THE GEORGE WASHINGTON UNIVERSITY
WASHINGTON, DC

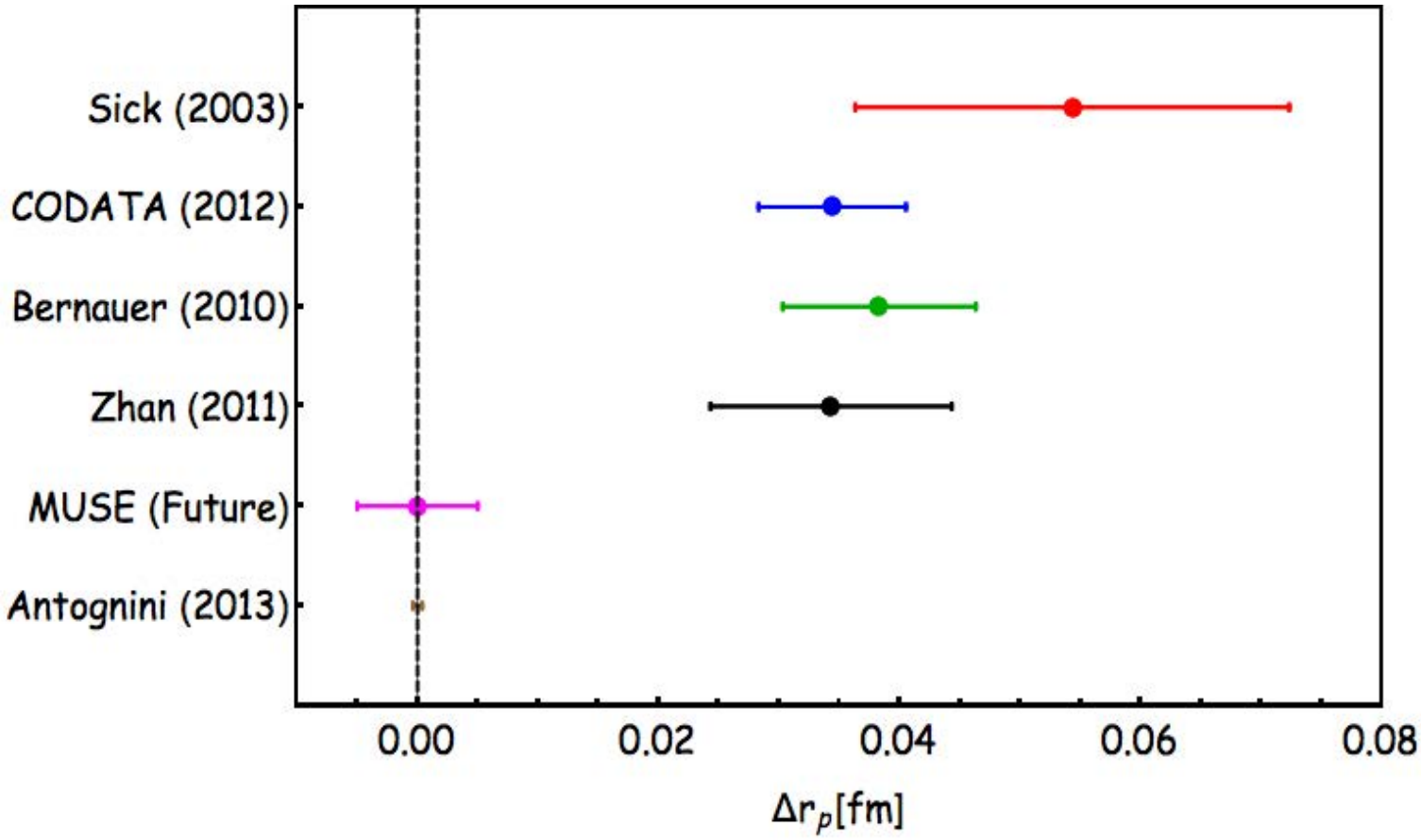
MUSE Update

Evangeline J. Downie
MUSE Collaboration

GW current awards:
PHY-1614850,1714833

The Proton Radius Puzzle: Are We Still Puzzled?

- Plot shown at BVR 48:



The Proton Radius Puzzle: Are We Still Puzzled?

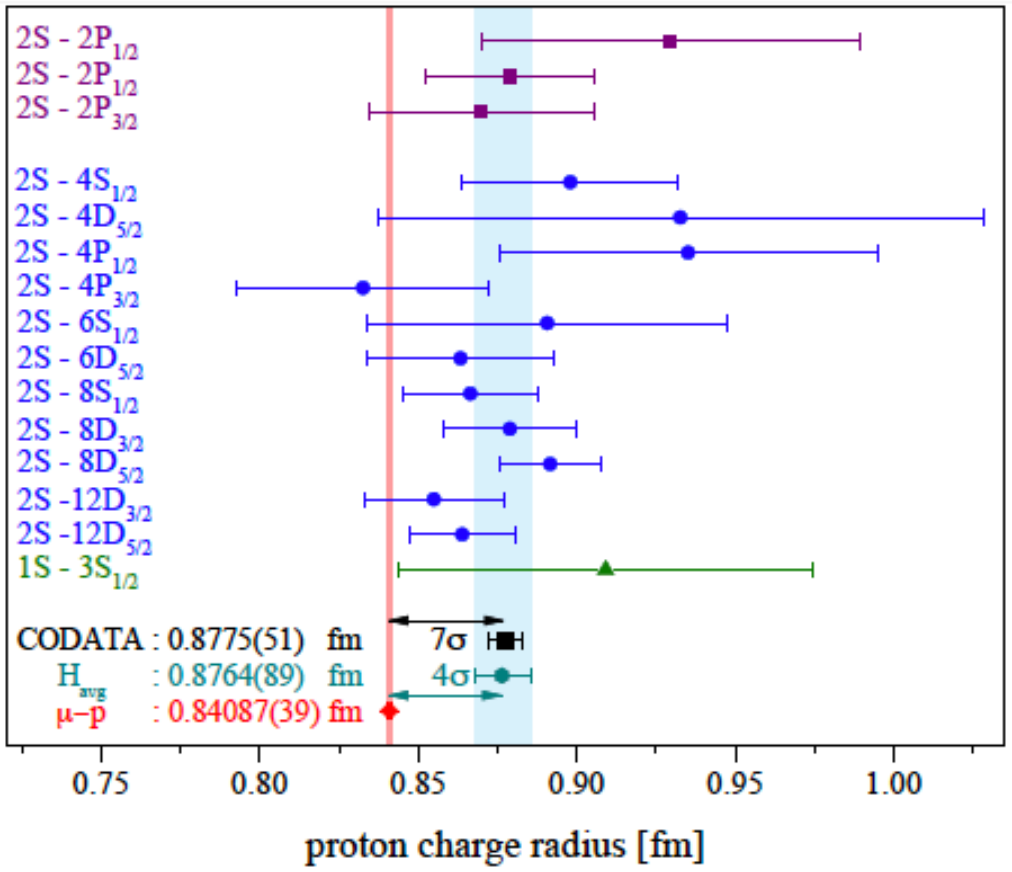
Spectroscopy of electronic Atoms and Ions:

- NPL, London: 2S-6S/D in atomic hydrogen
- MPQ, Garching:
  - 2S-4P in atomic hydrogen
  - 1S-3S in atomic hydrogen
  - He^+ (in preparation)
- LKB, Paris: 1S-3S atomic hydrogen
- YU, Toronto: 2S-2P „Lamb shift“

- VU, Amsterdam: He^+ (in preparation)
- NIST, Gaithersburg: highly charged ions

Spectroscopy of exotic atoms:

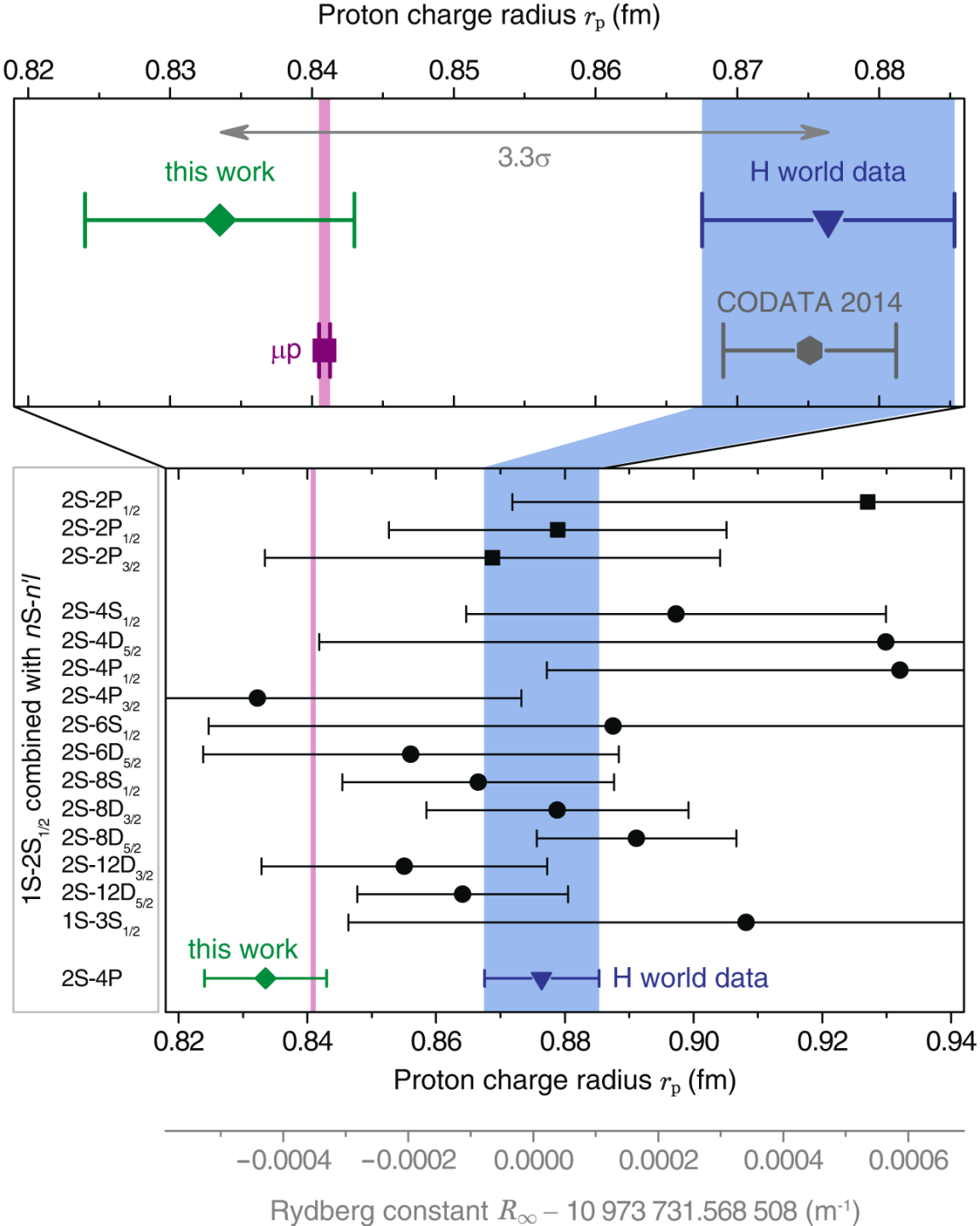
- ETH, Zurich (in preparation):
  - positronium (e^+e^-)
  - muonium (μ^+e^-)
- PSI, Villigen: μHe^+



New Radius Result: MPQ

Beyer *et al.*
Science **358**, 79-85 (2017)
6 October 2017

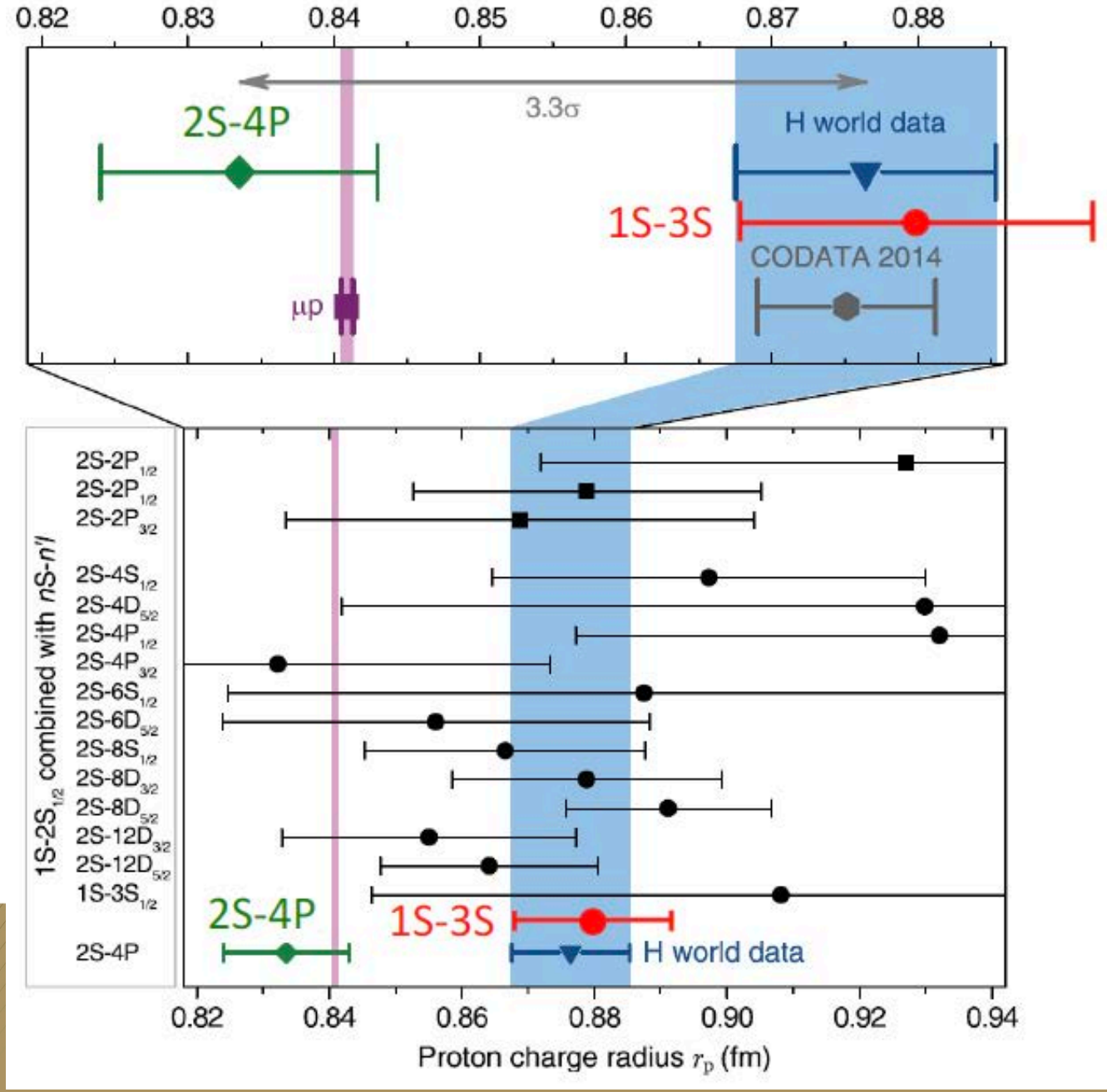
N.B.
5**σ** Rydberg deviation required



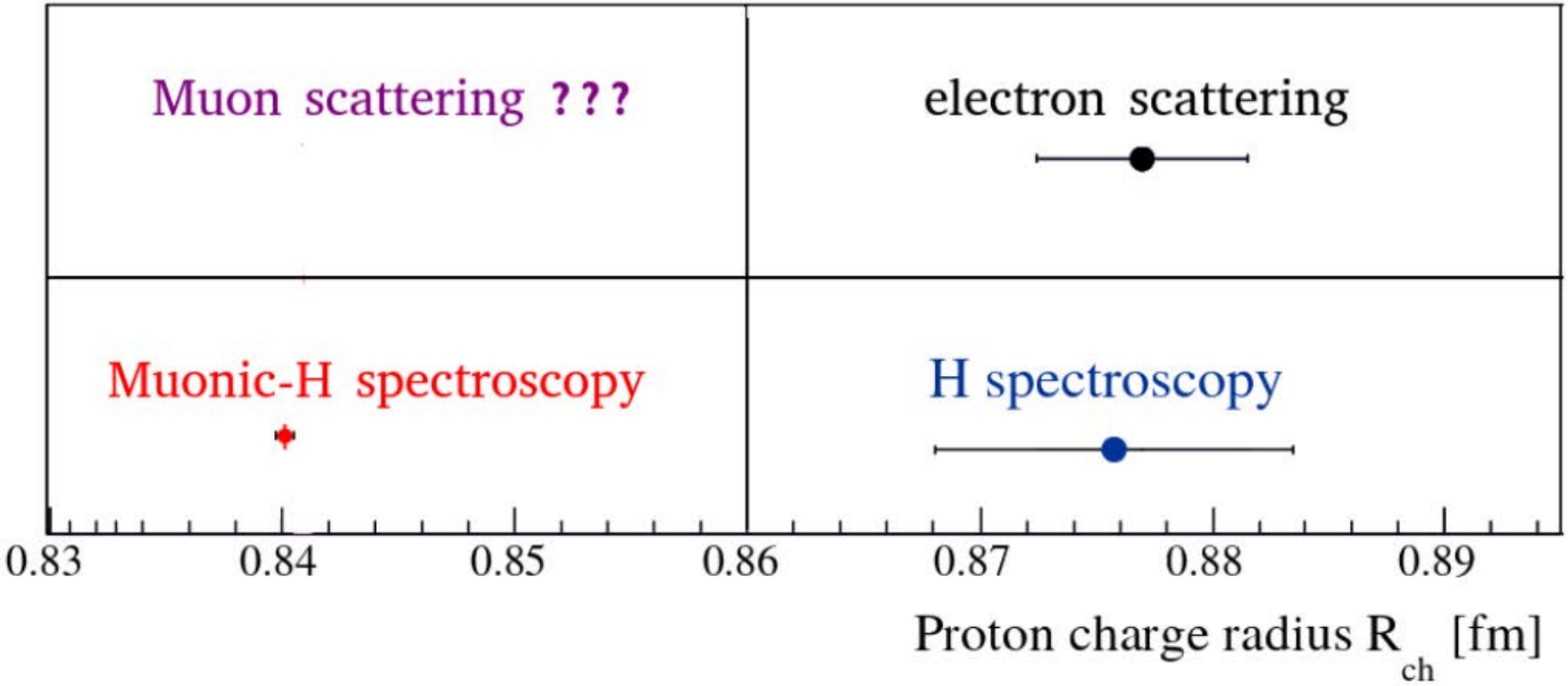
New Radius Result: Orsay

Hélène Fleurbaey, "Frequency metrology of the 1S-3S transition of hydrogen: contribution to the proton charge radius Puzzle," Université Pierre et Marie Curie (UPMC), 2017, https://tel.archives-ouvertes.fr/tel-01633631

N.B.
Agrees with Rydberg



Physics Update: The Need for MUSE



MUSE

$\theta \approx 20^\circ - 100^\circ$

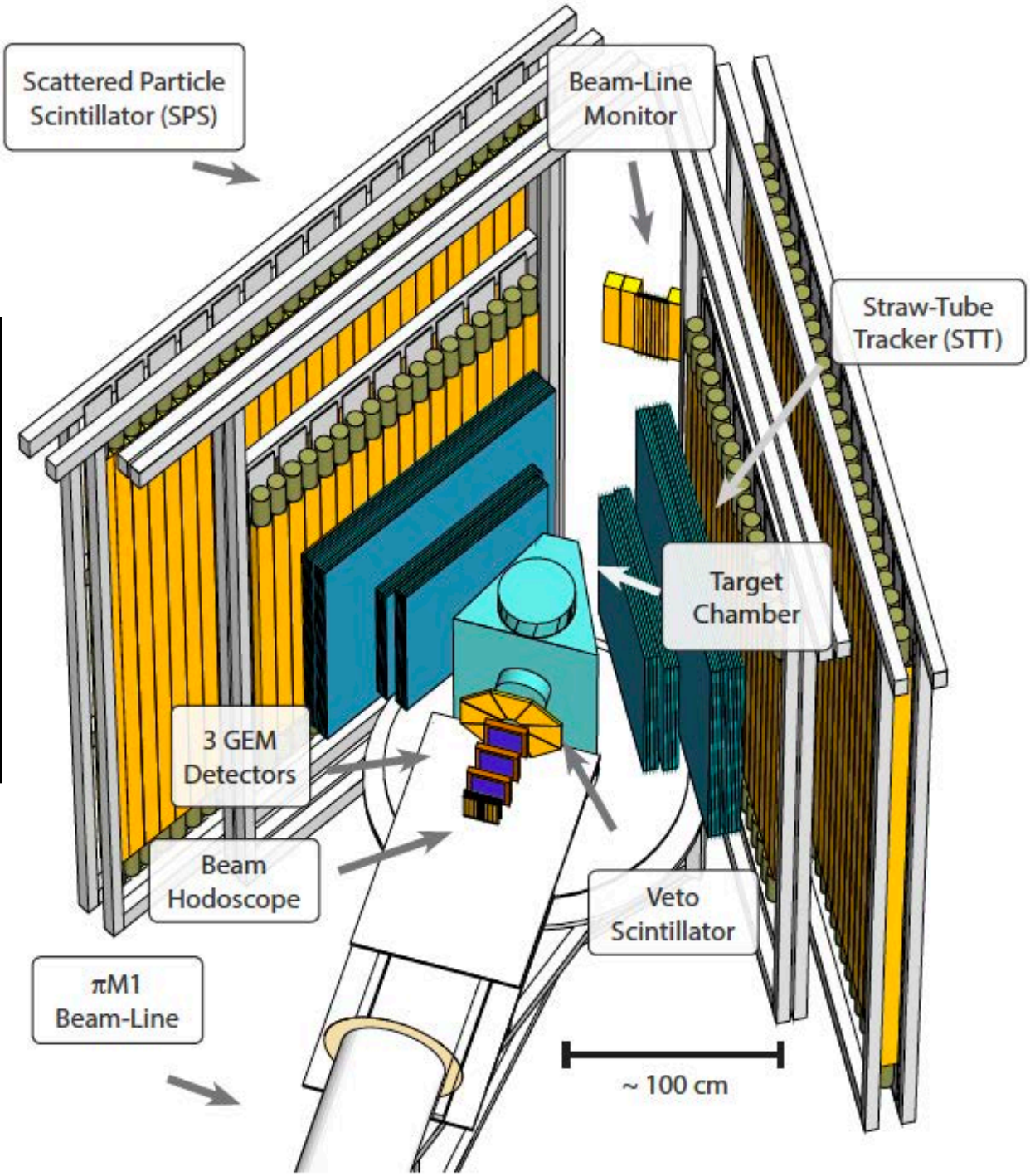
$Q^2 \approx 0.002 - 0.07\ \text{GeV}^2$

3.3 MHz total beam flux

≈ 2 – 15% **μ**'s

≈ 10 – 98% e's

≈ 0 – 80% **π**'s

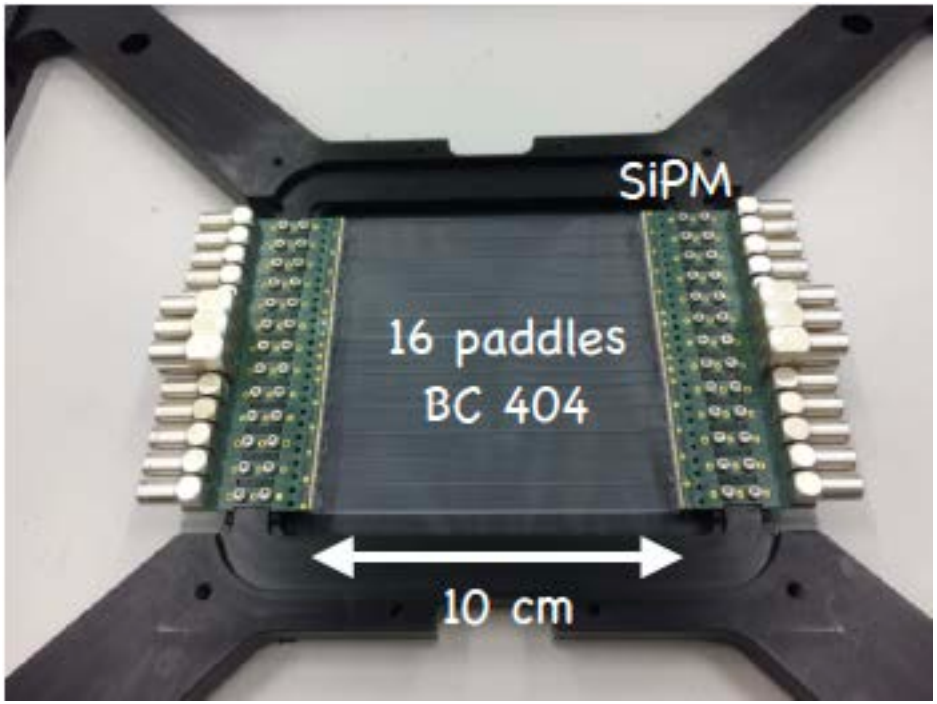


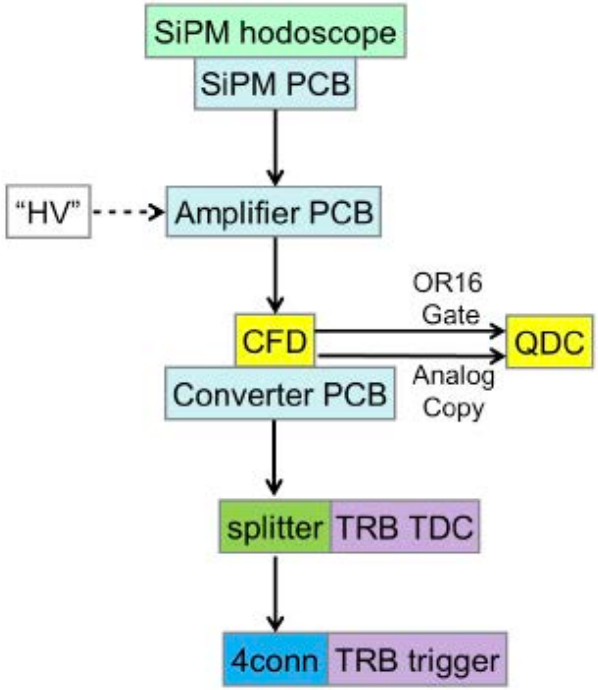
Beam Hodoscope

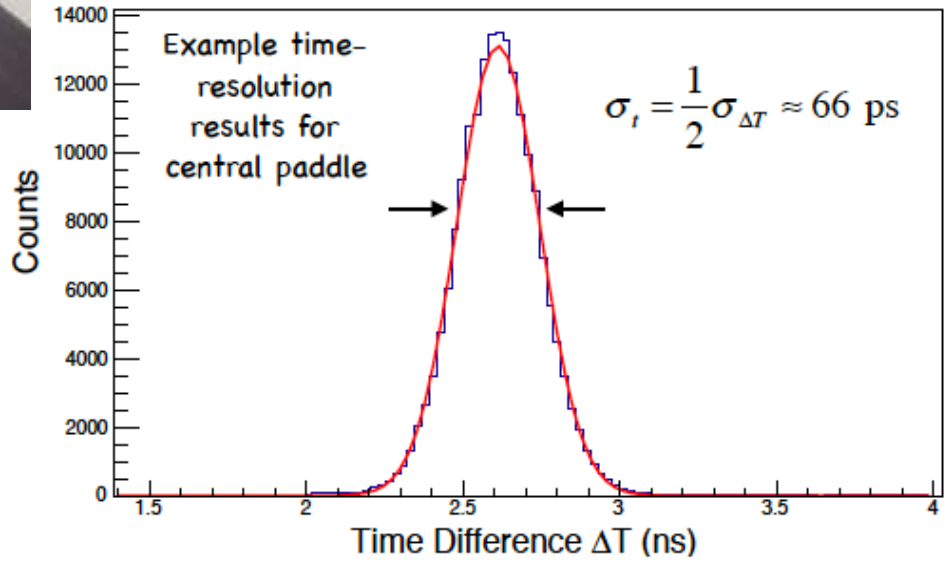
Parameter	Performance Requirement	Achieved
Time Resolution	<100 ps / plane	✓ 80 ps
Efficiency	99%	✓ 99.8%
Positioning	≈1 mm, ≈1 mr	not attempted; easy – calibrated by data
Rate Capability	3.3 MHz / plane	✓ >10 MHz / plane

- Two planes constructed, two will be built in Spring
- Four planes @ 210 MeV; 3 @ 153 MeV; 2 @ 115 MeV
- SiPMs radiation damage tested – not problematic

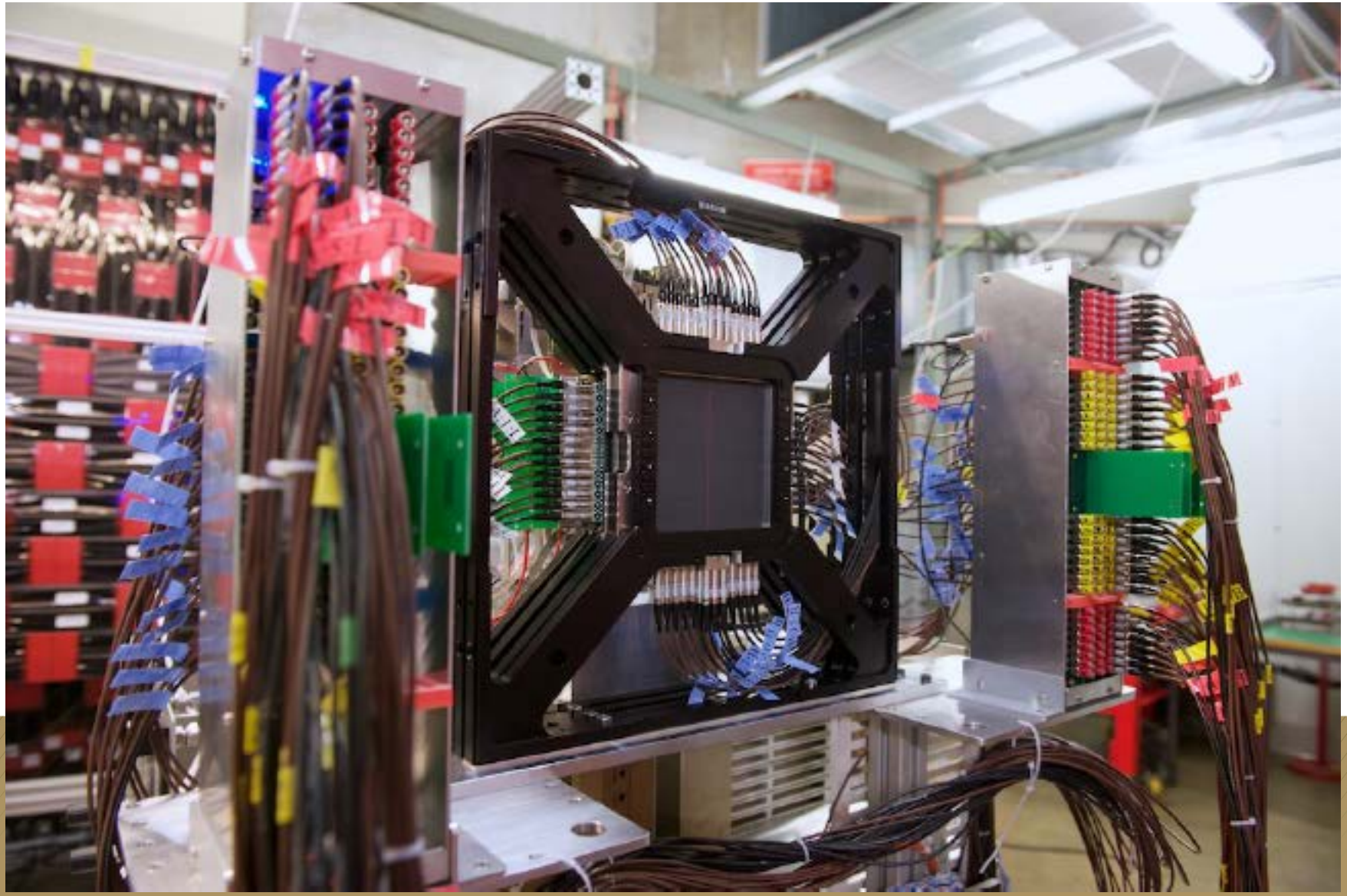
Beam Hodoscope



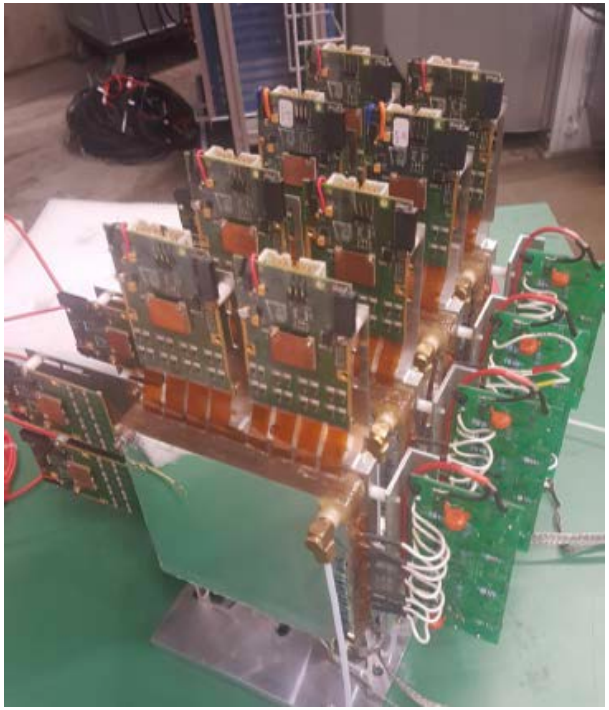




Beam Hodoscope – November 2017



GEM



Parameter	Performance Requirement	Achieved
Resolution	100 μm / element	✓ 70 μm
Efficiency	98%	✓ 98%
Positioning	$\approx$0.1 mm, $\approx$0.2 mr	planned
Rate Capability	3.3 MHz / plane	✓ 5 MHz
Readout Speed	2 kHz / 20% deadtime	1.5 kHz / 100% deadtime

Target

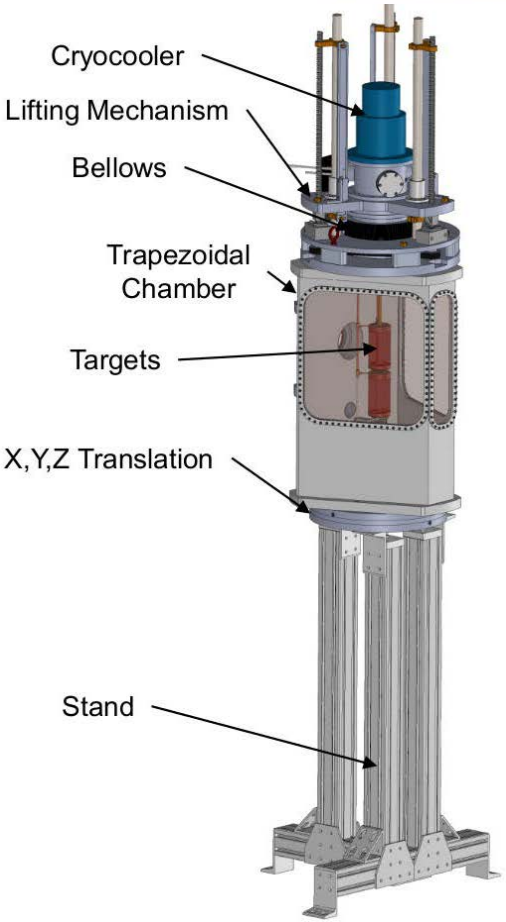
Parameter	Performance Requirement	Achieved?
Liquid hydrogen	maintain liquid hydrogen-filled cell at T≈19 k and P∼1 atm	not attempted; moderate
Cool down time	$<$ 3 days	✓ achieved; $<$ 2 hours!
Beam entrance window	>6 cm	✓ achieved; easy
Exit window(s) (One continuous or two symmetric on beam left and beam right)	$20° < \theta < 100°$; $\phi = 0° \pm 45°$ at $\theta = 60°$ beam up-down and beam left-right symmetry	✓ achieved; challenging

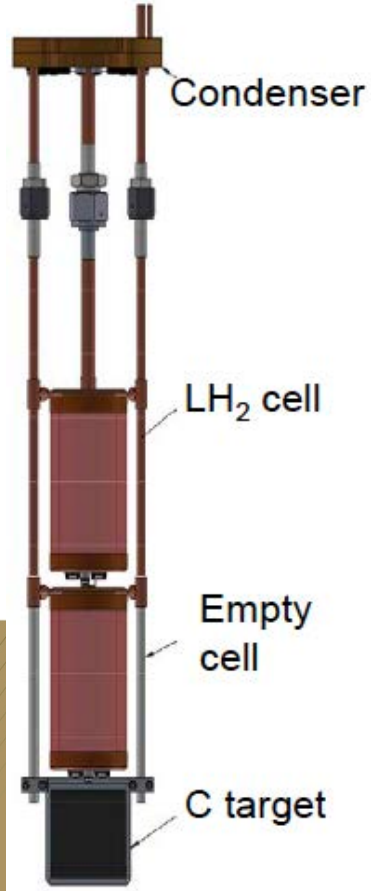
Target

final LH_2 cell
at ΔP = 2 bar & 77 K

Target ladder connected to lifting lid

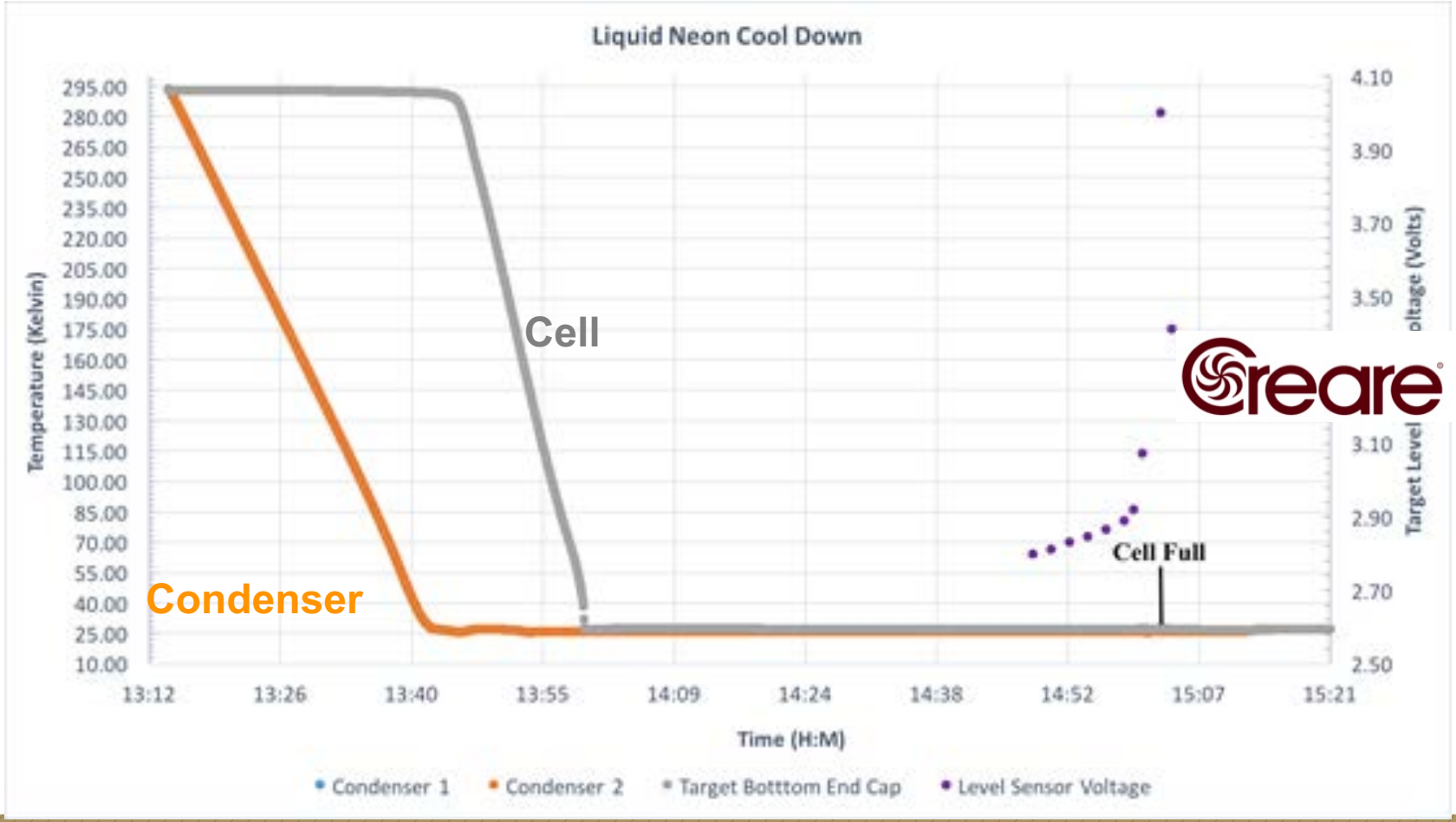
After full integration



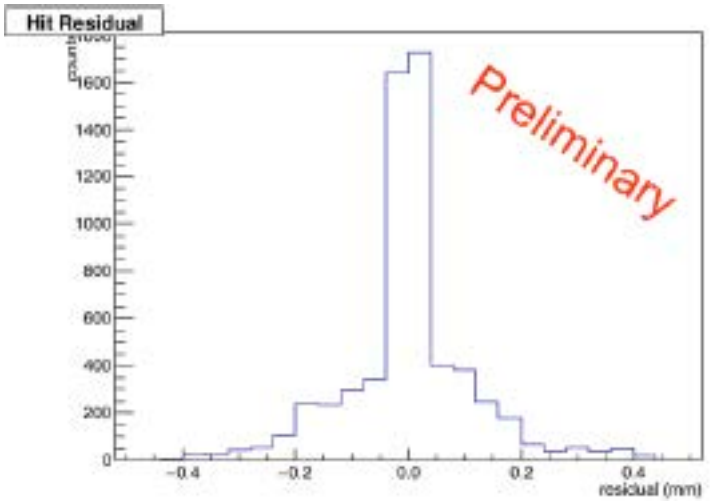


Chamber being leak tested

Target Cool-Down Curve from 12.02.2018!



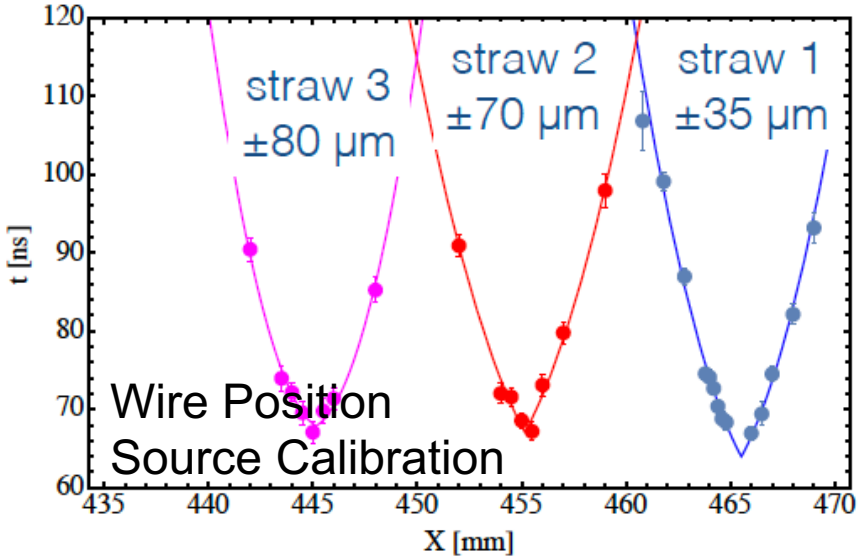
Straw Tube Tracker

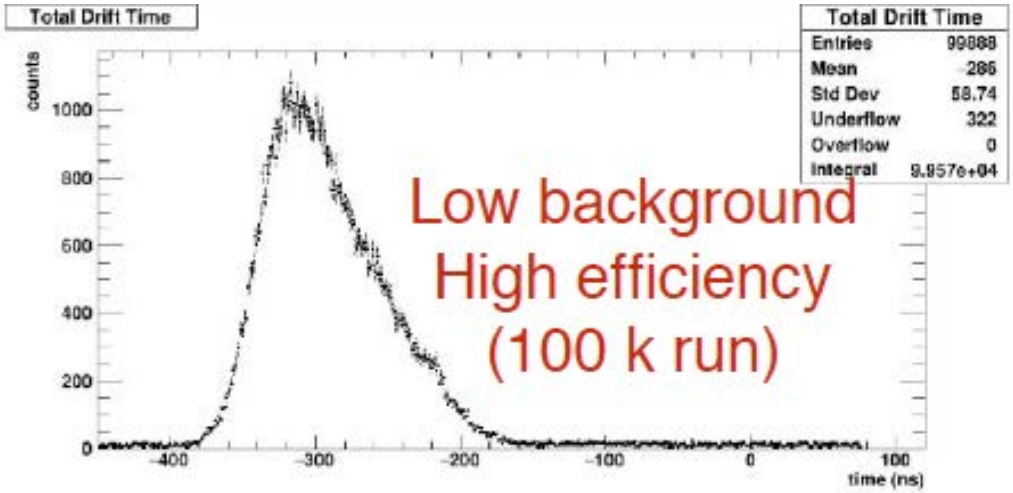


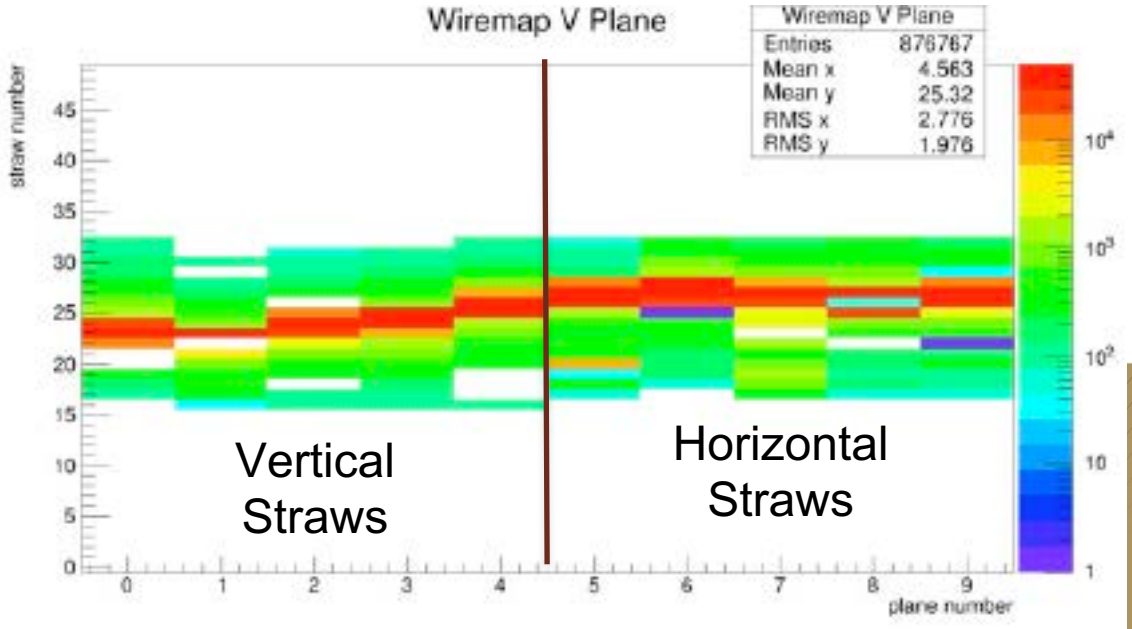
GenFit: 120μm residuals

Parameter	Performance Requirement	Achieved
Position Resolution	150 μm	✓ <120 μm
Efficiency	99.8% tracking	≈ 99% in prototype; moderate
Positioning	≈0.1 mm, 0.2 mr in θ	not attempted; moderate
Positioning	≈0.5 mr pitch, yaw, roll	not attempted; moderate
Positioning	50 μm wire spacing	✓ 35μm achieved in dress rehearsal
Rate Capability	0.5 MHz	✓ achieved in dress rehearsal

Straw Tube Tracker







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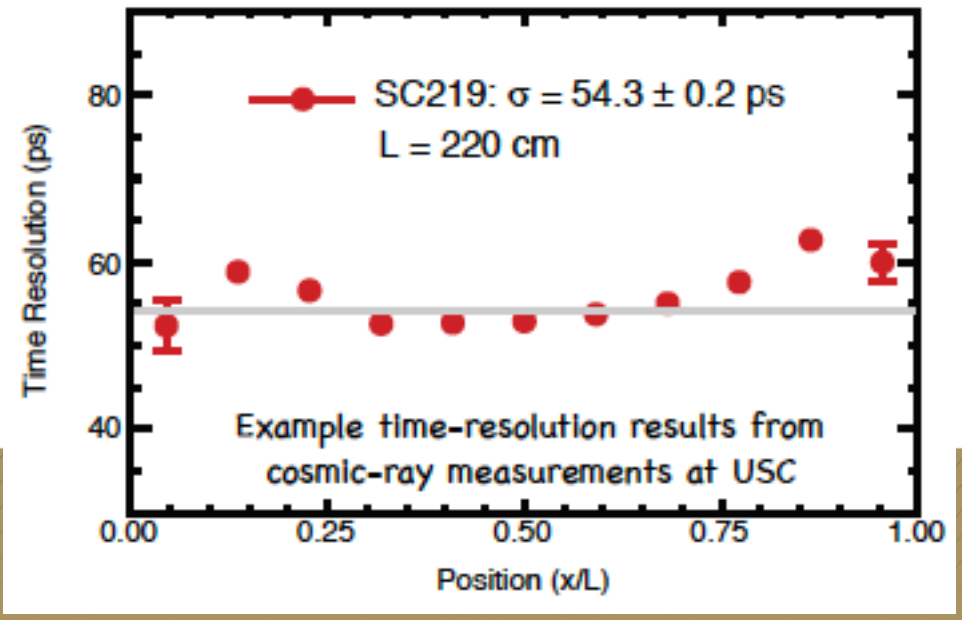
Scattered Particle Scintillators

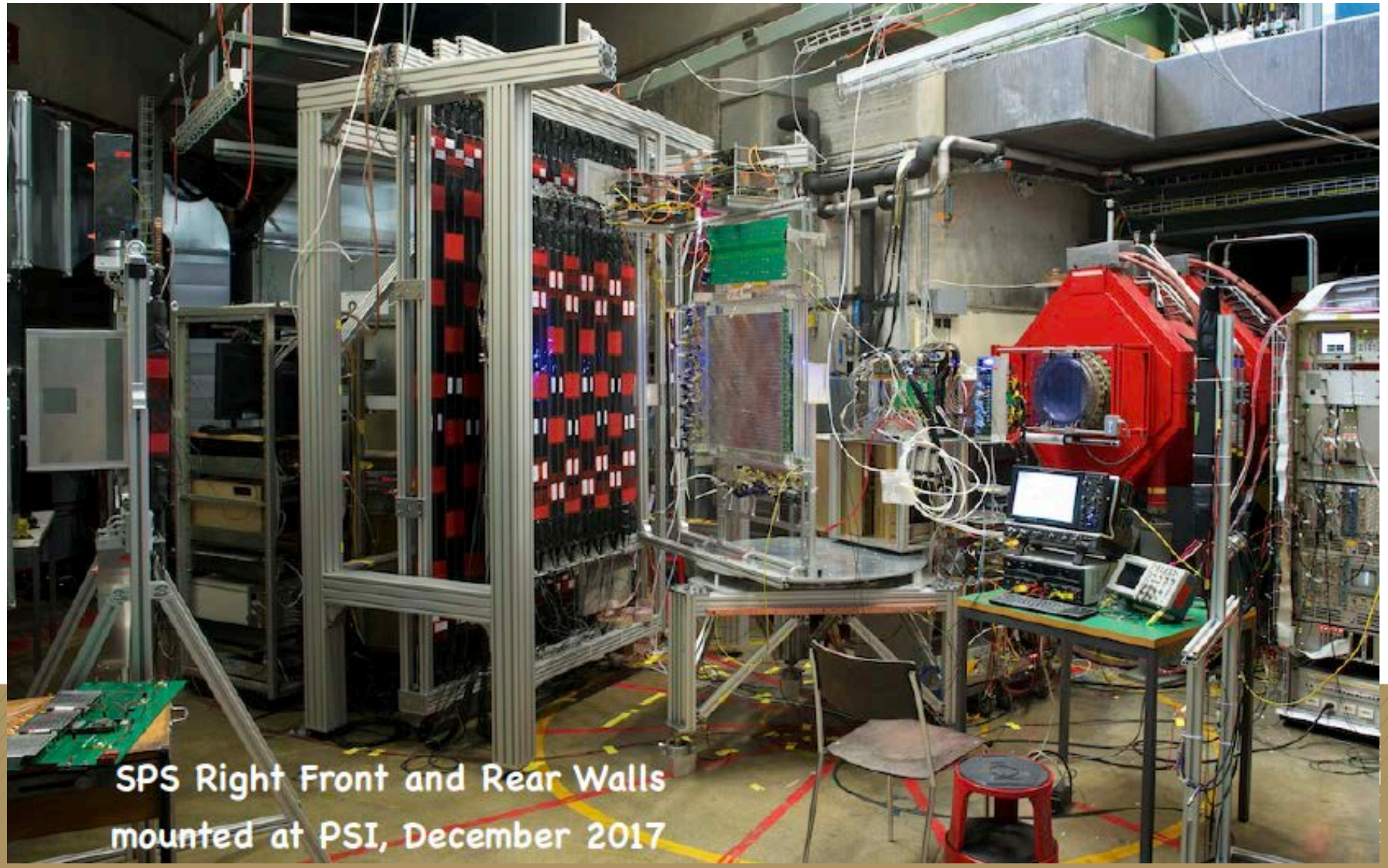
Parameter	Performance Requirement	Achieved
Time Resolution	≈60 ps / plane	✓ 55 ps
Efficiency	99%, $\ll$ 1% paddle to paddle uncertainty	✓ 99%, paddle to paddle not attempted, moderate
Positioning	≈1 mm, ≈1 mr	not attempted; easy
Rate Capability	0.5 MHz / paddle	✓ 1 MHz

Scattered Particle Scintillators

- One complete side mounted at PSI
- Time resolution exceeds requirements:
  - ✓ σ (front) < 50ps
  - ✓ σ (rear) < 60ps

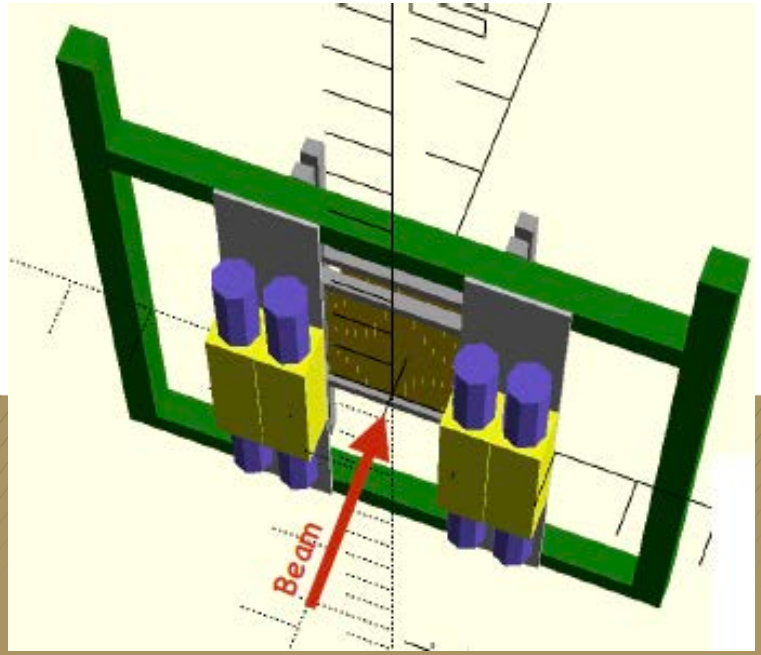


Scattered Particle Scintillators

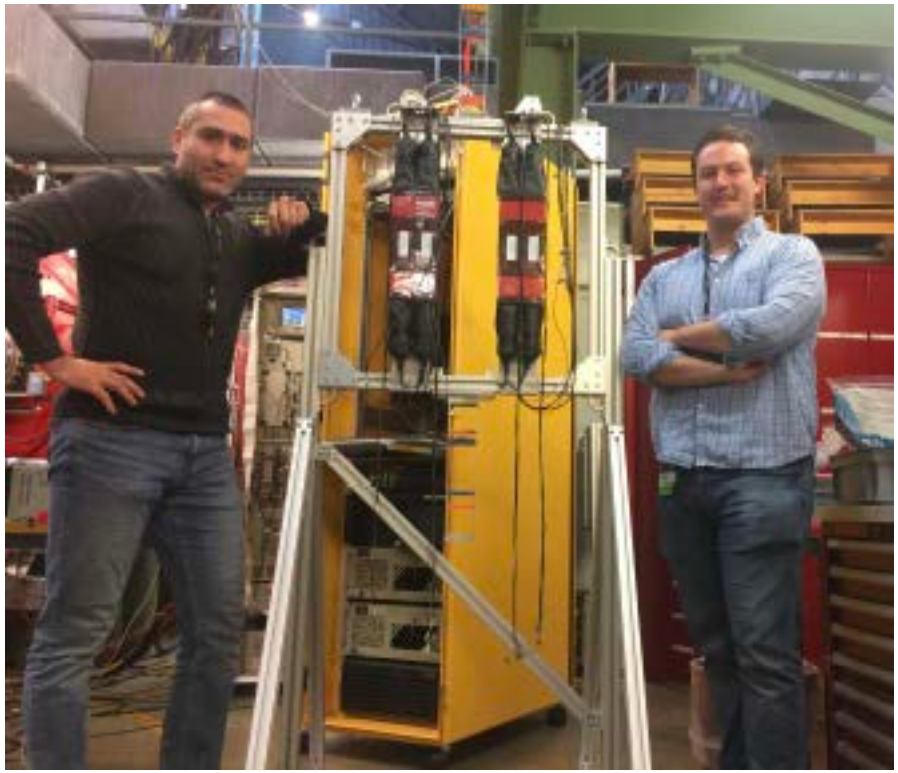


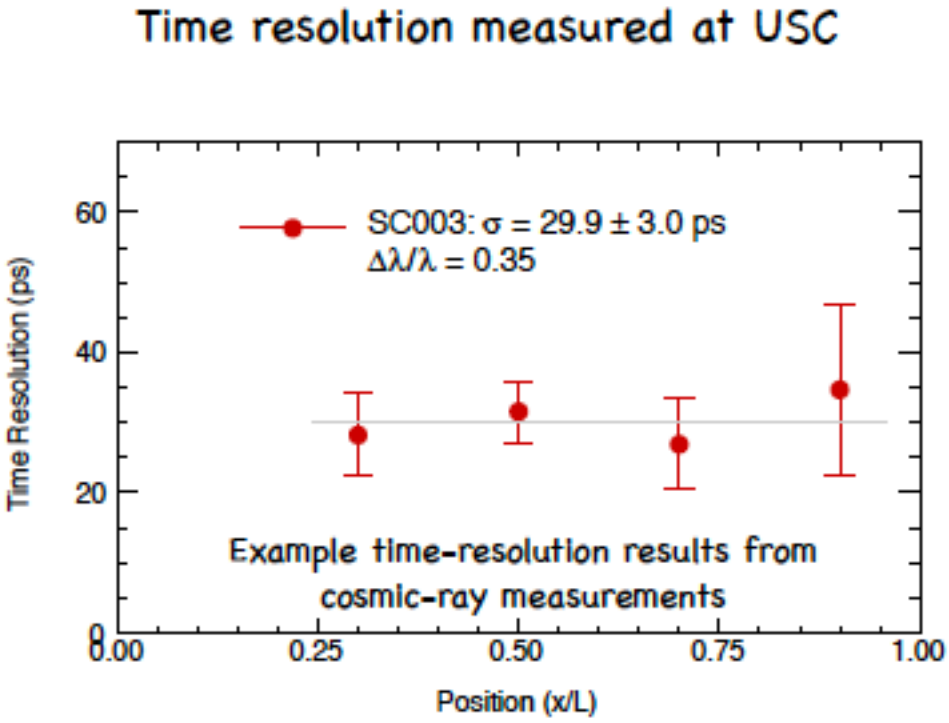
Beam Monitor

Parameter	Performance Requirement	Achieved
Time Resolution	< 100 ps / paddle (bar)	✓ 60 ps (30 ps)
Efficiency	99%	✓99.8%
Positioning	≈1 mm, ≈1 mr	not attempted; easy
Rate Capability	3.3 MHz / plane	not attempted; easy

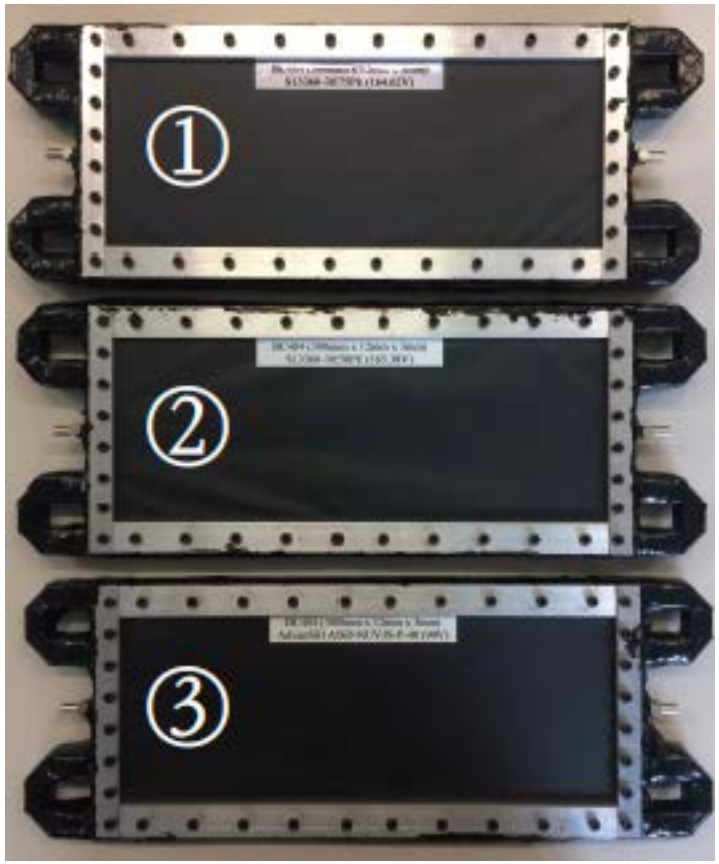


Beam Monitor Scintillators

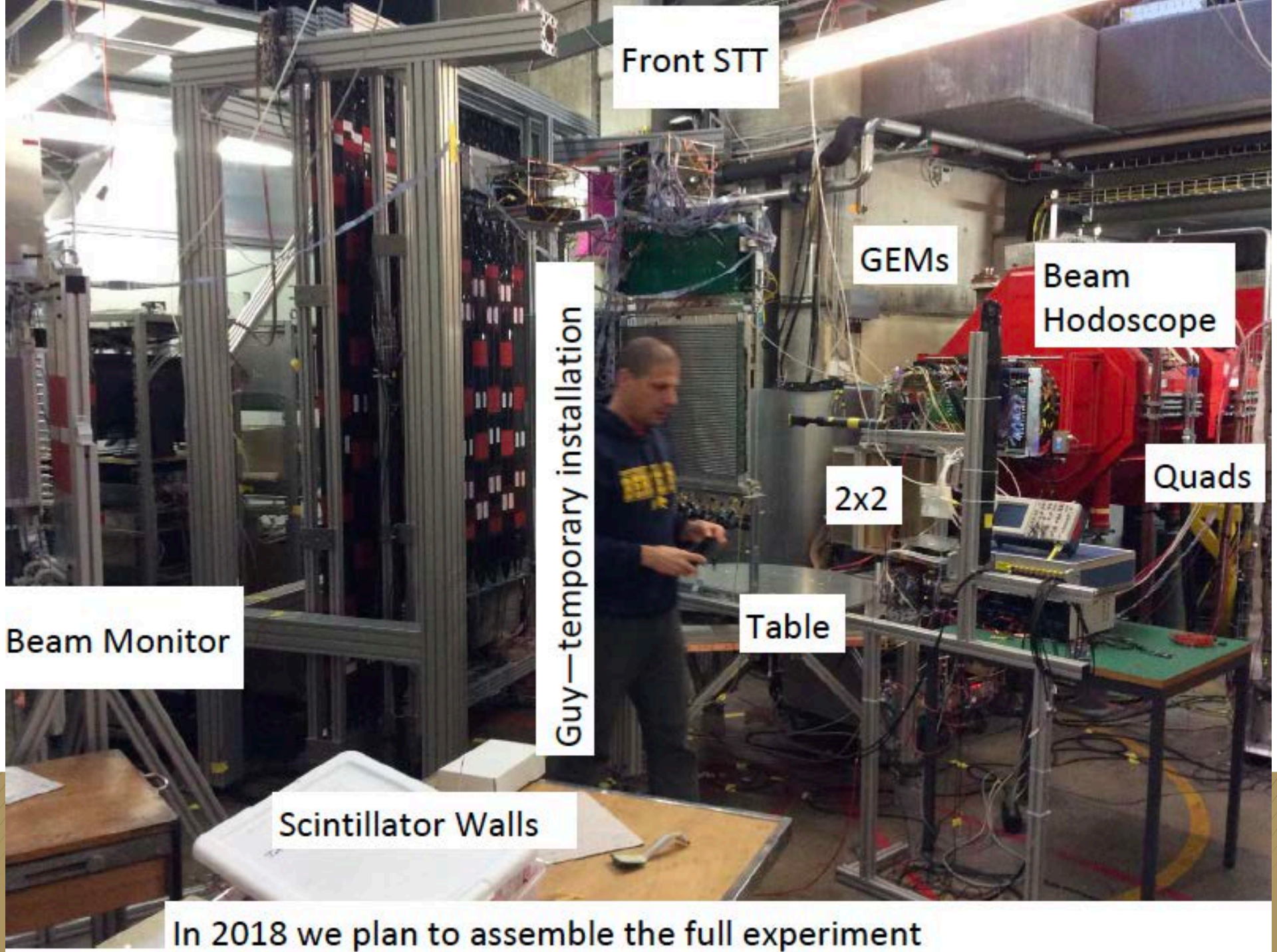




Beam Monitor Thin Scintillator SiPM Detectors



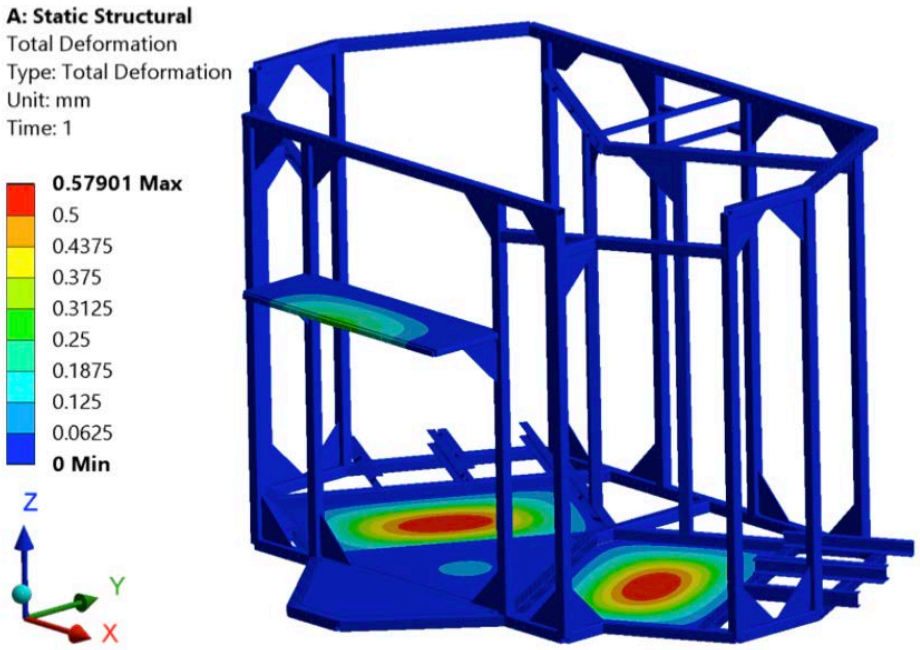
	SiPM	σ_T	Efficiency
1	S13360-3075PE	59 ps	99.9%
2	S13360-3050PE	60 ps	99.7%
3	AdvanSiD	65 ps	99.0%



In 2018 we plan to assemble the full experiment

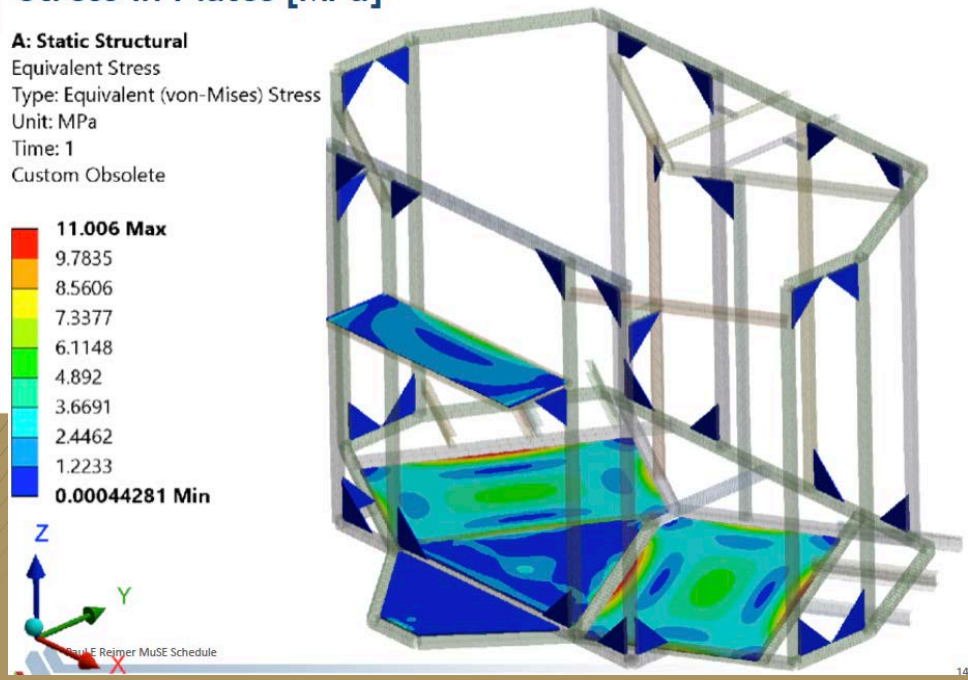
Crane-able Platform

Total Deflection [mm]



- Design by Argonne
- Passed stress analysis

Stress in Plates [MPa]



MUSE Beamtime Request: Inputs

- Long term MUSE request: 12 months of production data
- Moderate confidence we can be ready July 1st 2018
  - Limiting factor: new STT readout card production timeline
  - ***Should have more certainty by April 15th***
- Studied MUSE installation / de-installation
  - Remove MUSE platform from the hall: ***3 days***
  - Move MUSE into the hall and get ready to take beam: ***14 days*** (including target cool-down and straw alignment measurement)

MUSE Beamtime Request: Conclusion

- Plan: set up MUSE on platform in PiM1 April – June 2018
- Requested and preferred (single installation):
  - July 23rdst: 2 wks reinstallation + 2 wks of debugging time
  - September 1st: 4 months of production data
- Alternate scenario (assumes already set up in PiM1):
  - July 1st: 2 wks of debugging time + 2 wks test data
  - September 1st: 2 wks reinstallation + 3.5 months of production data
- Lose ≥15 days each installation / de-installation cycle