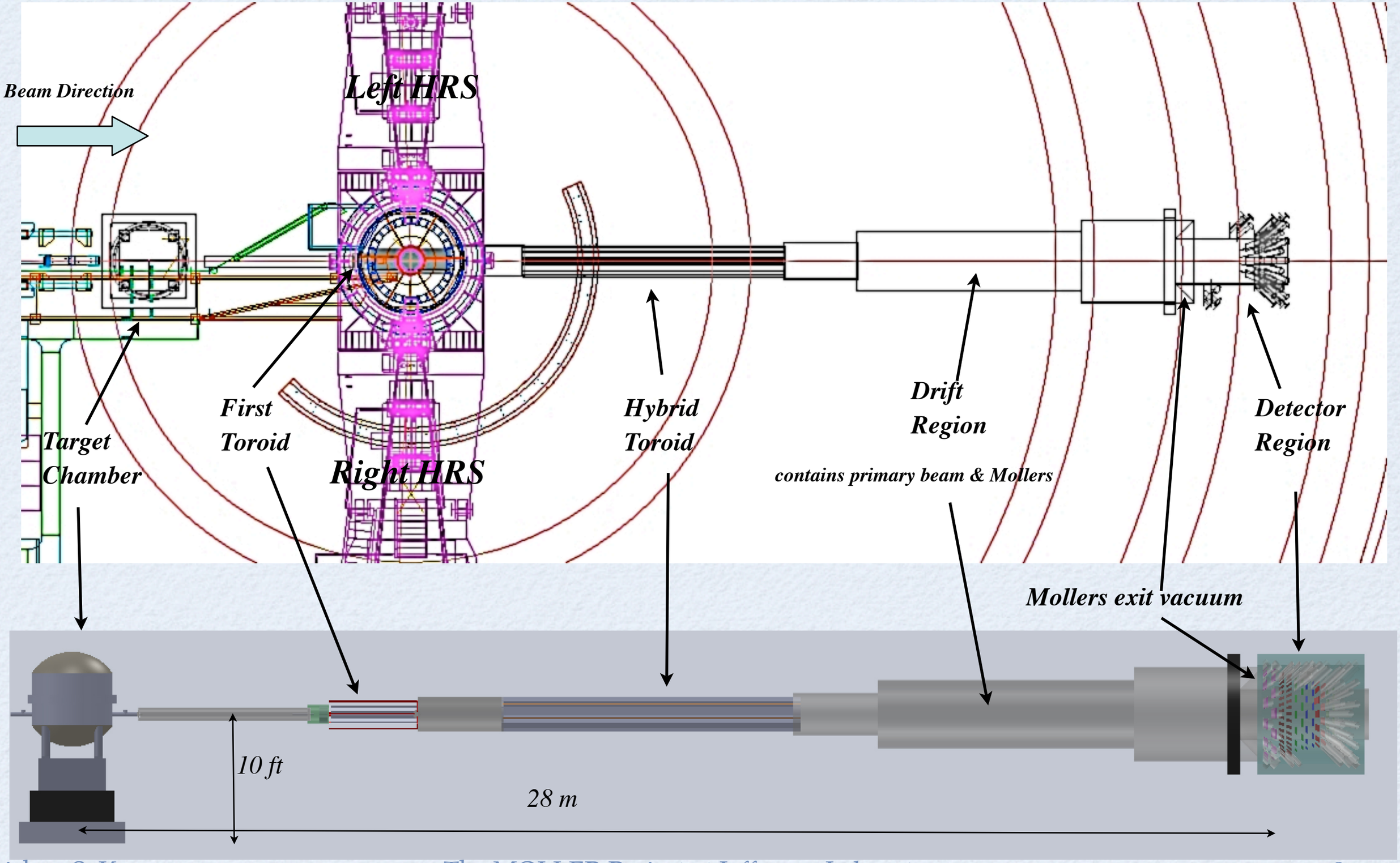




FOOTPRINT IN HALL A



MOLLER HALL LAYOUT

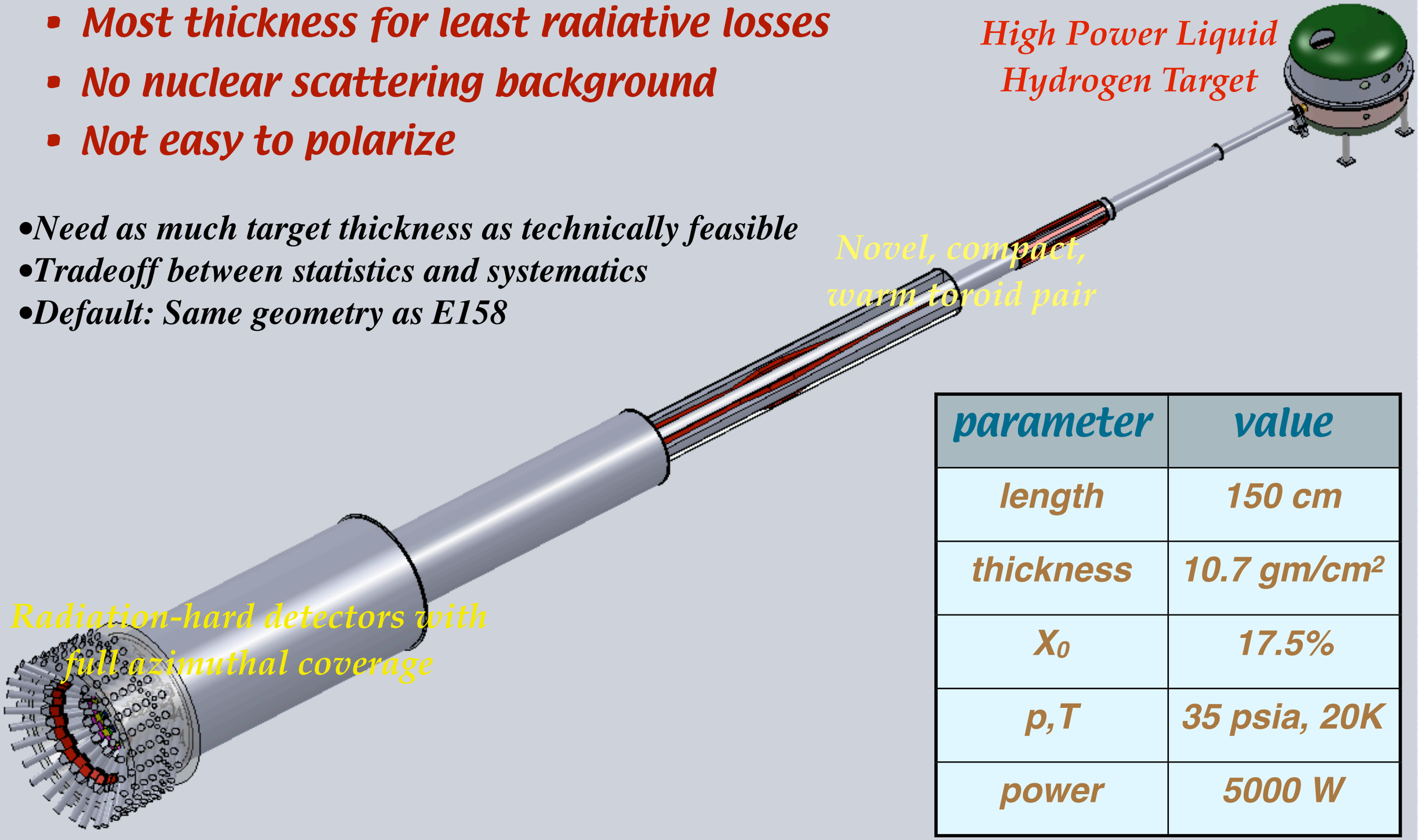


MOLLER APPARATUS

Target, spectrometer, detectors

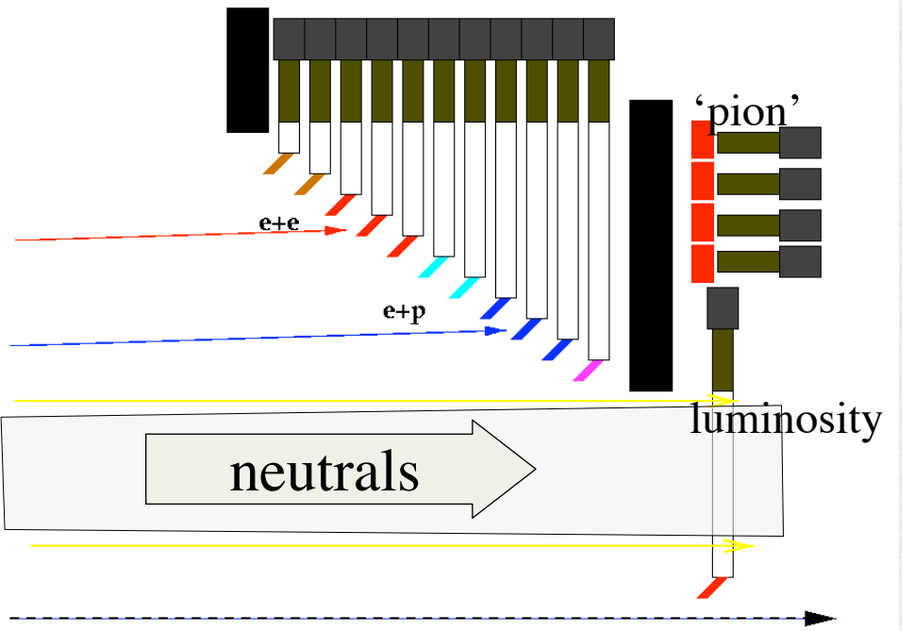
- ***Most thickness for least radiative losses***
- ***No nuclear scattering background***
- ***Not easy to polarize***

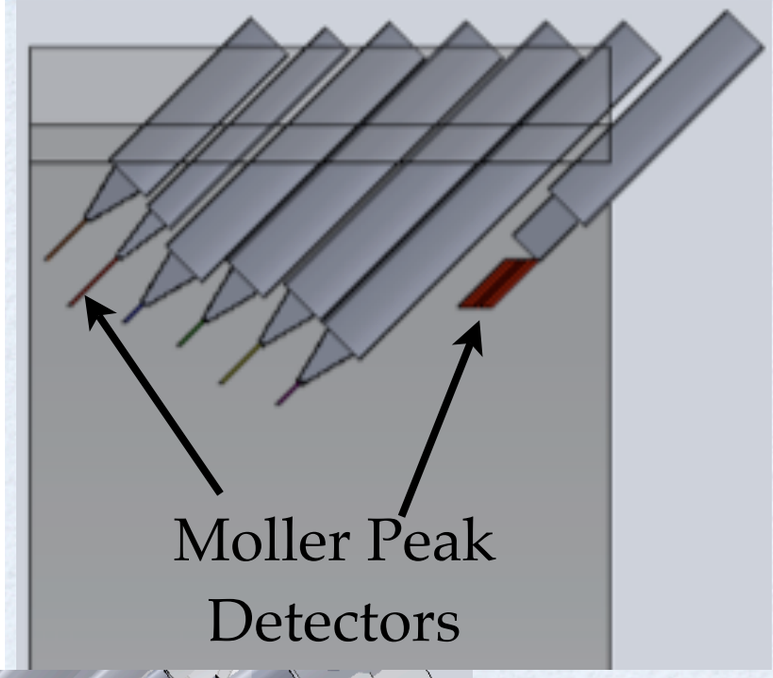
- ***Need as much target thickness as technically feasible***
- ***Tradeoff between statistics and systematics***
- ***Default: Same geometry as E158***



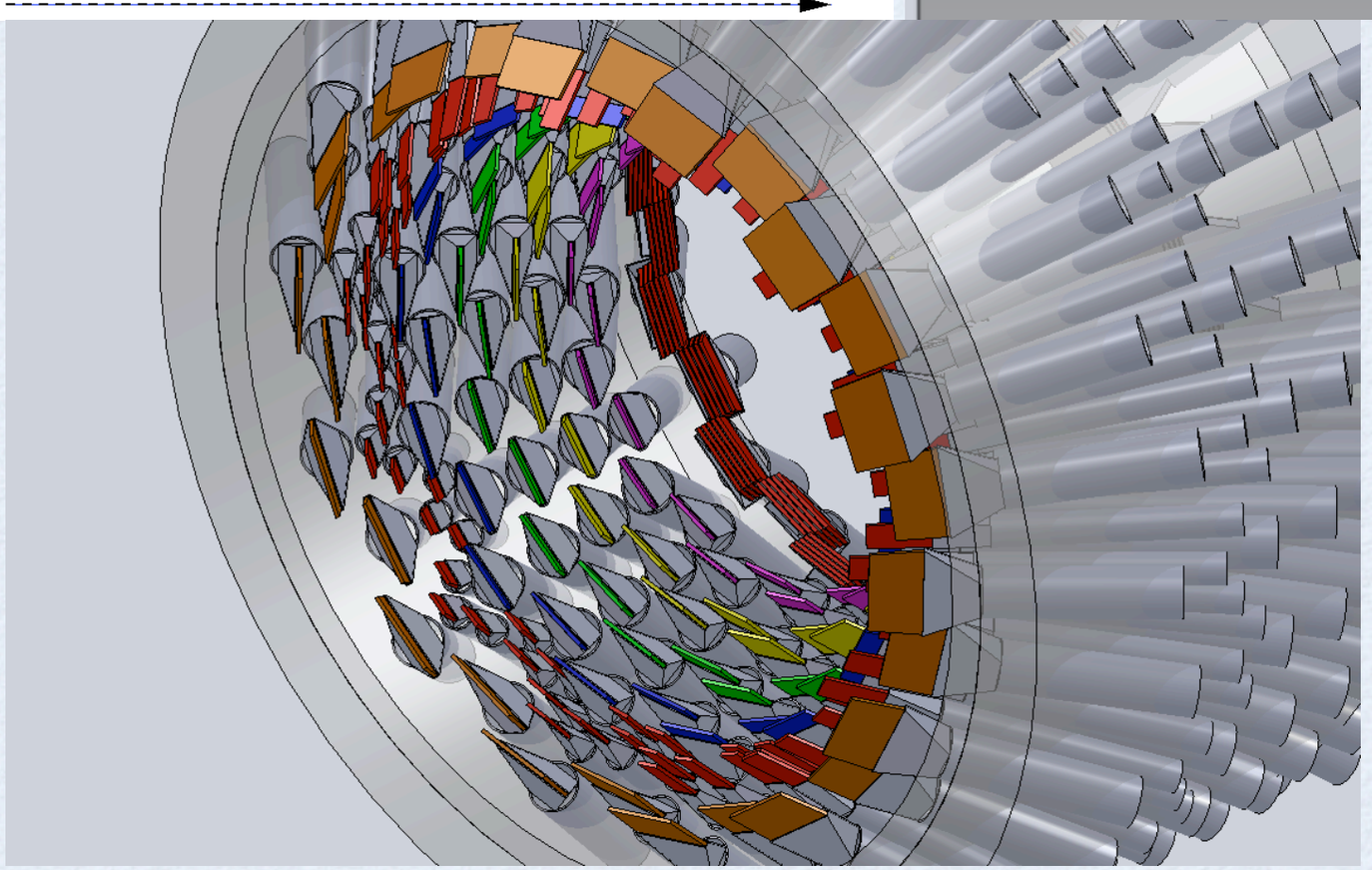
parameter	value
length	150 cm
thickness	10.7 gm/cm²
X_0	17.5%
p,T	35 psia, 20K
power	5000 W

DETECTOR SYSTEMS





- ***Other Detectors***
  - **Tracking detectors**
    - *3 planes of GEMs/Straws*
    - *Critical for systematics/ calibration/debugging*
  - **Integrating Scanners**
    - *quick checks on stability*



- ***Integrating Detectors:***
  - **Moller and e-p Electrons:**
    - *radial and azimuthal segmentation*
    - *quartz with air lightguides & PMTs*
  - **pions and muons:**
    - *quartz sandwich behind shielding*
  - **luminosity monitors**
    - *beam & target density fluctuations*

TECHNICAL CHALLENGES

- ***~ 150 GHz scattered electron rate***
  - Design to flip Pockels cell ~ 2 kHz
  - 80 ppm pulse-to-pulse statistical fluctuations
    - *Electronic noise and density fluctuations < 10^{-5}*
    - *Pulse-to-pulse beam jitter ~ 10s of microns at 1 kHz*
    - *Pulse-to-pulse beam monitoring resolution ~ 10 ppm and few microns at 1 kHz*
- ***1 nm control of beam centroid on target***
  - Modest improvement on control of polarized source laser transport elements
  - Improved methods of "slow helicity reversal"
- ***> 10 gm/cm^2 target needed to achieve desired luminosity***
  - 1.5 meter Liquid Hydrogen target: ~ 5 kW @ 85 μA
- ***Full Azimuthal acceptance with θ_{lab} ~ 5 mrad***
  - novel two-toroid spectrometer
  - radiation hard, highly segmented integrating detectors
- ***Robust and Redundant 0.4% beam polarimetry***
  - Plan to pursue both Compton and Atomic Hydrogen techniques

STATUS AND PLANS

- Project received PAC approval: Jan '09
- Director's review of physics goals and concept: Jan '10
- Aim to develop project funding (US + foreign): 2011-12
- Aim to install at JLab after 12 GeV upgrade: late 2015

Director's review report was strongly supportive

A key recommendation was to seek engineering input for the spectrometer "sooner" rather than "later"

Challenge: Develop concept enough to take advantage of pre-project funding, if available

MOLLER SPECTROMETER

- ***The spectrometer magnets are the heart of the apparatus***
- ***Total project cost is in the ~15M$ range***
- ***Spectrometer will be ~20-25% of this cost (we think)***
- ***Dominated by engineering & design manpower***
- ***Fundamental changes in design affect everything else***
- ***Magnet Advisory Group:***
  - *George Clark (TRIUMF), Ernie Ihloff (MIT-Bates), Vladimir Kashikhin (Fermilab), Jim Kelsey (MIT-Bates), Dieter Walz (SLAC), Robin Wines (JLab)*
- ***We need to optimize optics; but we don't want to proceed too deeply into the design without getting feedback on feasibility/buildability***