Measurement of the proton's weak charge at the Qweak experiment

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MIT
(for the Qweak collaboration)

DPF meeting
August 12th, 2011

Massachusetts Institute of Technology

Jefferson Lab
Thomas Jefferson National Accelerator Facility

DOE, NSF, NSERC

A SEARCH FOR NEW PHYSICS
Qweak

Overview

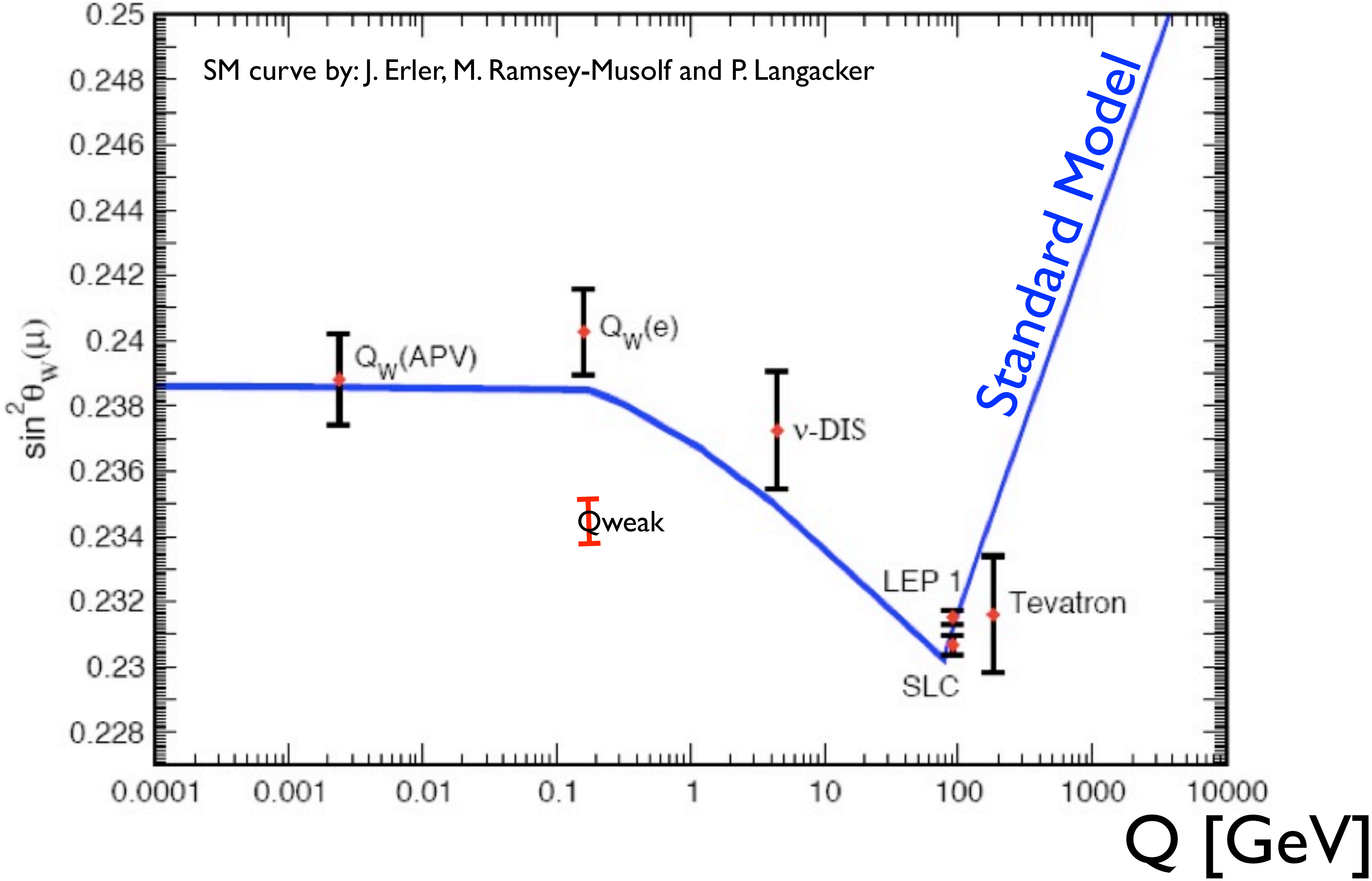
- Qweak the value
- Qweak the experiment
- Run 1 winter 2011
- Perspective for Run II 2011-2012

Qweak, the value

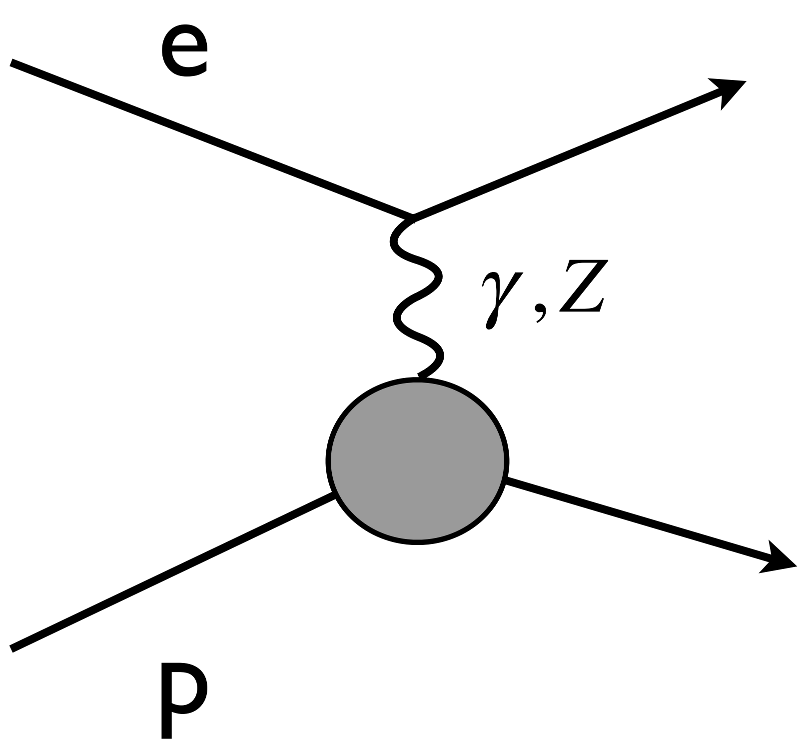
	Q^{γ}	Q^{Z}
u	+2/3	$1-\frac{8}{3}\sin^2\theta_w$
d	-1/3	$-1+\frac{4}{3}\sin^2\theta_w$
p(uud)	+1	$1-4\sin^2\theta_w$
n(udd)	0	-1

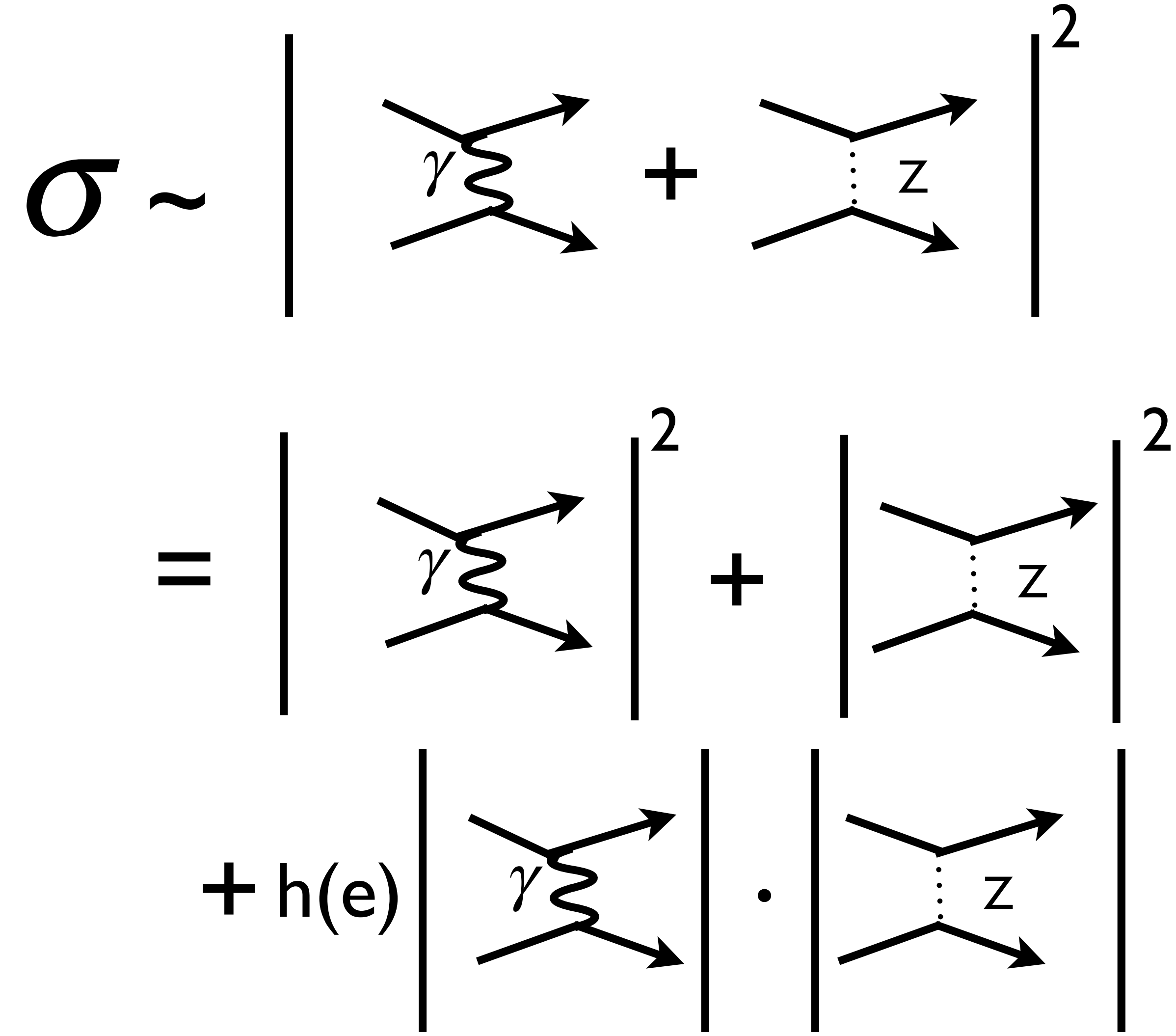
Qweak ~0.074 (at tree level)
Smallness increases sensitivity to BSM physics

Running of $\sin^2\theta_w$



Accessing Qweak through PVES





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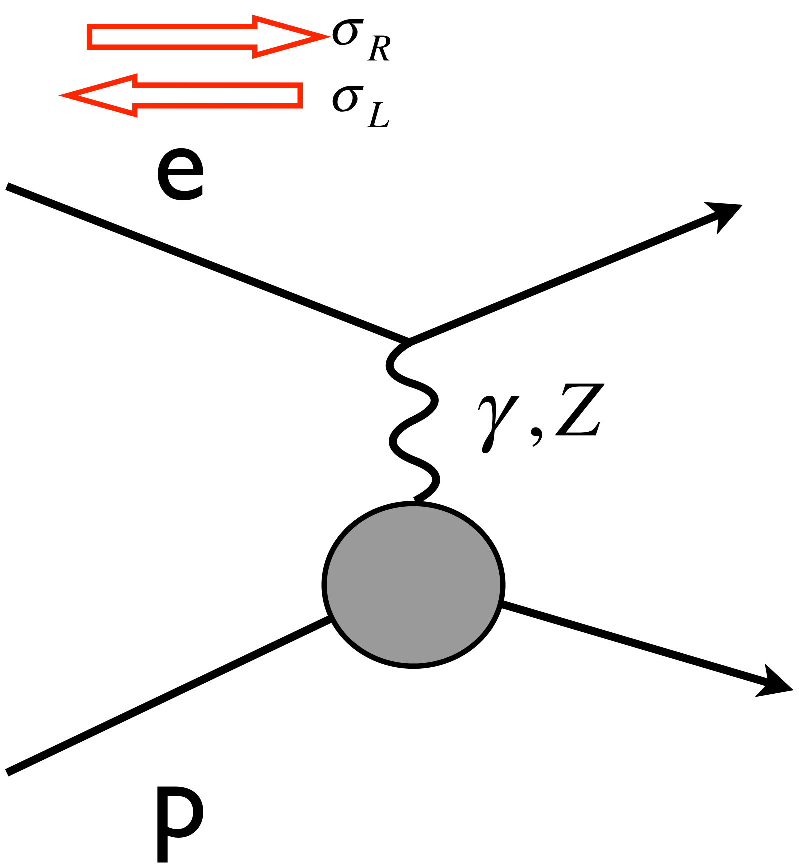
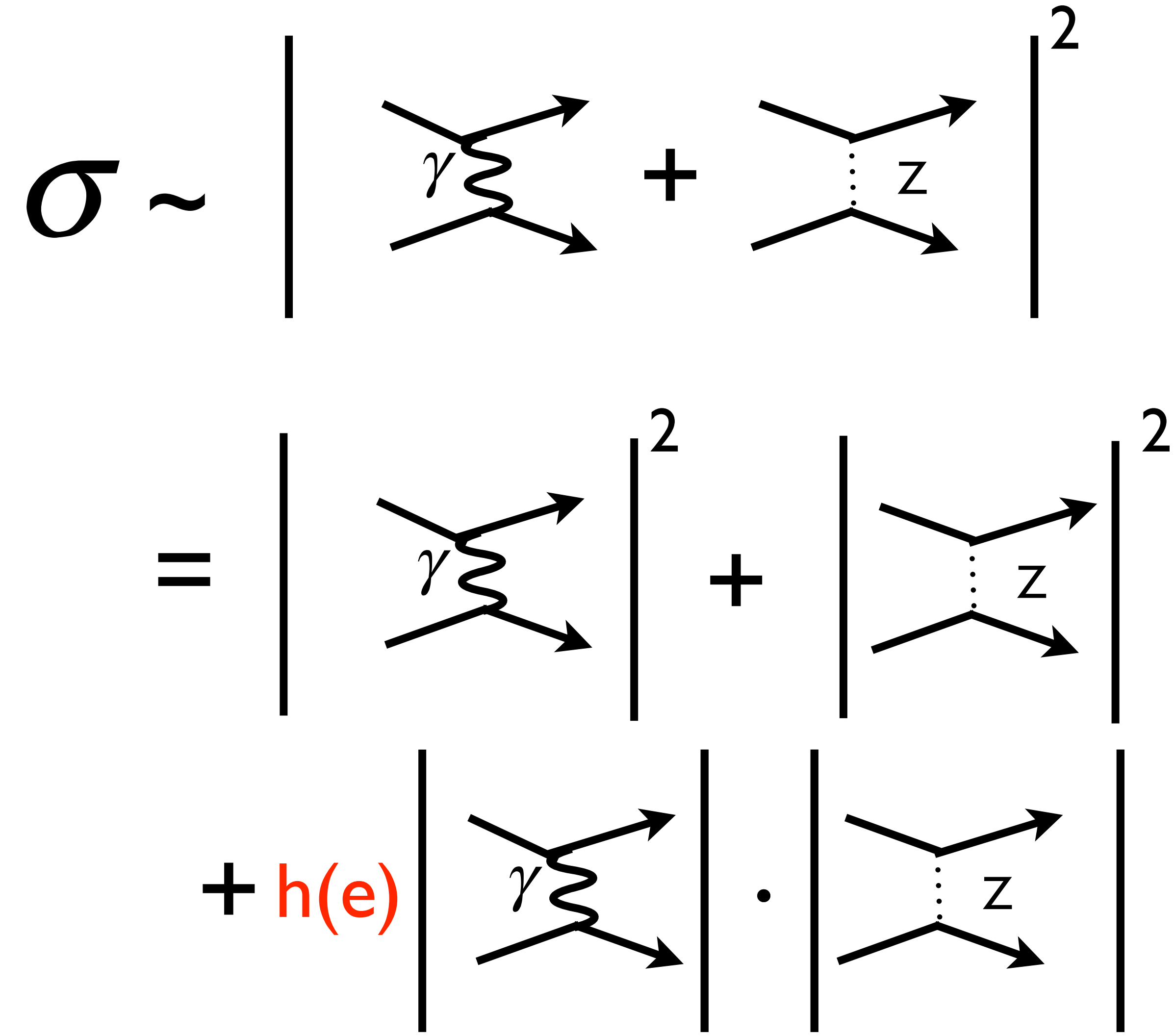
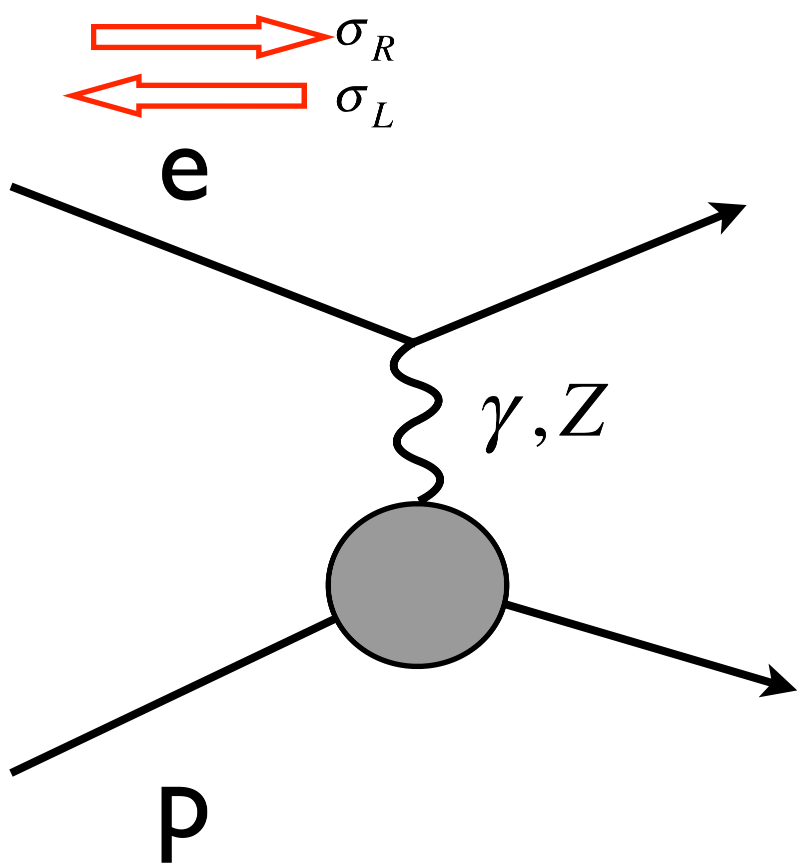
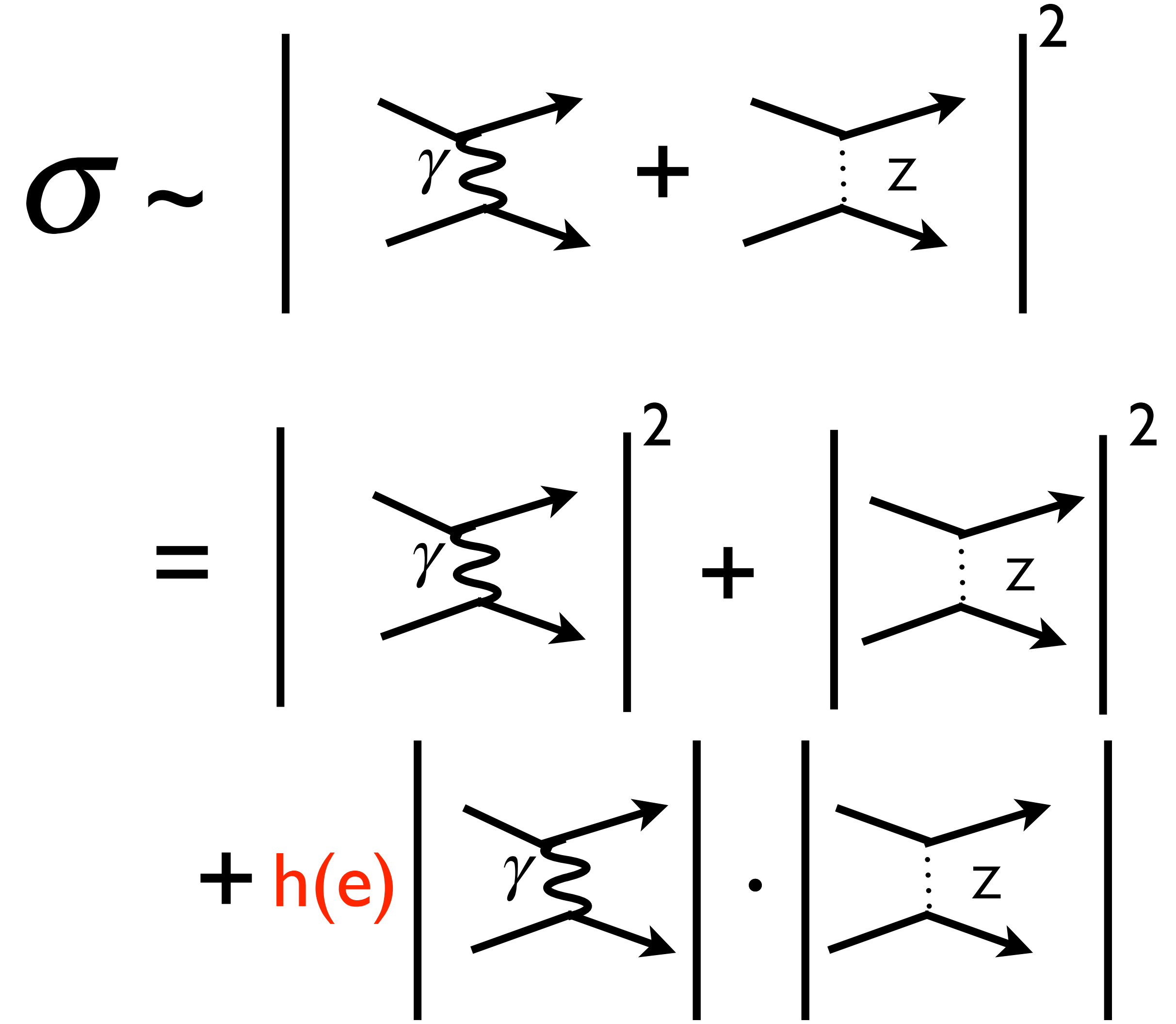
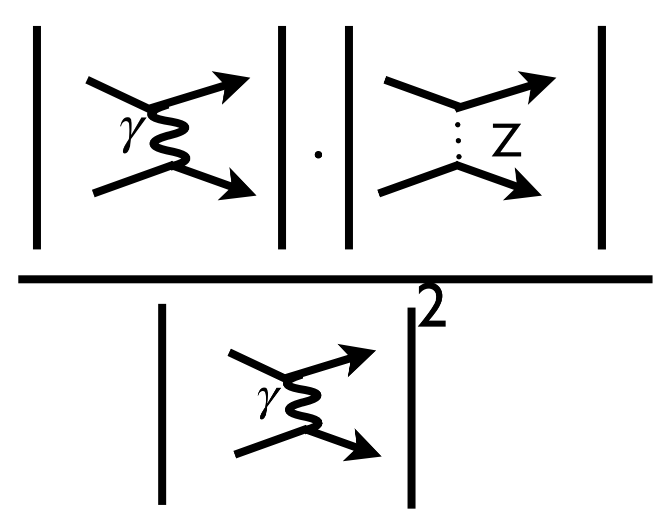




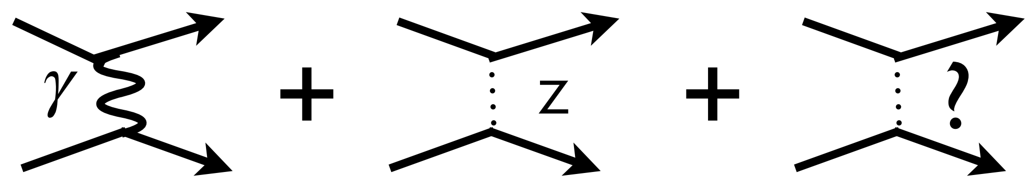
Accessing Qweak through PVES





$A = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L} \sim$  ~ -0.23ppm

Physics beyond the standard model



Examples

- Extra neutral gauge bosons (e.g. SUSY)
- Leptoquarks
- Composite fermions
- etc.

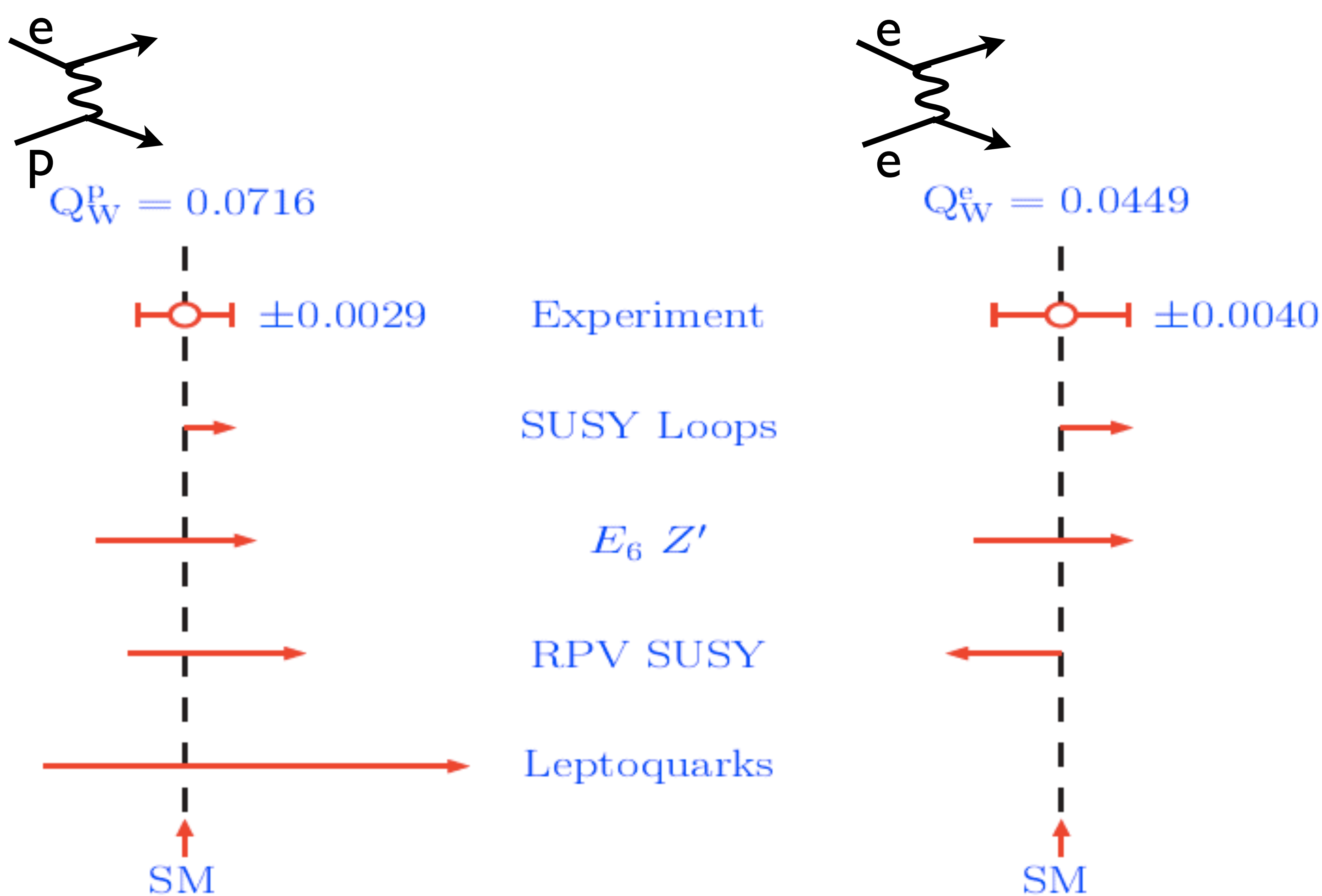
Model independent

$$\frac{\Lambda}{g} = \frac{1}{\sqrt{\sqrt{2}G_F}} \cdot \frac{1}{\sqrt{\Delta Q_w(p)}}$$

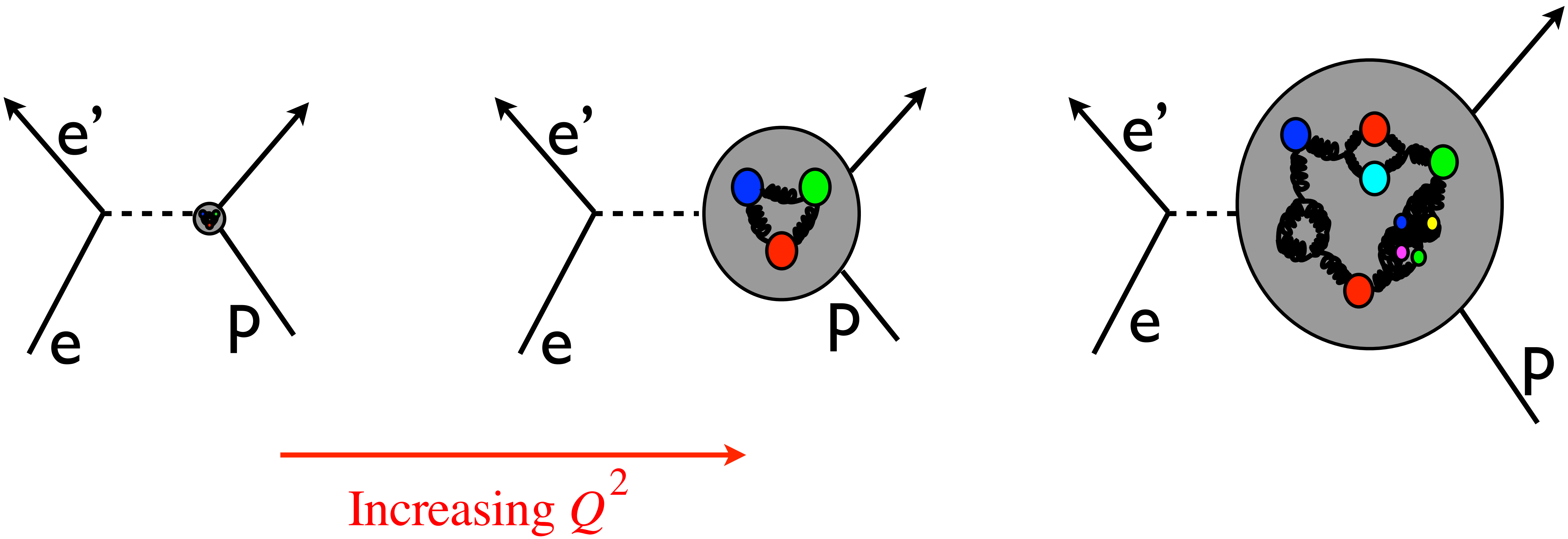
4% measurement of Qweak probes 2-3 TeV scale

Physics beyond the standard model

Complementarity of p and e weak charge experiments



The proton’s structure



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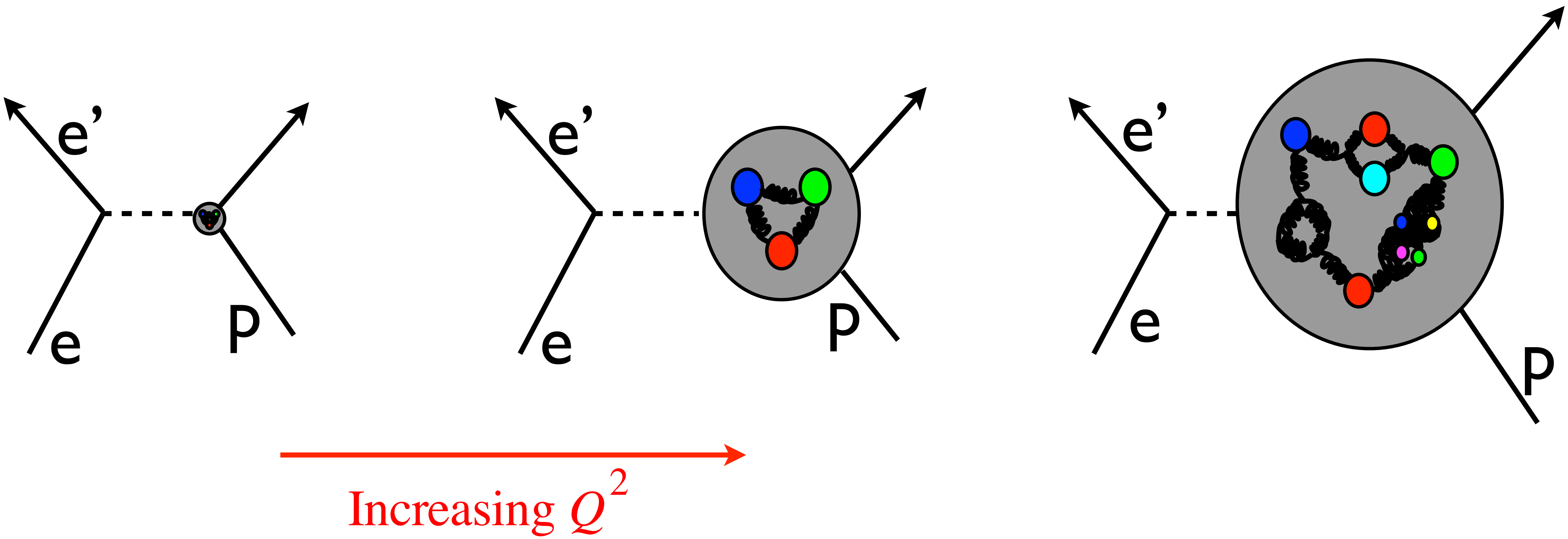
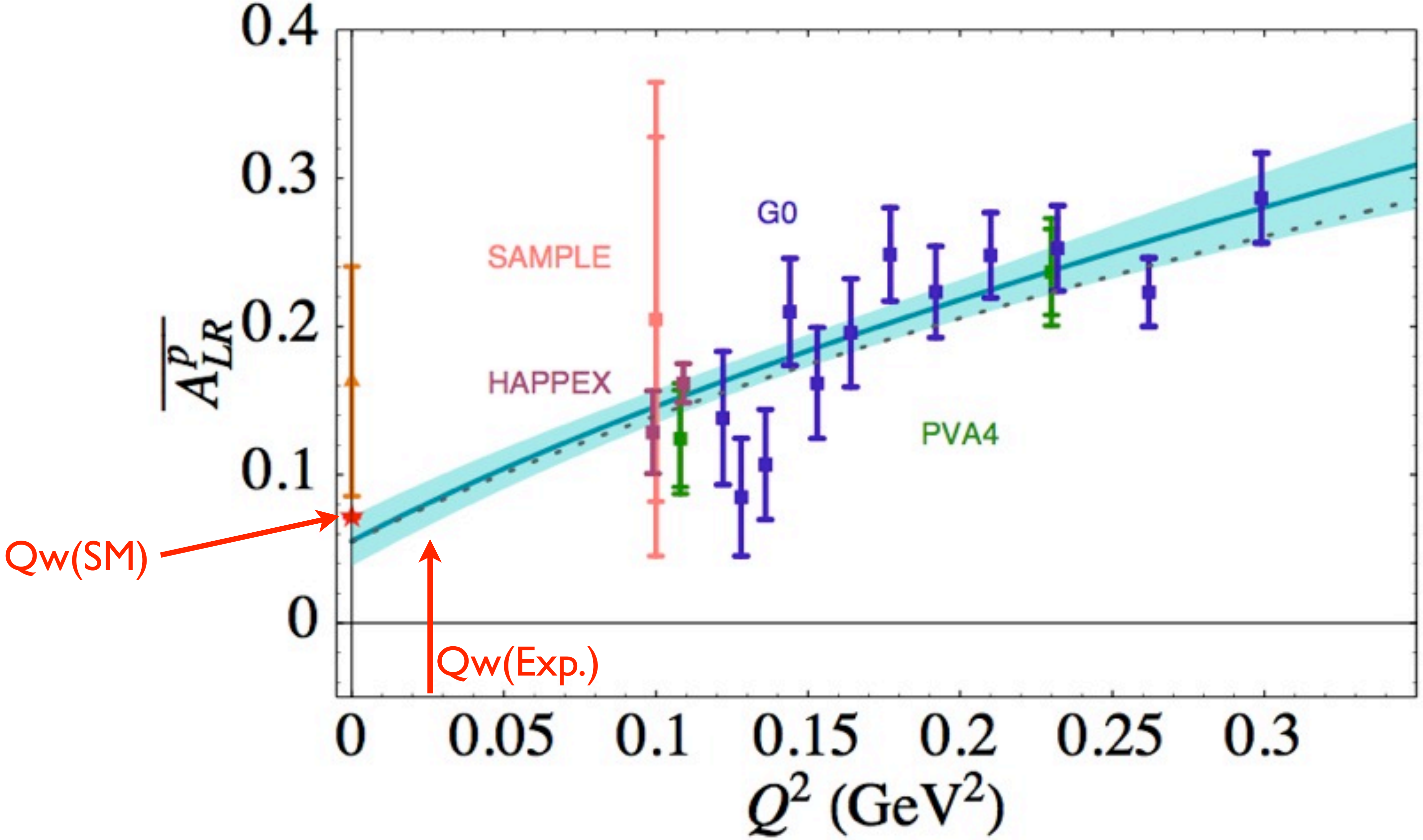


$$A = A_0\left[Q^p_{weak}Q^2 + B(Q^2)Q^4\right]$$

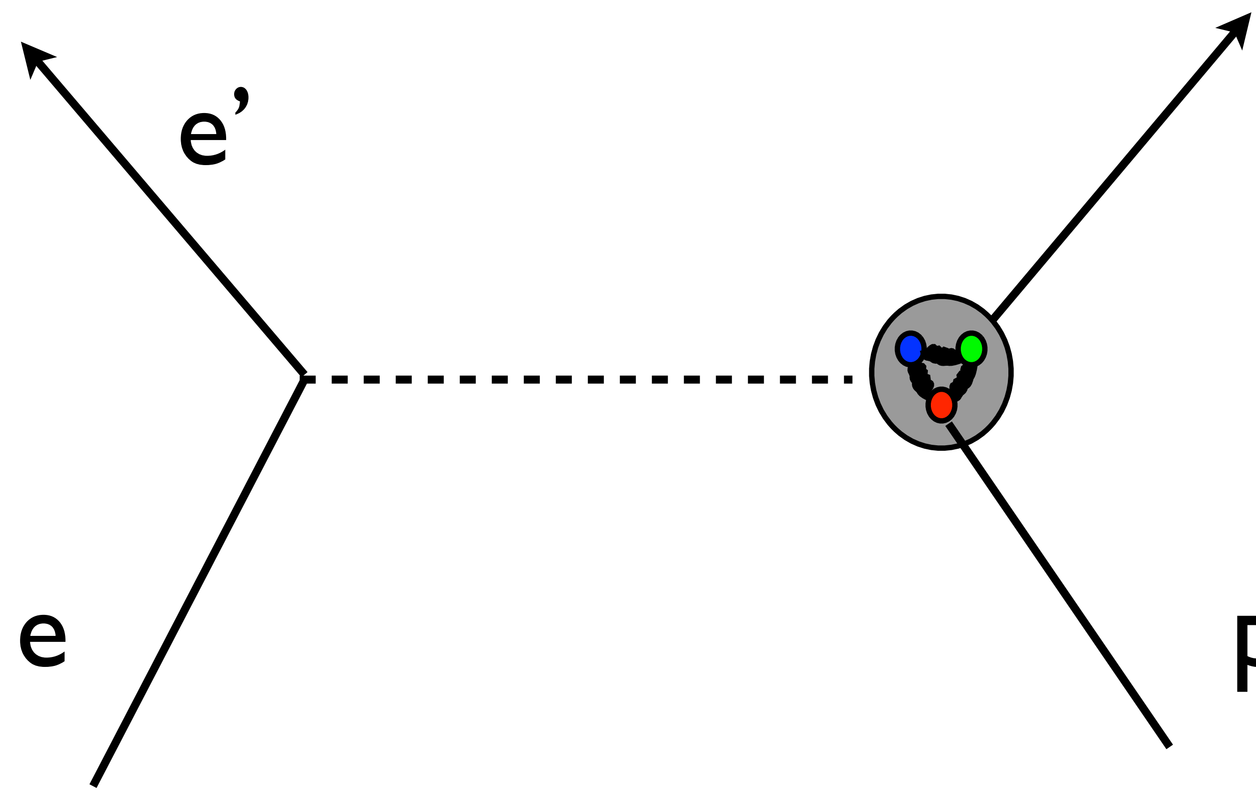
the smaller the Q2, the less we are affected by hadronic structure.

Using previous PVES to extrapolate $Q^2 \to 0$



A precise measurement at low Q2, combined with previous PVES, leads to a precise determination of Qweak.

Qweak the experiment

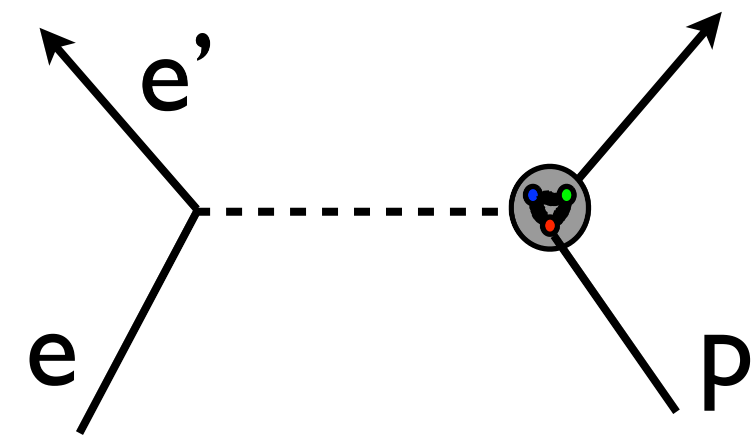


Error budget

Source of error	Contribution to $\Delta A_{phys}/A_{phys}$	Contribution to $\Delta Q^p_w / Q^p_W$
Counting Statistics (106 days)	2.1%	3.2%
Hadronic structure	—	1.9%
Beam polarimetry	1.0%	1.5%
Absolute Q^2	0.5%	1.0%
Backgrounds	0.5%	0.7%
Helicity-correlated beam properties	0.5%	0.7%
TOTAL:	2.5%	4.1%

Qweak the experiment

- Electron beam
- Target
- Detector system



Qweak the experiment

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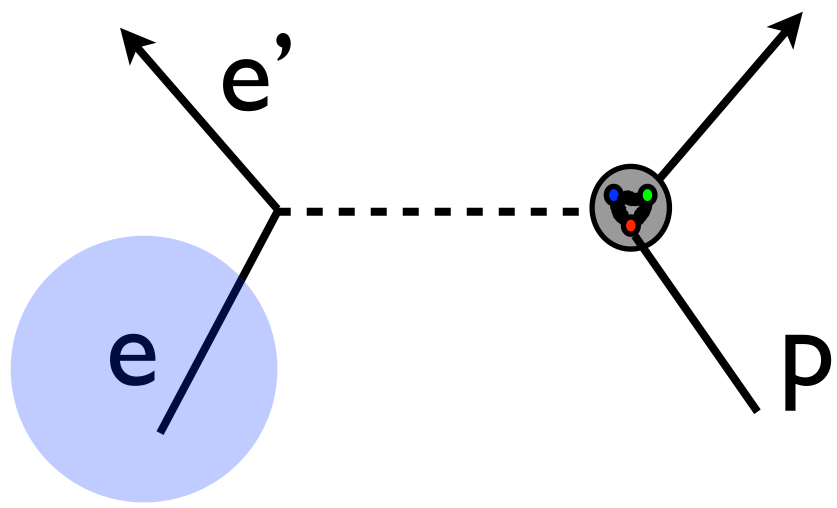
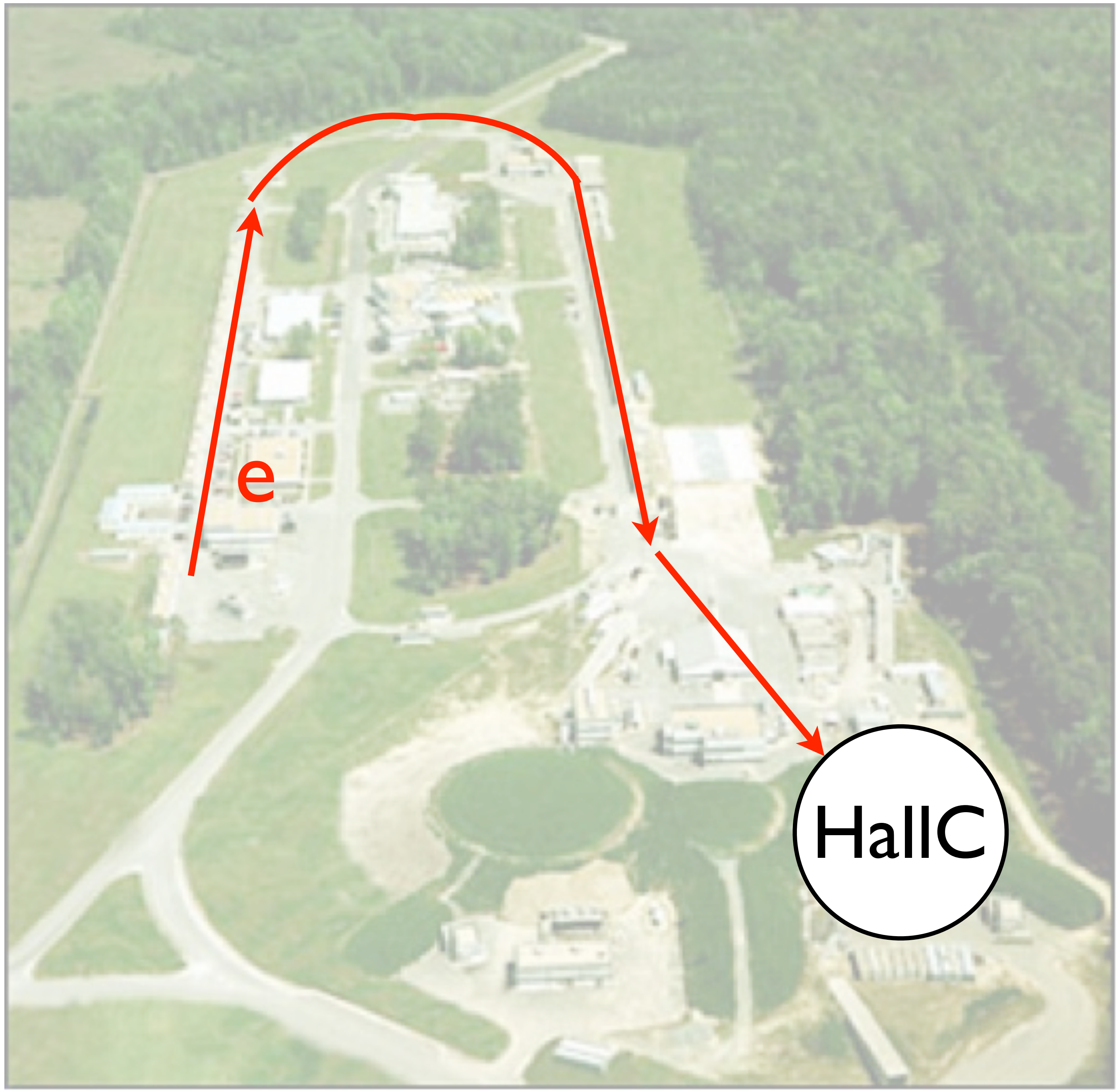


Electron beam: JLab

Electron beam: JLab



Spin flip
@ 960Hz

E=1.165GeV
Current:180uA
Polarization ~85%

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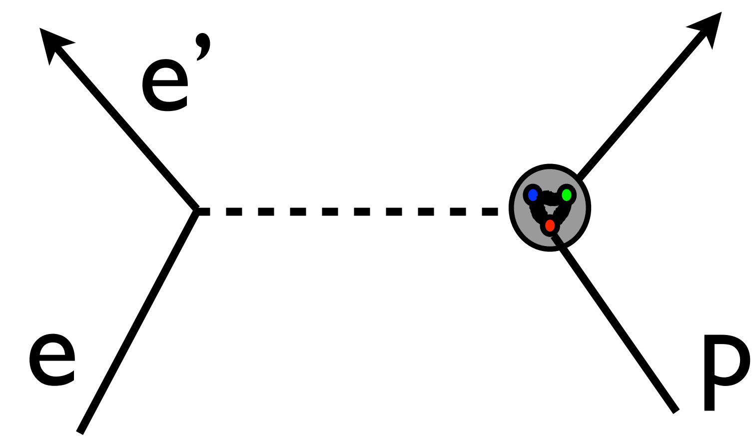

Qweak the experiment

- Electron beam
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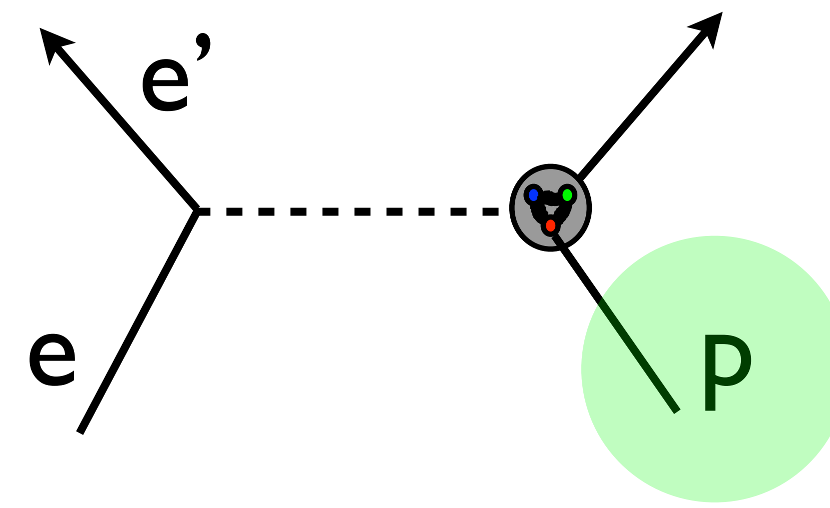
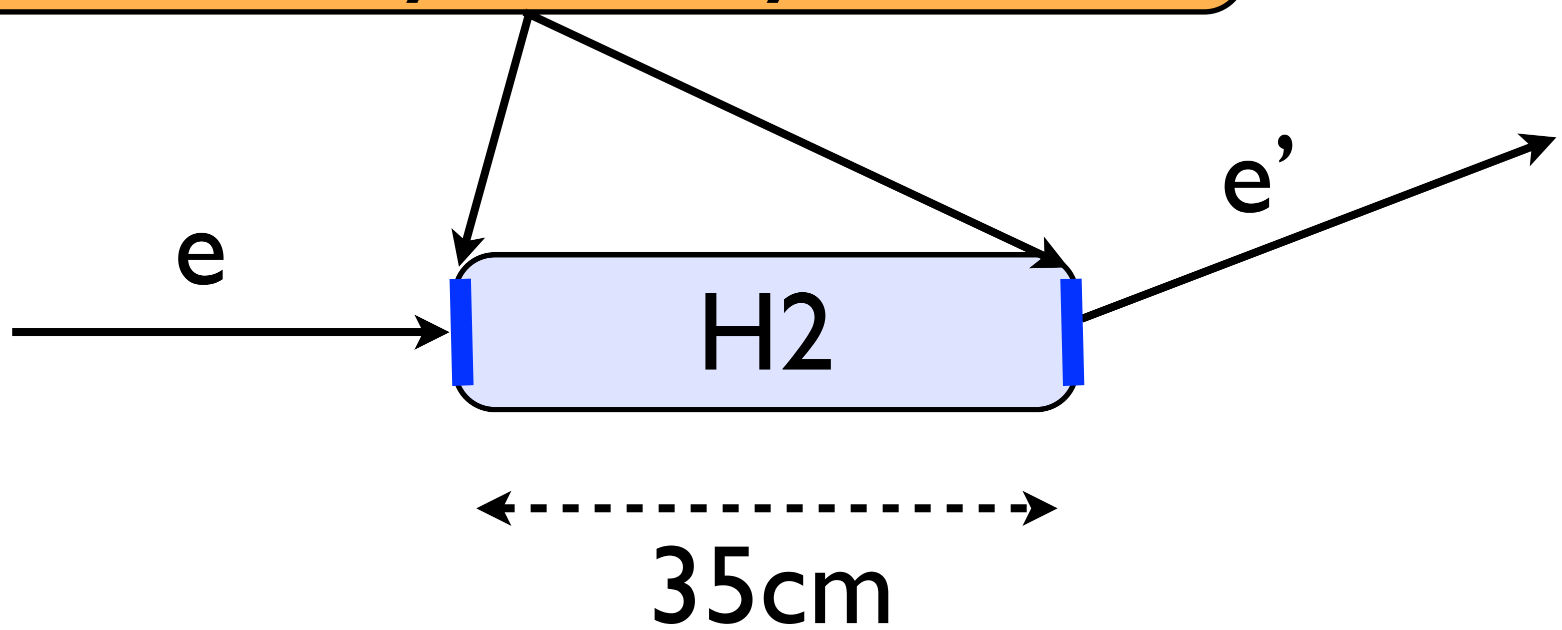


Target

Al windows, need to be accounted for in the asymmetry

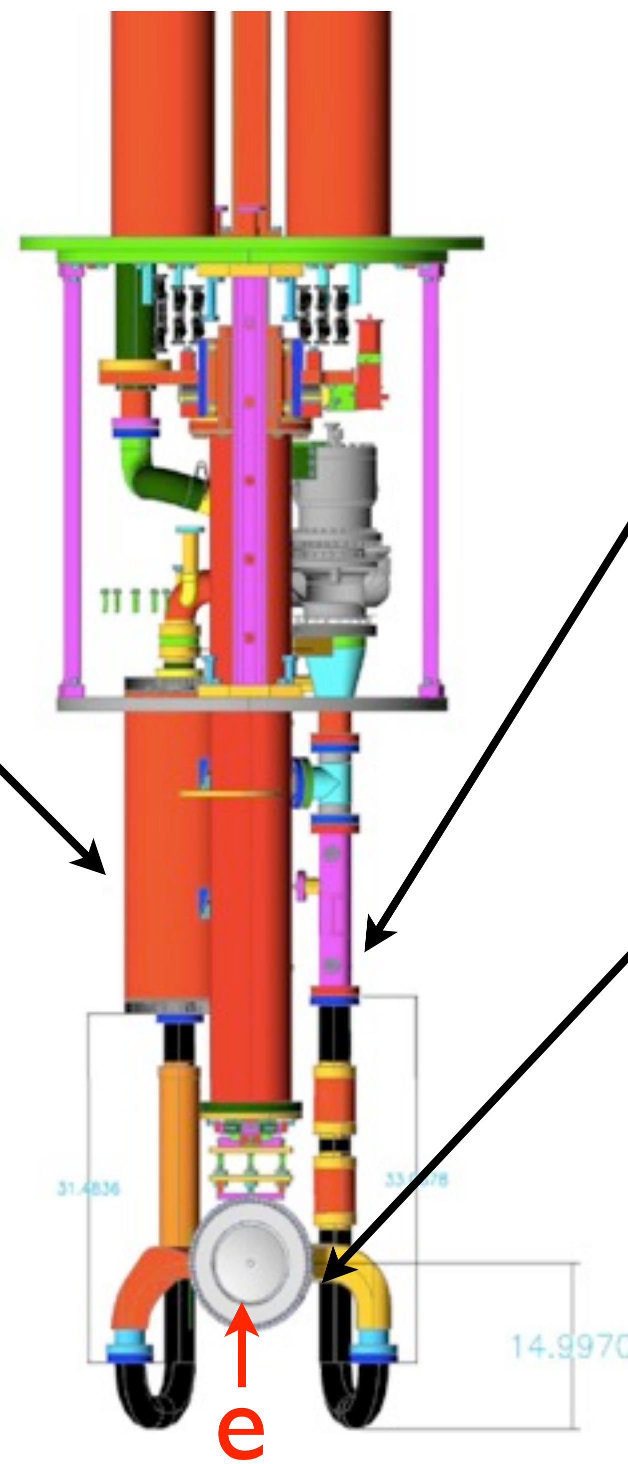


2500W cooling power to sustain a 180 uA beam

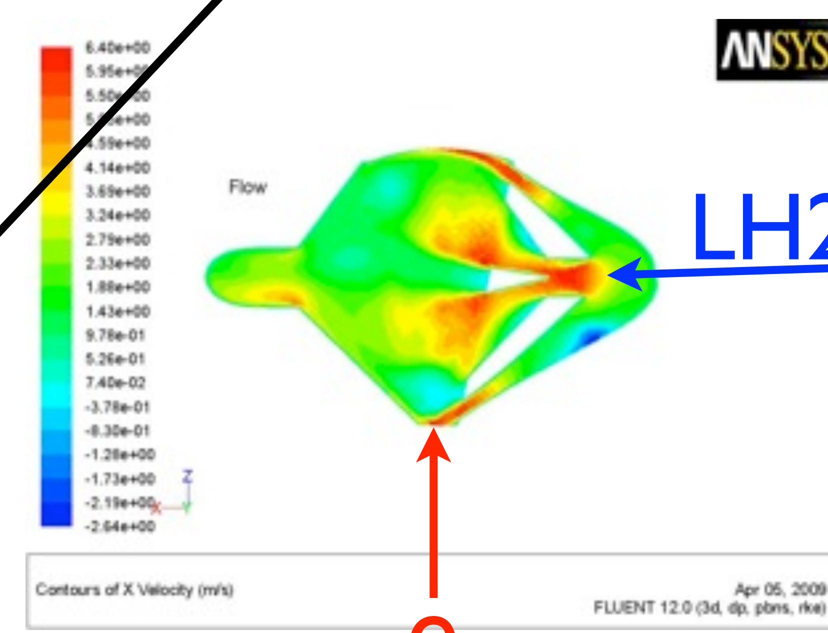
Target

Heat exchanger

Heater



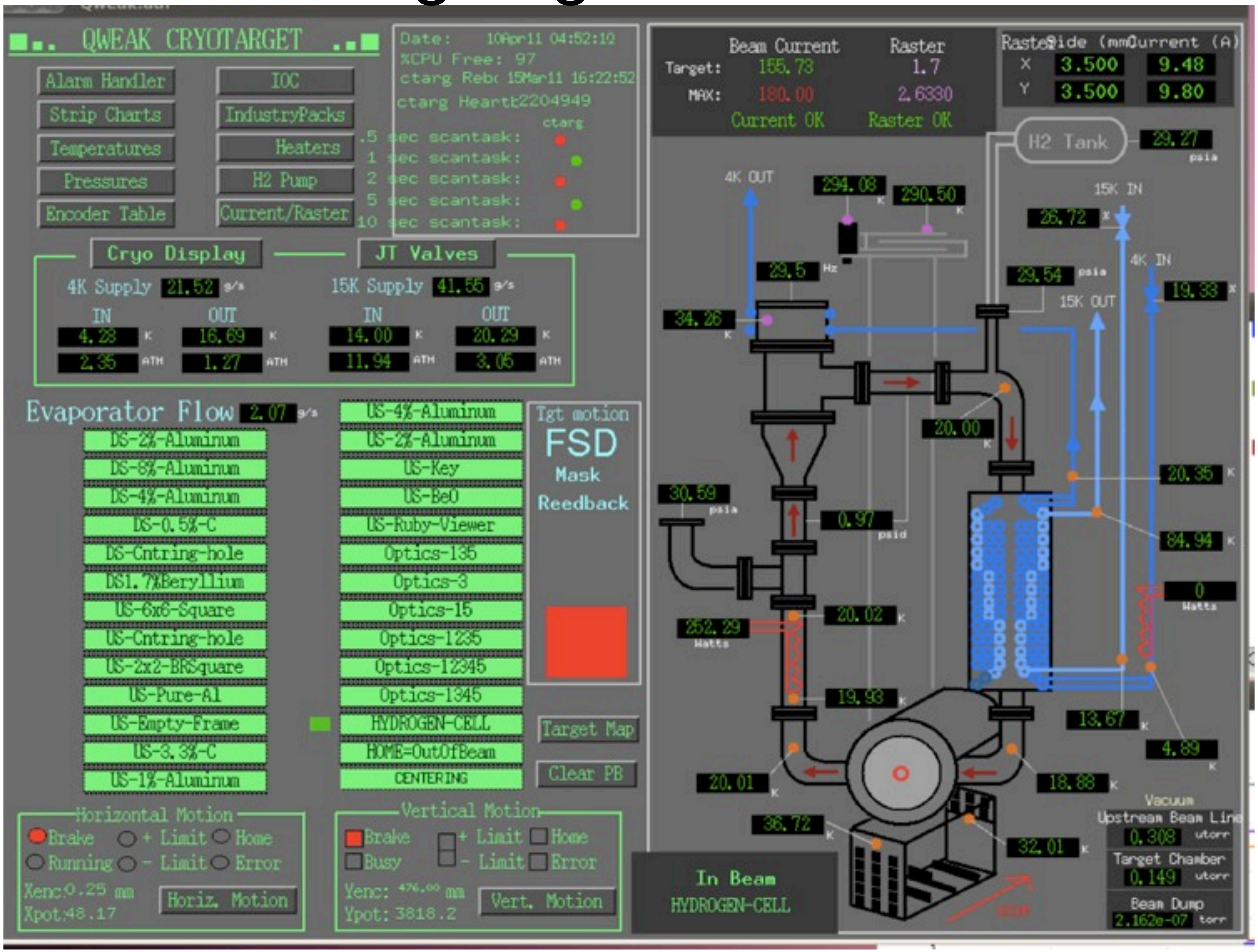
H2 flow



Design results in small temperature and pressure inhomogeneities

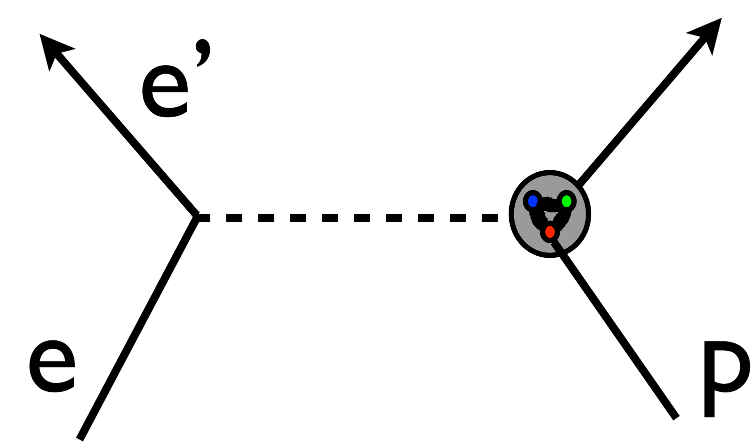
Target

Monitoring: target dedicated shift



Qweak the experiment

- Electron beam
- Target
- Detector system



Qweak the experiment

- Electron beam
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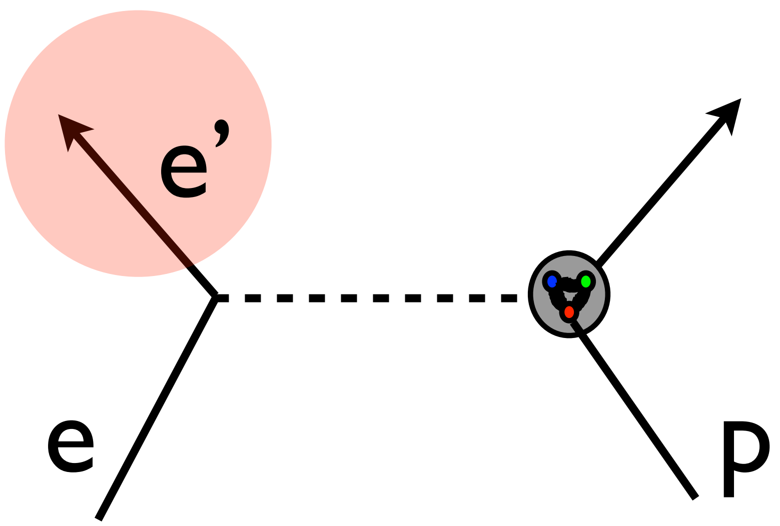
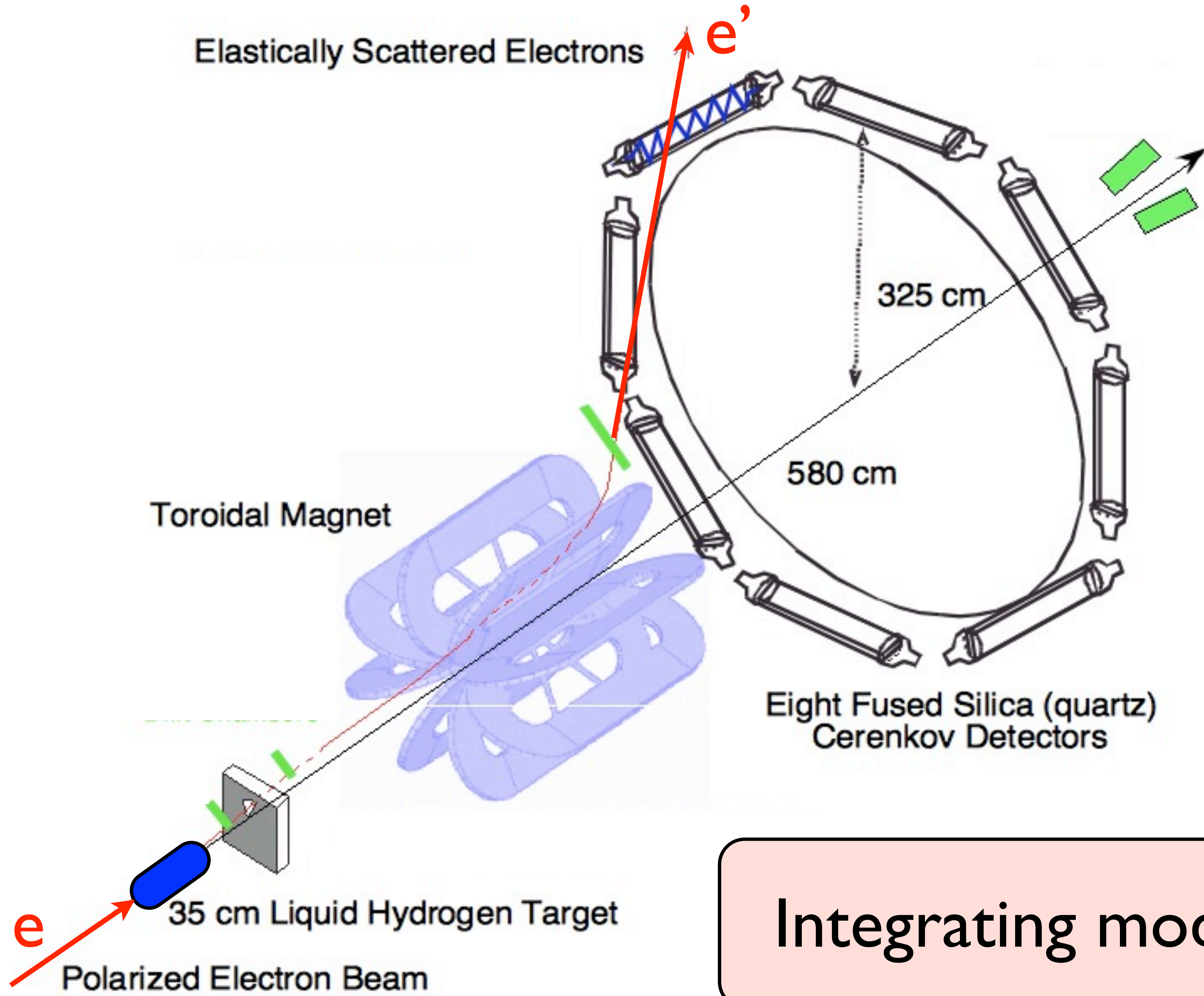
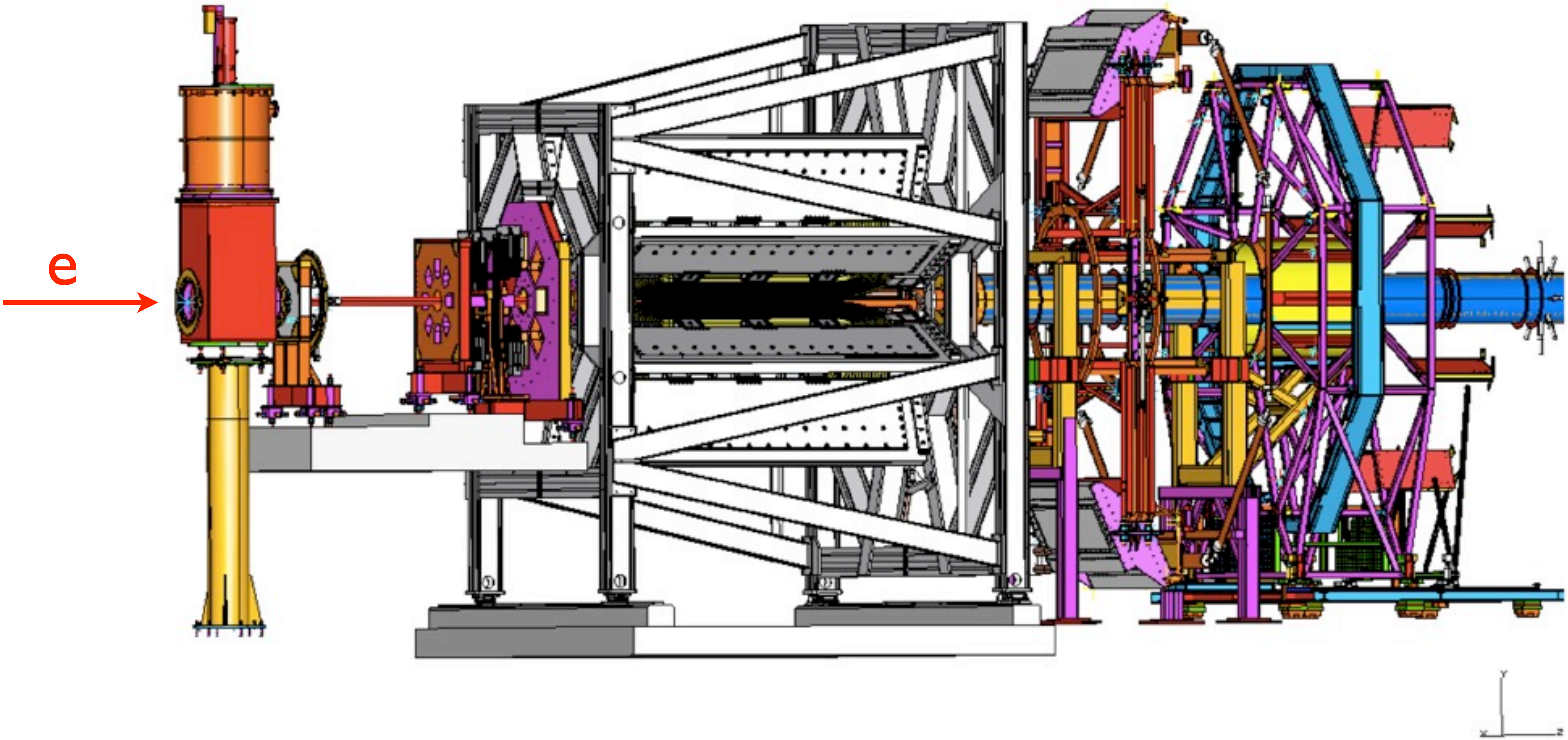


Schematic of the Qweak Experiment



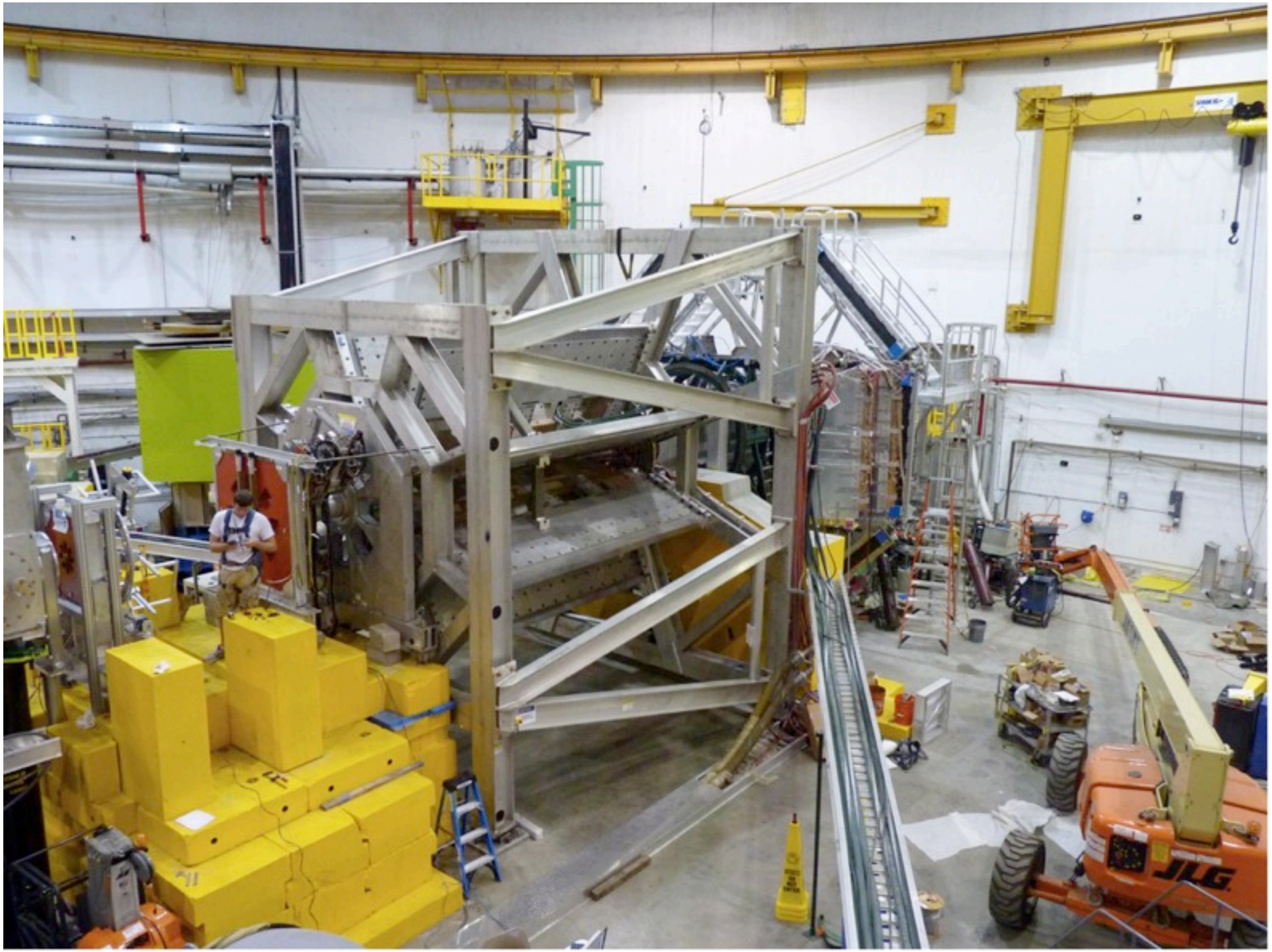
Integrating mode

Realistic representation



The actual setup

e

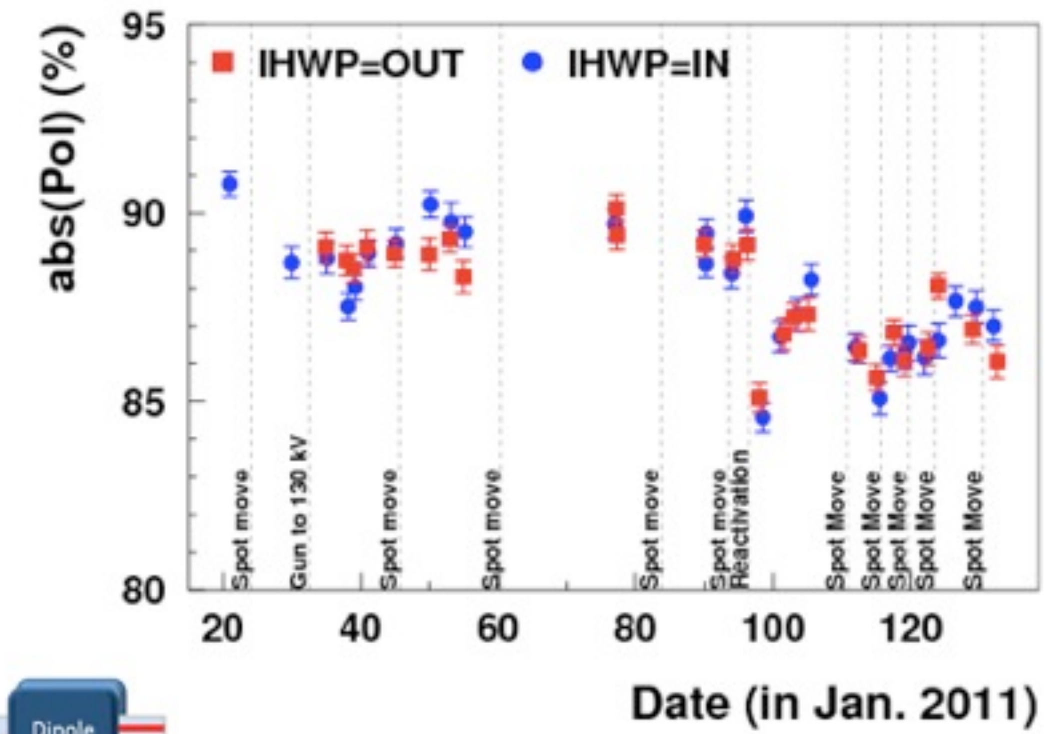


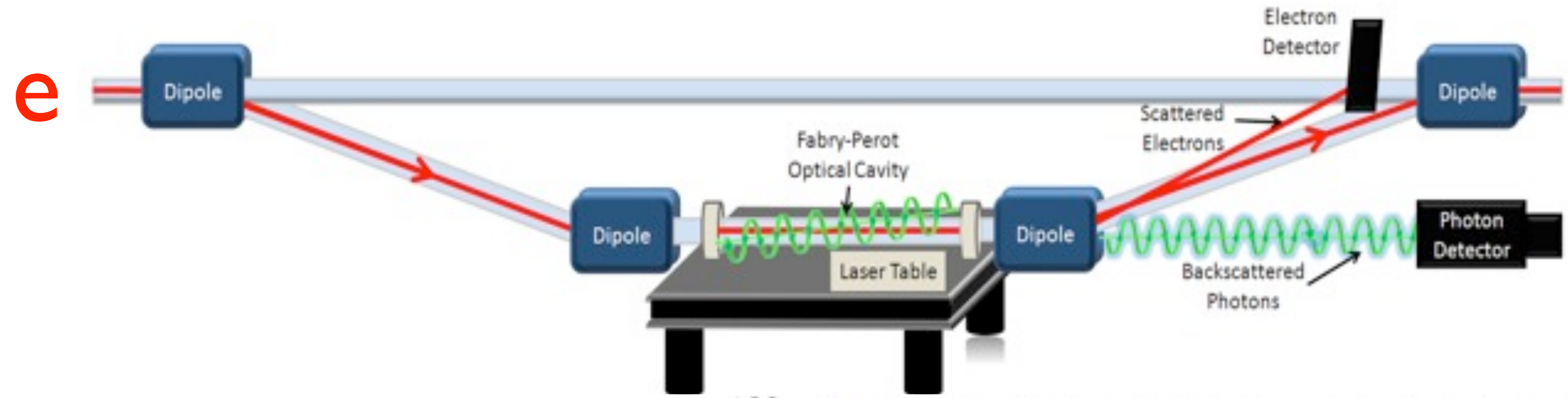
Further considerations

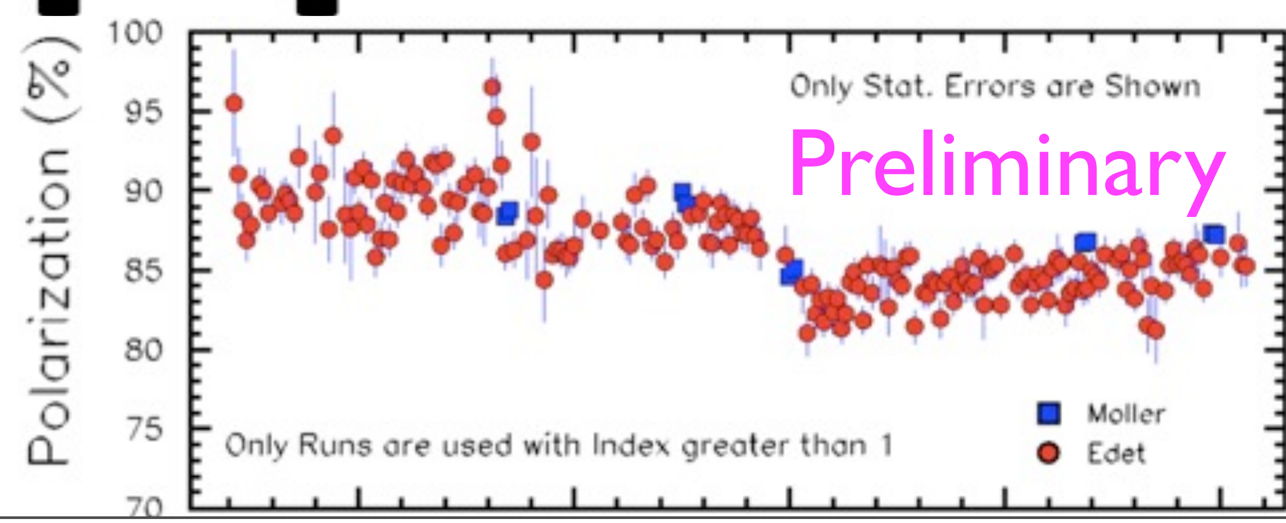
Polarimetry

Precision needed: 1%

- Moller: Invasive, precise
- Compton, Electron: non-invasive, always on



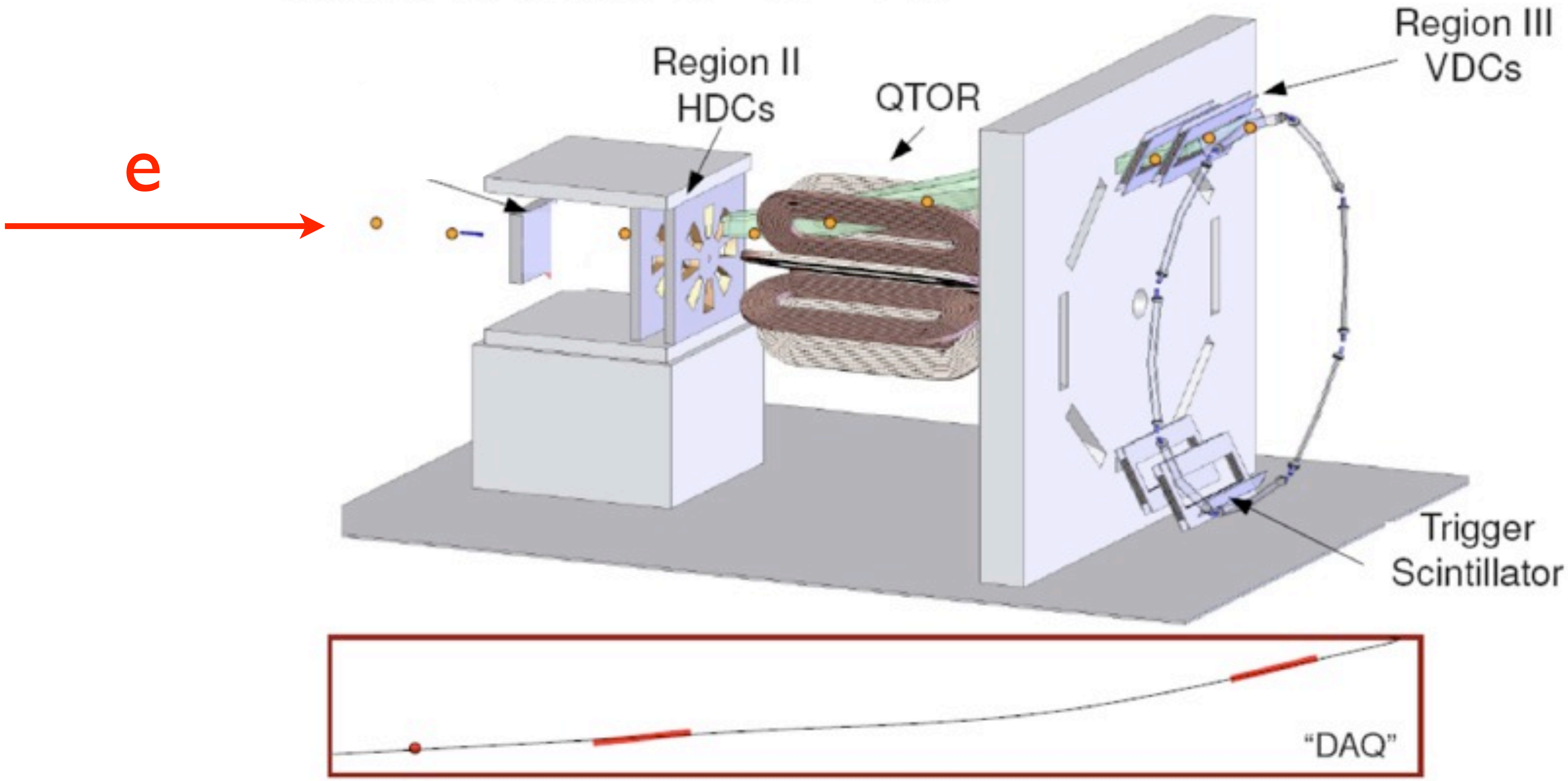




Tracking

Drift chambers before and after magnetic deflection (lower current)

- Need to know Q^2 to ~1%



Background

$$A_{meas} = P_e(1-f)A_{phys}(Q^2) + fA_{bkg} + A_{false}$$

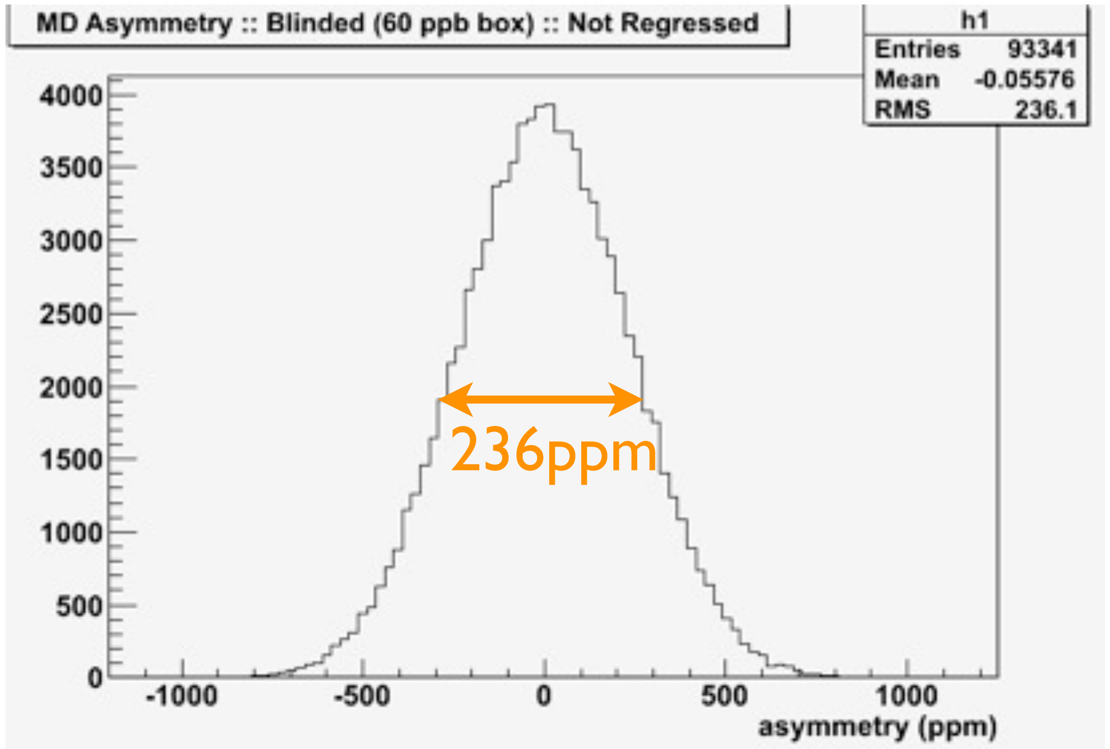
Dilution: $f = \dfrac{Y_{bkg}}{Y_{phys} + Y_{bkg}}$

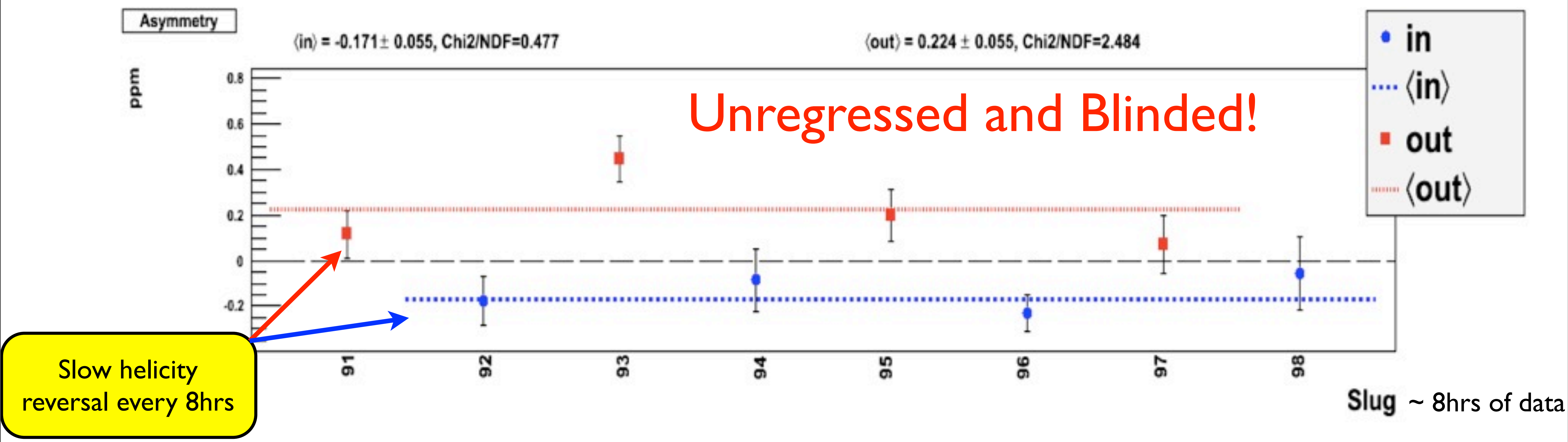
- Aluminum window background: determined with (empty) Al target (~10% correction)
- False Asymmetry: Need to minimize beam correlated beam property (beam properties monitored constantly).

Results

Uncertainty on the measured asymmetry:

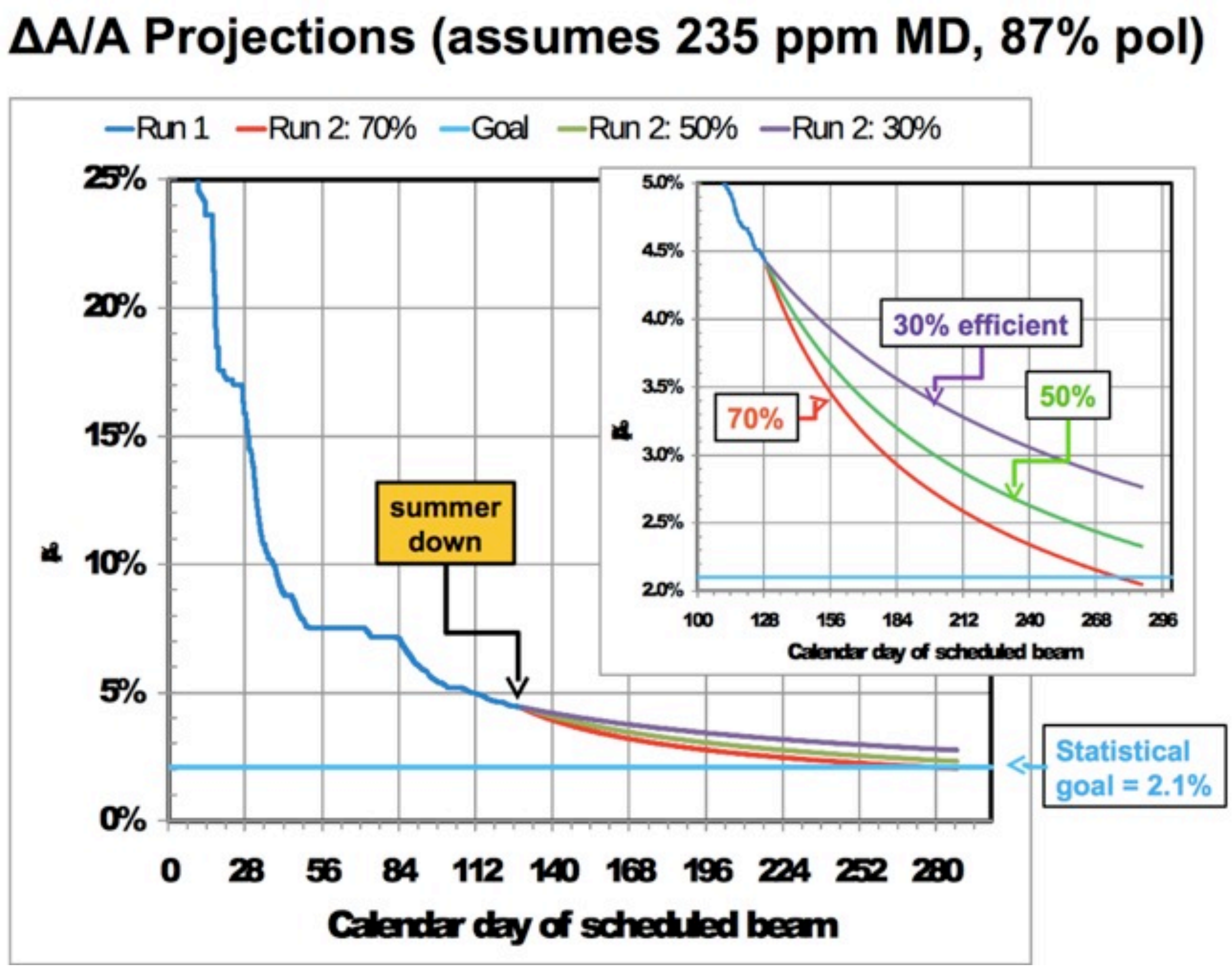
$$\sim \frac{\sigma}{\sqrt{N_q}}$$





Status and projection

- ~500 Coulombs until now
- 180 uA tested: OK
- Polarization > 85%
- Asym. width ~ 236ppm (expected 233ppm)
- Already better than 5% in statistical precision



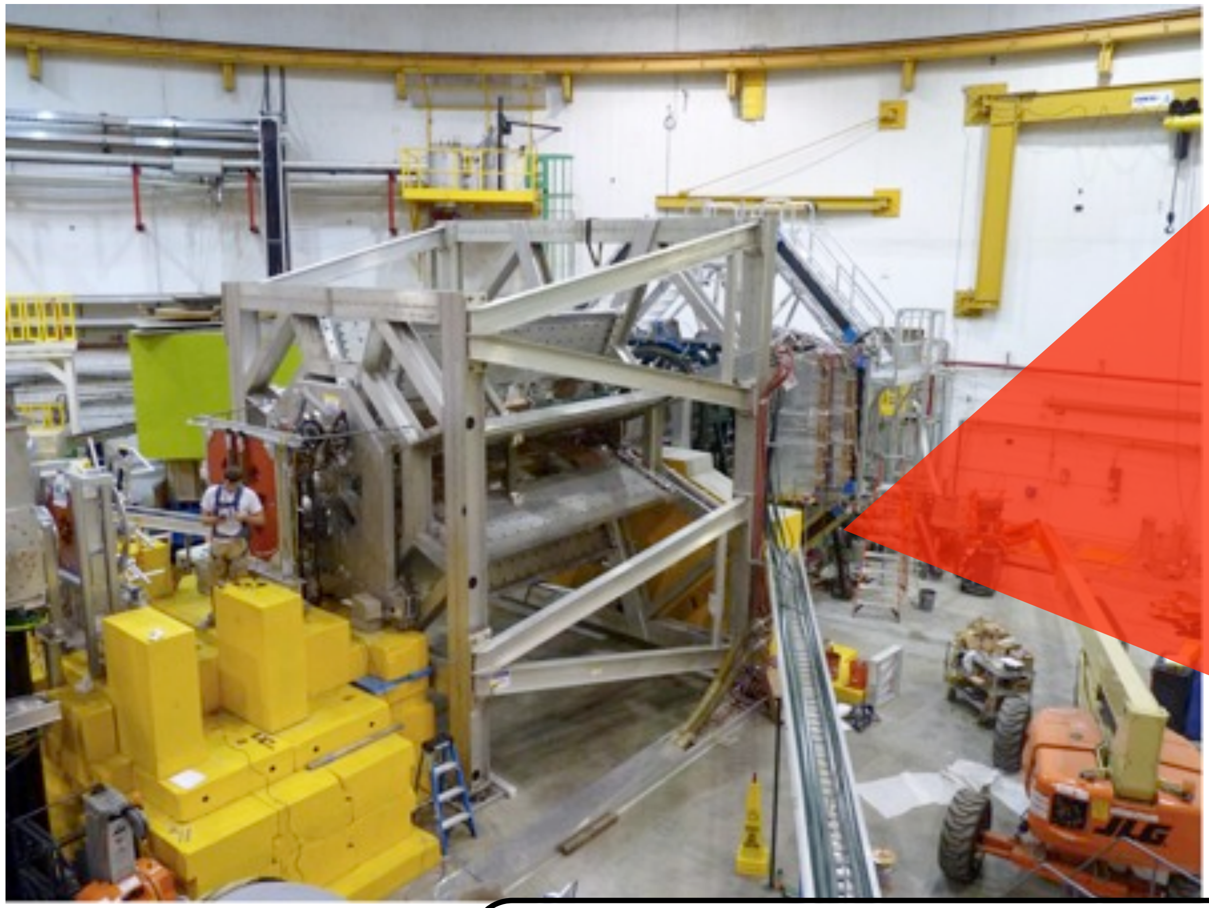
Conclusion

- Qweak is well under way and no show stopper to achieve a ~4% precision.
- Search for parity-violating BSM physics up to the ~2TeV scale.
- Data taking will resume this Fall until May 2012
- Lots of work to be done to achieve our goal (all members are very busy)
- Ancillary measurement
  - Aluminum asymmetry
  - Transverse polarization asymmetry
  - N->Delta

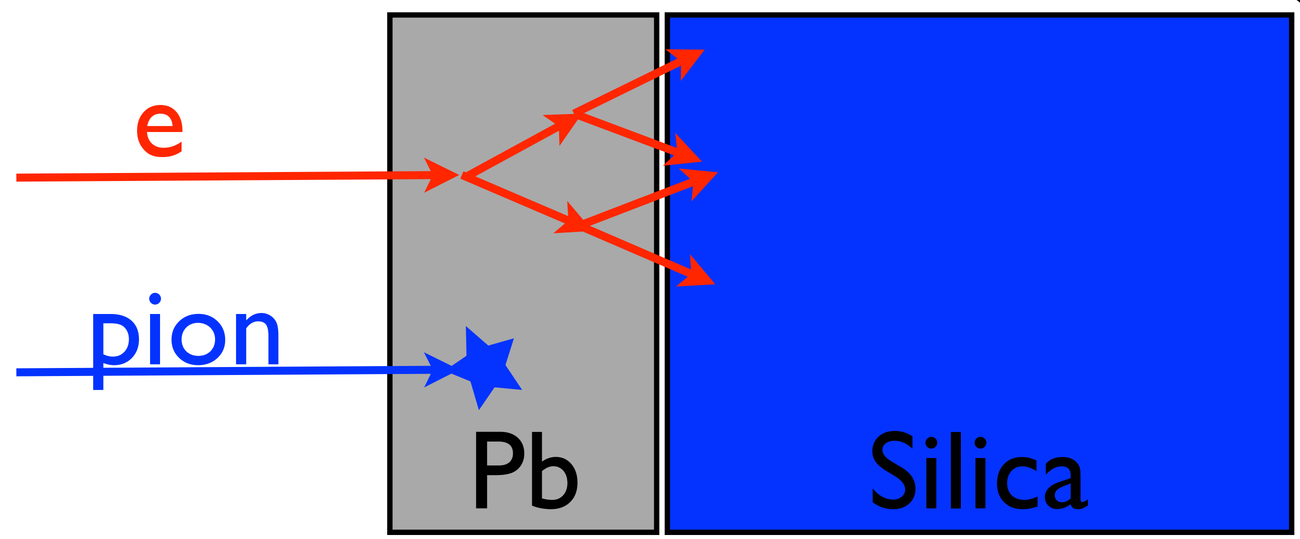
A. Almasalha, D. Androic, D.S. Armstrong, A. Asaturyan, T. Averett, J. Balewski, R. Beminiwattha, J. Benesch, F. Benmokhtar, J. Birchall, R.D. Carlini1 (Principal Investigator), G. Cates, J.C. Cornejo, S. Covrig, M. Dalton, C. A. Davis, W. Deconinck, J. Diefenbach, K. Dow, J. Dowd, J. Dunne, D. Dutta, R. Ent, J. Erler, W. Falk, J.M. Finn1*, T.A. Forest, M. Furic, D. Gaskell, M. Gericke, J. Grames, K. Grimm, D. Higinbotham, M. Holtrop, J.R. Hoskins, E. Ihloff, K. Johnston, D. Jones, M. Jones, R. Jones, K. Joo, E. Kargiantoulakis, J. Kelsey, C. Keppel, M. Kohl, P. King, E. Korkmaz, S. Kowalski1, J. Leacock, J.P. Leckey, A. Lee, J.H. Lee, L. Lee, N. Luwani, S. MacEwan, D. Mack, J. Magee, R. Mahurin, J. Mammei, J. Martin, M. McHugh, D. Meekins, J. Mei, R. Michaels, A. Micherdzinska, A. Mkrtchyan, H. Mkrtchyan, N. Morgan, K.E. Myers, A. Narayan, Nuruzzaman, A.K. Opper, S.A. Page1, J. Pan, K. Paschke, S.K. Phillips, M. Pitt, B.M. Poelker, J.F. Rajotte, W.D. Ramsay, M. Ramsey-Musolf, J. Roche, B. Sawatzky, T. Seva, R. Silwal, N. Simicevic, G. Smith2, T. Smith, P. Solvignon, P. Souder, D. Spayde, A. Subedi, R. Subedi, R. Suleiman, E. Tsentalovich, V. Tvaskis, W.T.H. van Oers, B. Waidyawansa, P. Wang, S. Wells, S.A. Wood, S. Yang, R.D. Young, S. Zhamkochyan, D. Zou

1Spokespersons *deceased 2Project Manager

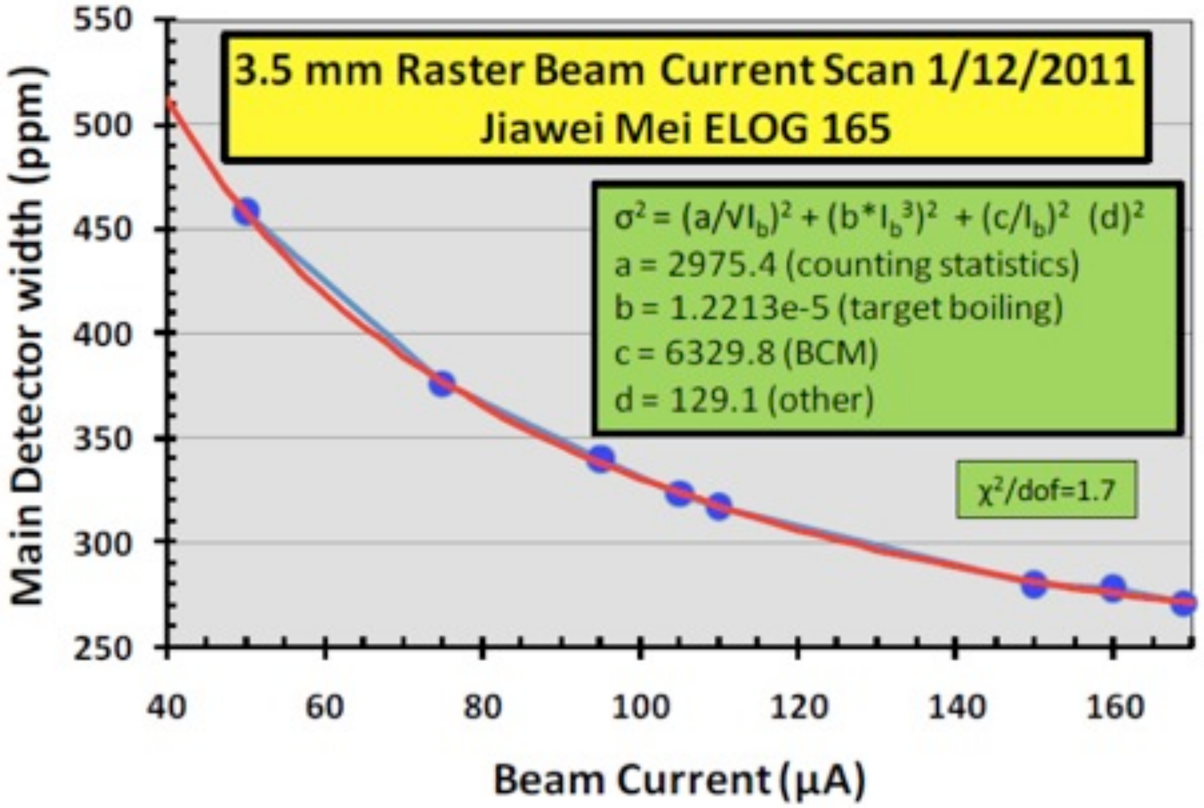
More detector

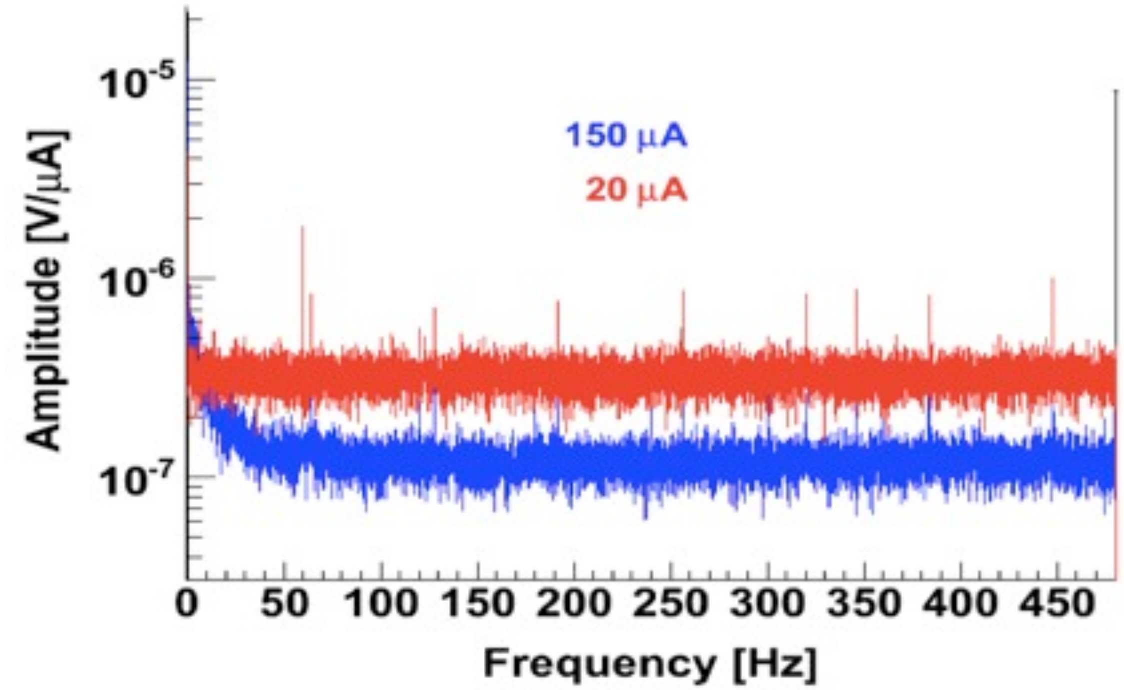


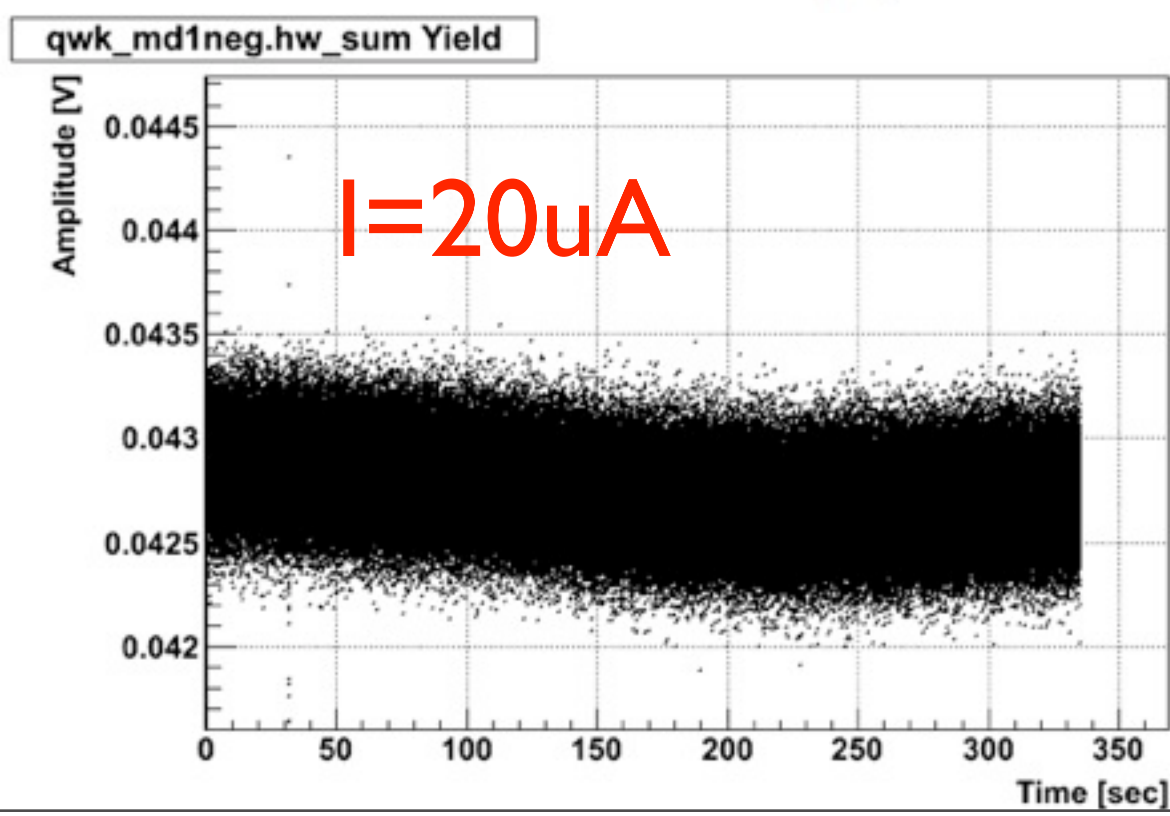
Preradiator:
Increases the signal and reduces the background.

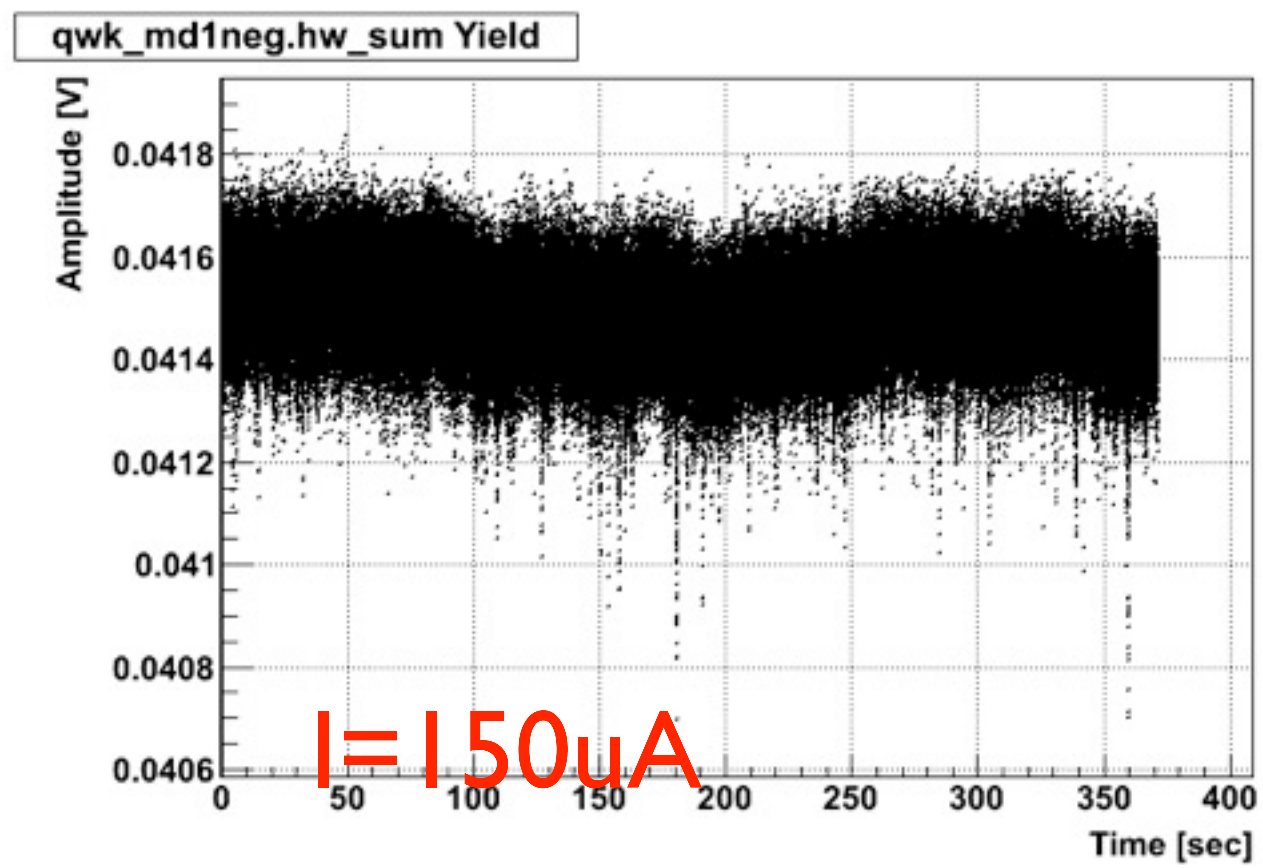


More target

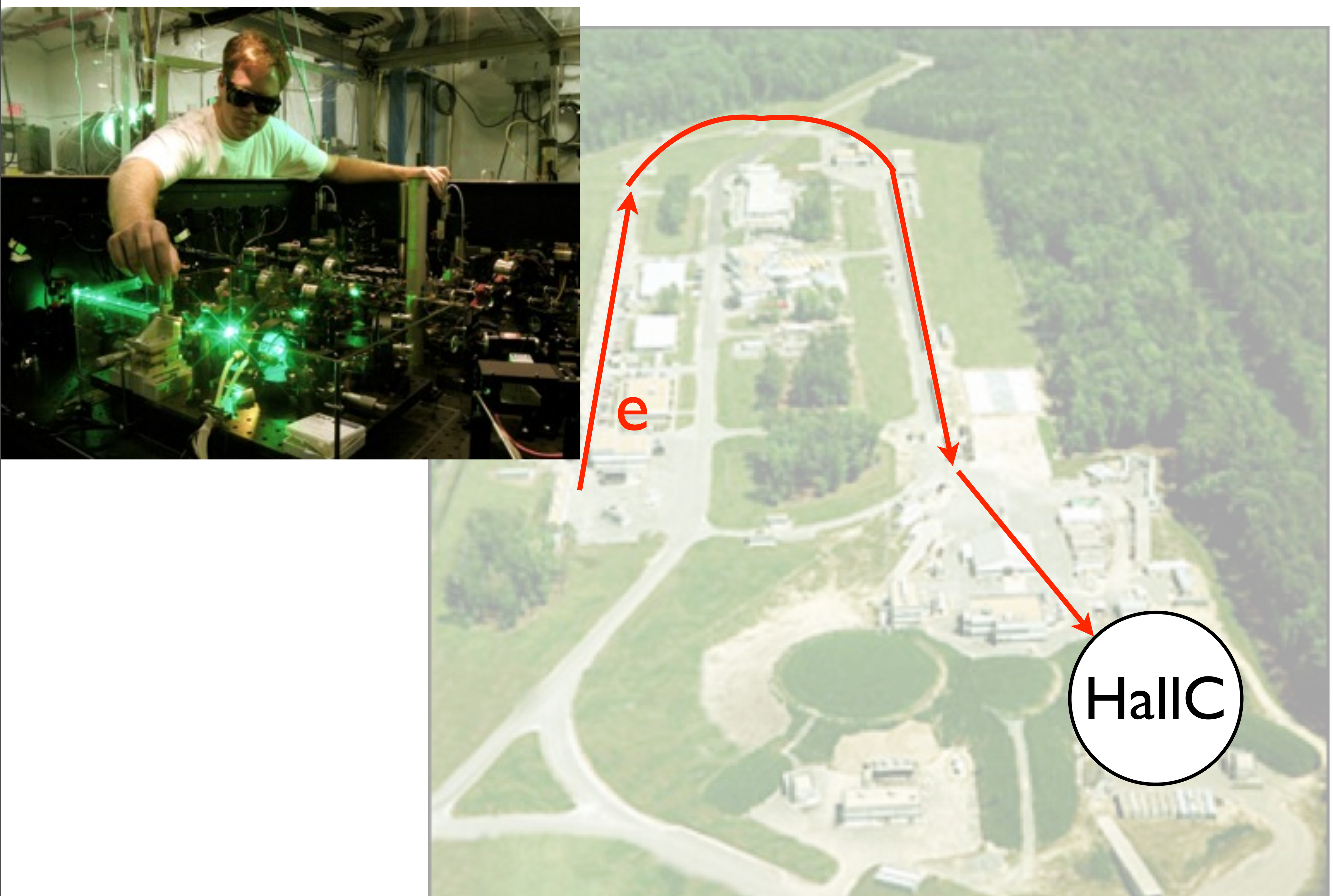

3.5 mm Raster Beam Current Scan 1/12/2011
Jiawei Mei ELOG 165
σ² = (a/√I_b)² + (b*I_b³)² + (c/I_b)² (d)²
a = 2975.4 (counting statistics)
b = 1.2213e-5 (target boiling)
c = 6329.8 (BCM)
d = 129.1 (other)
χ²/dof=1.7
Main Detector width (ppm)
550
500
450
400
350
300
250
40
60
80
100
120
140
160
Beam Current (μA)


150 μA
20 μA
Amplitude [V/μA]
10⁻⁵
10⁻⁶
10⁻⁷
0
50
100
150
200
250
300
350
400
450
Frequency [Hz]


qwk_md1neg.hw_sum Yield
I=20uA
Amplitude [V]
0.0445
0.044
0.0435
0.043
0.0425
0.042
0
50
100
150
200
250
300
350
Time [sec]


qwk_md1neg.hw_sum Yield
I=150uA
Amplitude [V]
0.0418
0.0416
0.0414
0.0412
0.041
0.0408
0.0406
0
50
100
150
200
250
300
350
400
Time [sec]

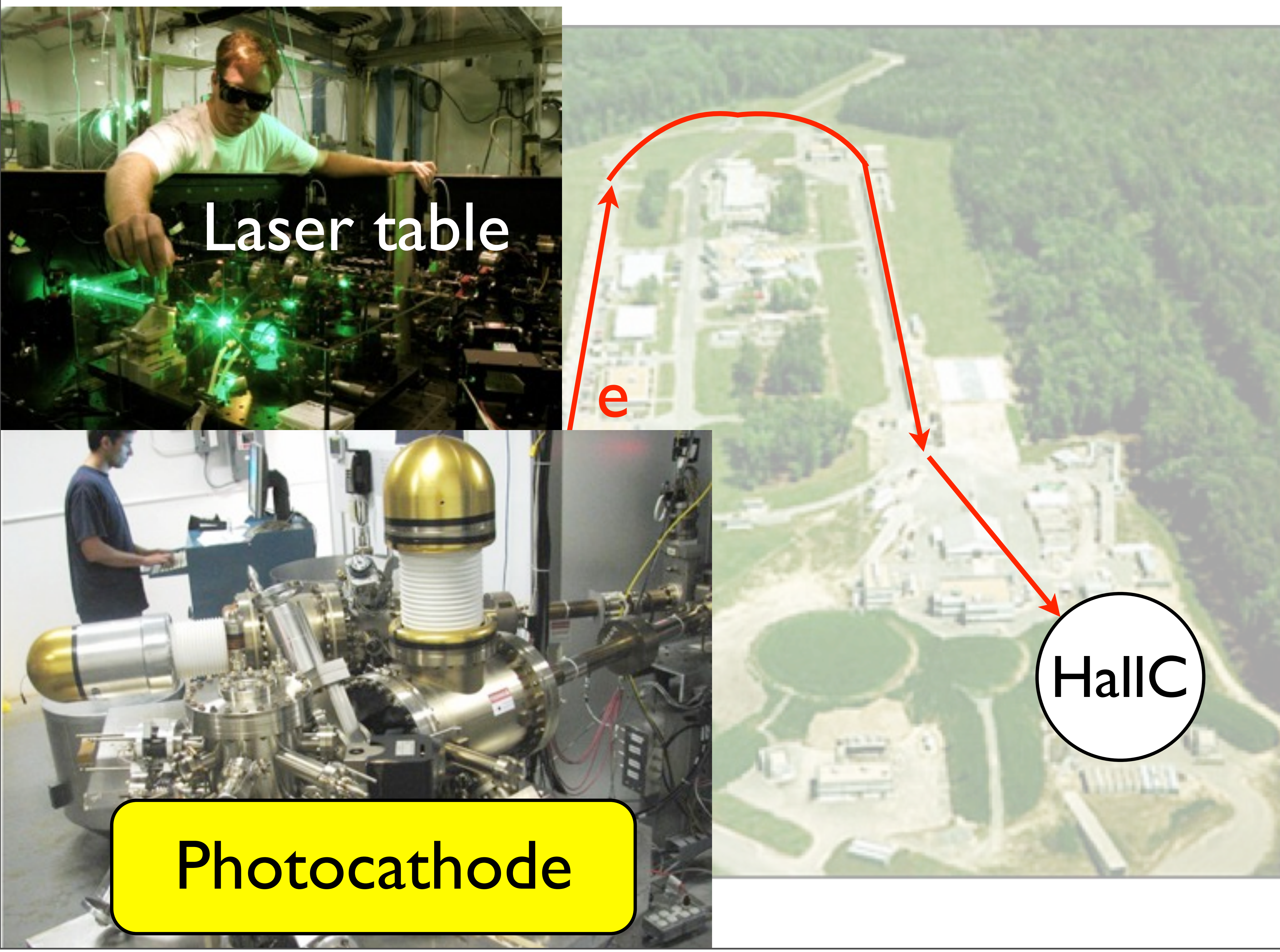
More electron beam



Spin flip
@ 960Hz

E=1.165GeV
Current:180uA
Polarization ~85%

More electron beam



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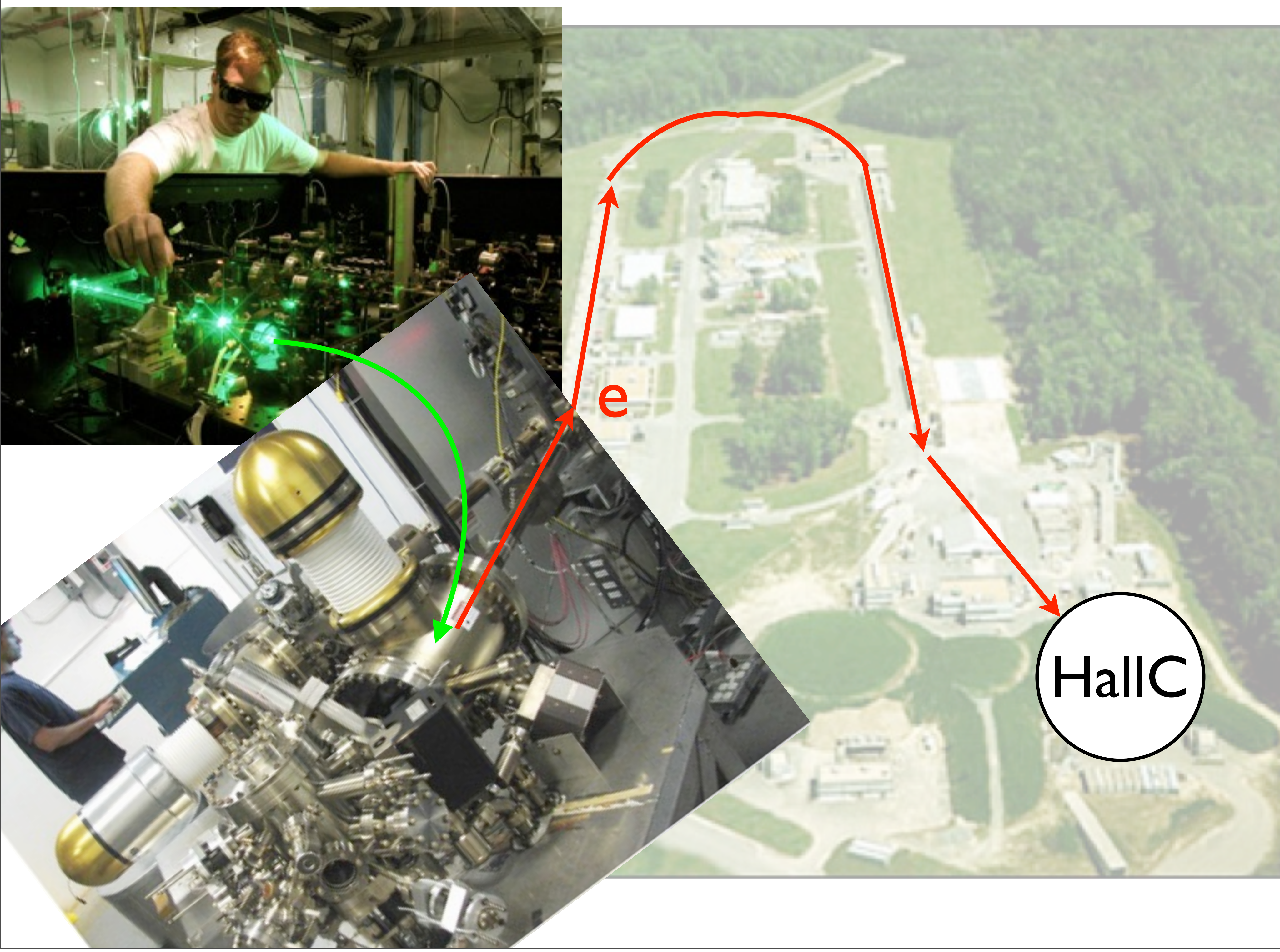
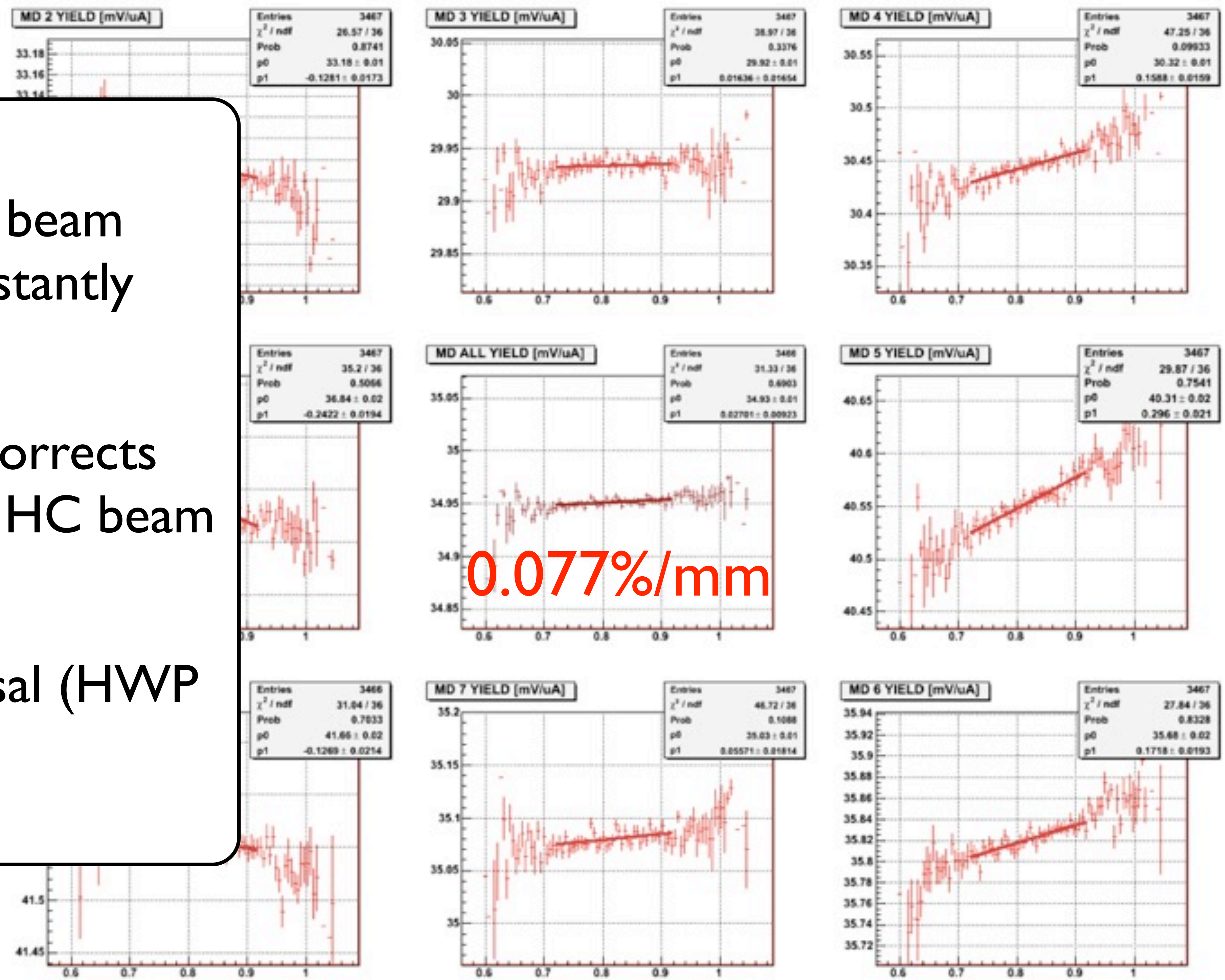


Spin flip
@ 960Hz

E=1.165GeV
Current:180uA
Polarization ~85%

Beam quality

- Helicity correlated beam properties are constantly monitored.
- Linear regression corrects the asymmetry for HC beam properties.
- Slow helicity reversal (HWP and Wien)



Constraints on light quarks weak charges