Preparations for Jeopardy PAC review of the Charged Pion Polarizability (CPP) experiment

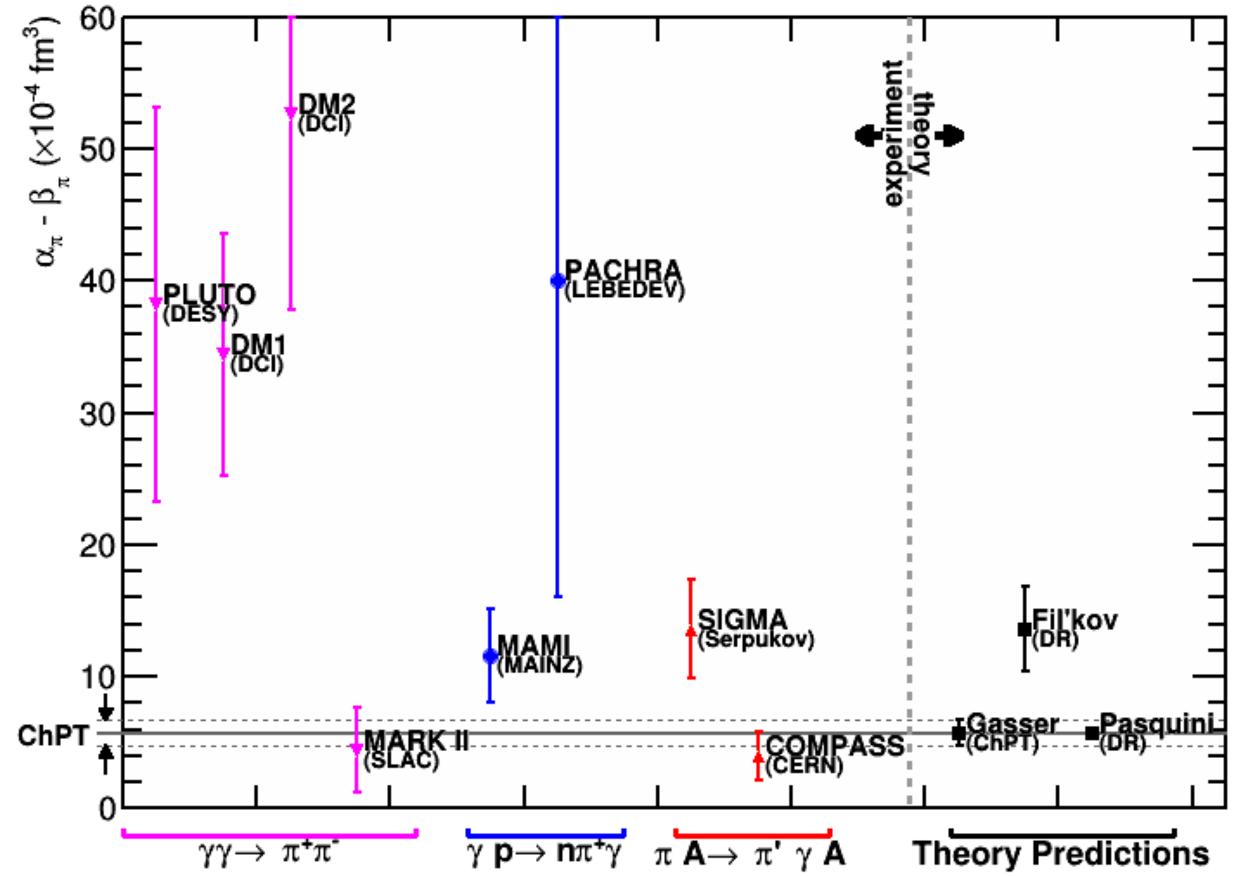
Need to prepare a 10 page written update + 10 slide/10 min presentation, both focusing on progress since PAC approval

Outline of jeopardy document:

- Overview of experimental goals
- New results on CPP since last PAC: Compass result
- GEANT4 design studies for the muon chambers and iron absorbers
- Design for detector and shielding installation in Hall D
- Muon chamber contruction and testing
- TOF trigger studies for CPP
- Development of MVA tools for the analysis of:
    i. $\gamma p \to e^+e^-(p)$ Bethe-Heitler events (CPP background)
    ii. $\gamma p \to \pi^+\pi^-(p)$ low-t, low-s events ($\sim$ CPP signal)
- Update on theoretical calculations

- **Overview of experimental goals**
  - ✓ Precision measurement of charged pion polarizabity
  - ✓ Test of low-energy QCD
  - ✓ CPP is complementary to precision measurements of neutral pion lifetime (see *I. Larin et al., Science, 368:506-509, 2020*) in that CPP probes the even parity sector of QCD, and $\Gamma_{\pi^0 \to \gamma\gamma}$ probes the odd parity (anomalous) sector.
  - ✓ Measurements of CPP and NPP constrain and test calculations of hadronic-light-by-light scattering corrections to muon g-2

- **New results for CPP since the last PAC: the COMPASS result**



160 GeV pions on Nickel: $\pi^- Ni \to \pi^- \gamma\ Ni$

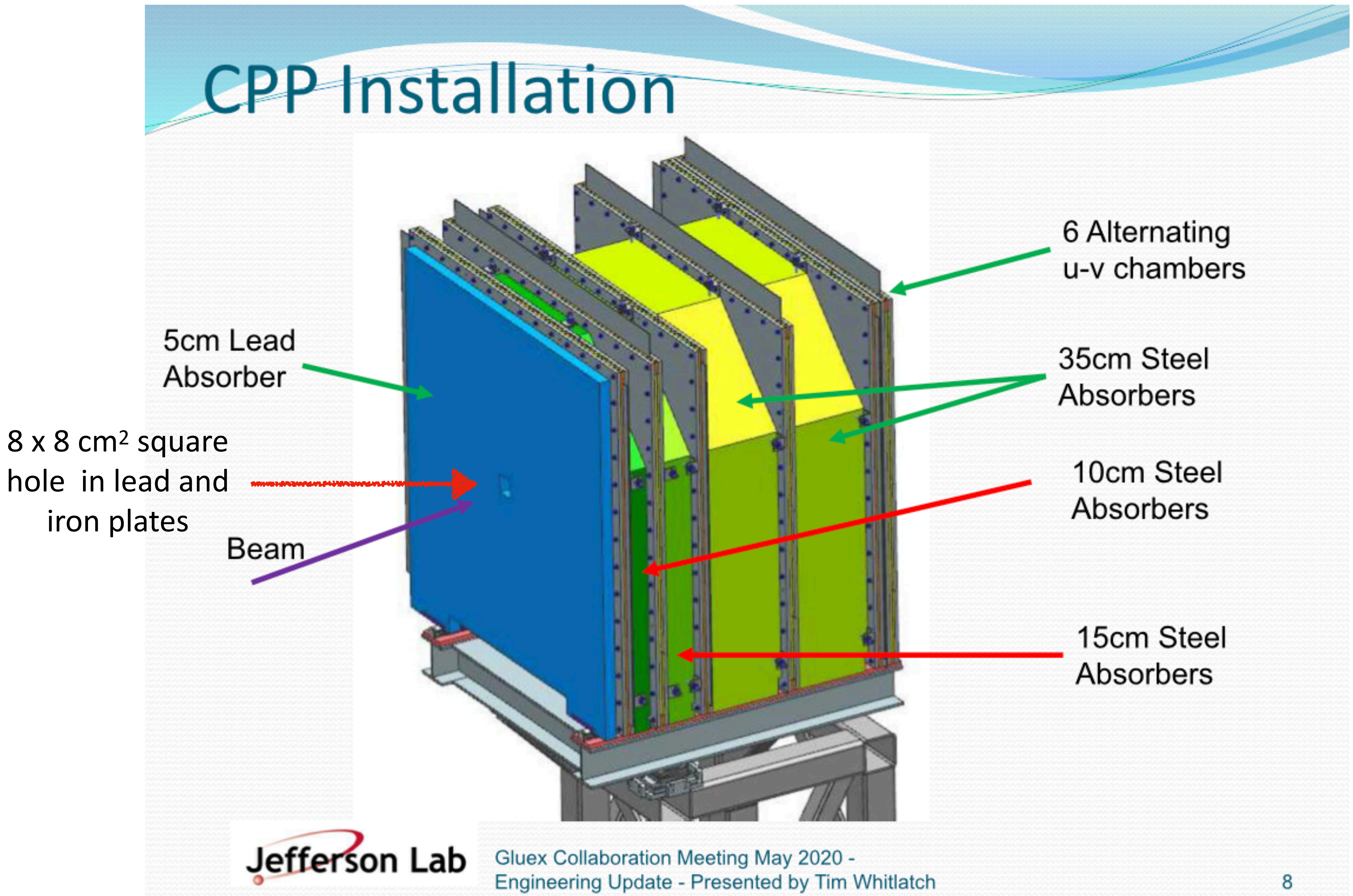
Result is very sensitive to dN/dE_γ at $E_\gamma \approx E_{beam}$. Effect of nuclear coherent and incoherent backgrounds, e.g. $\pi^- A \to \rho^- A \to \pi^- \gamma A$, and $\pi^- A \to \rho^- A \to \pi^- \pi^0 A$?

$\alpha_\pi - \beta_\pi = 4.0 \pm 1.2(stat) \pm 1.4(sys) \times 10^{-4} fm^3$, analyzed with the assumption $\alpha_\pi = -\beta_\pi$

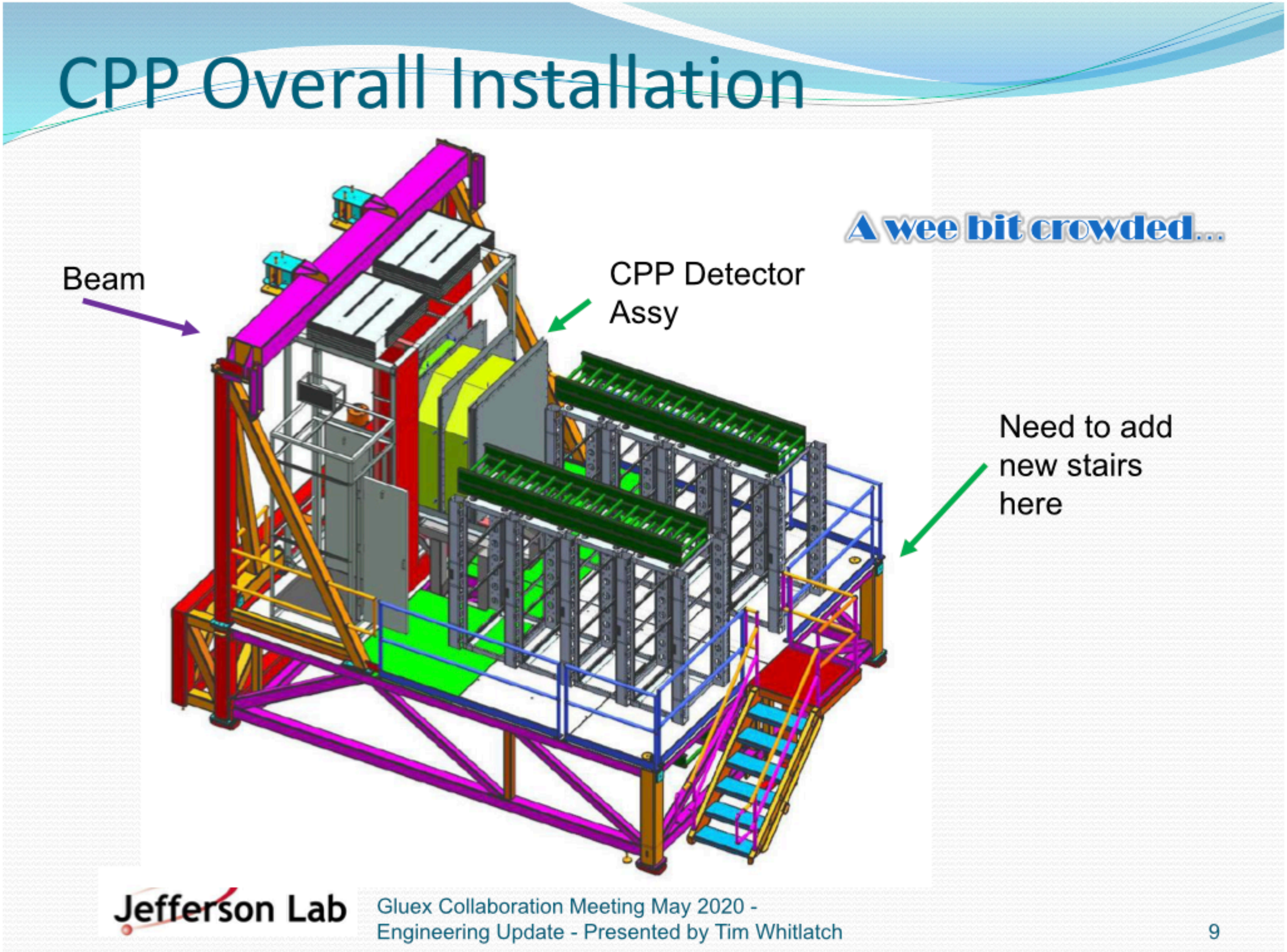
✓ The JLab and COMPASS experiments have different backgrounds and systematic errors. The measurements are complementary

- **GEANT4 design studies for the muon chambers and iron absorbers**

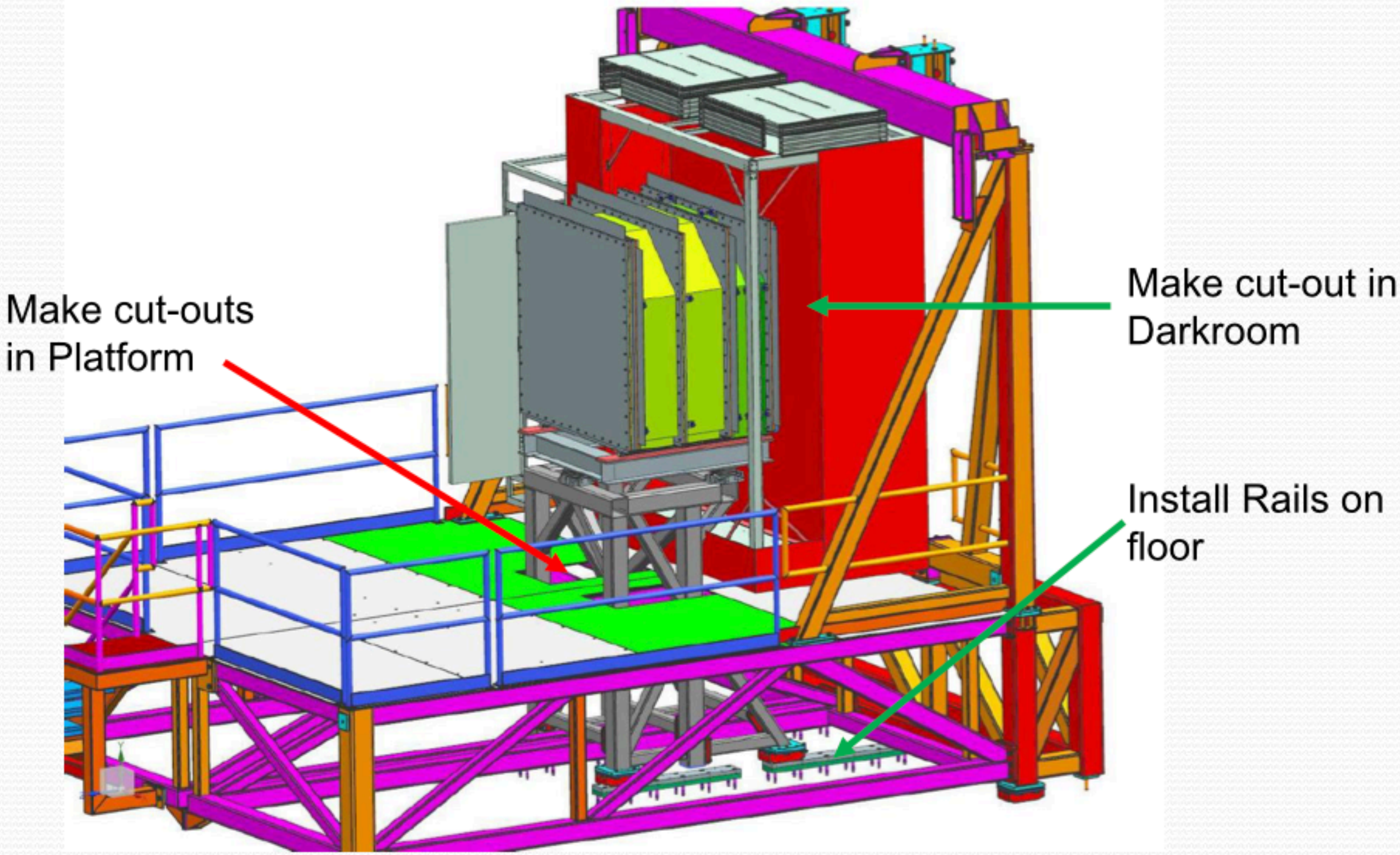
✓ Design studies indicate that nearly equivalent π/μ separation can be obtained for 5 cm of lead + 95 cm of iron and 6 muon chambers, as compared to 140 cm of iron and 8 muon chambers.



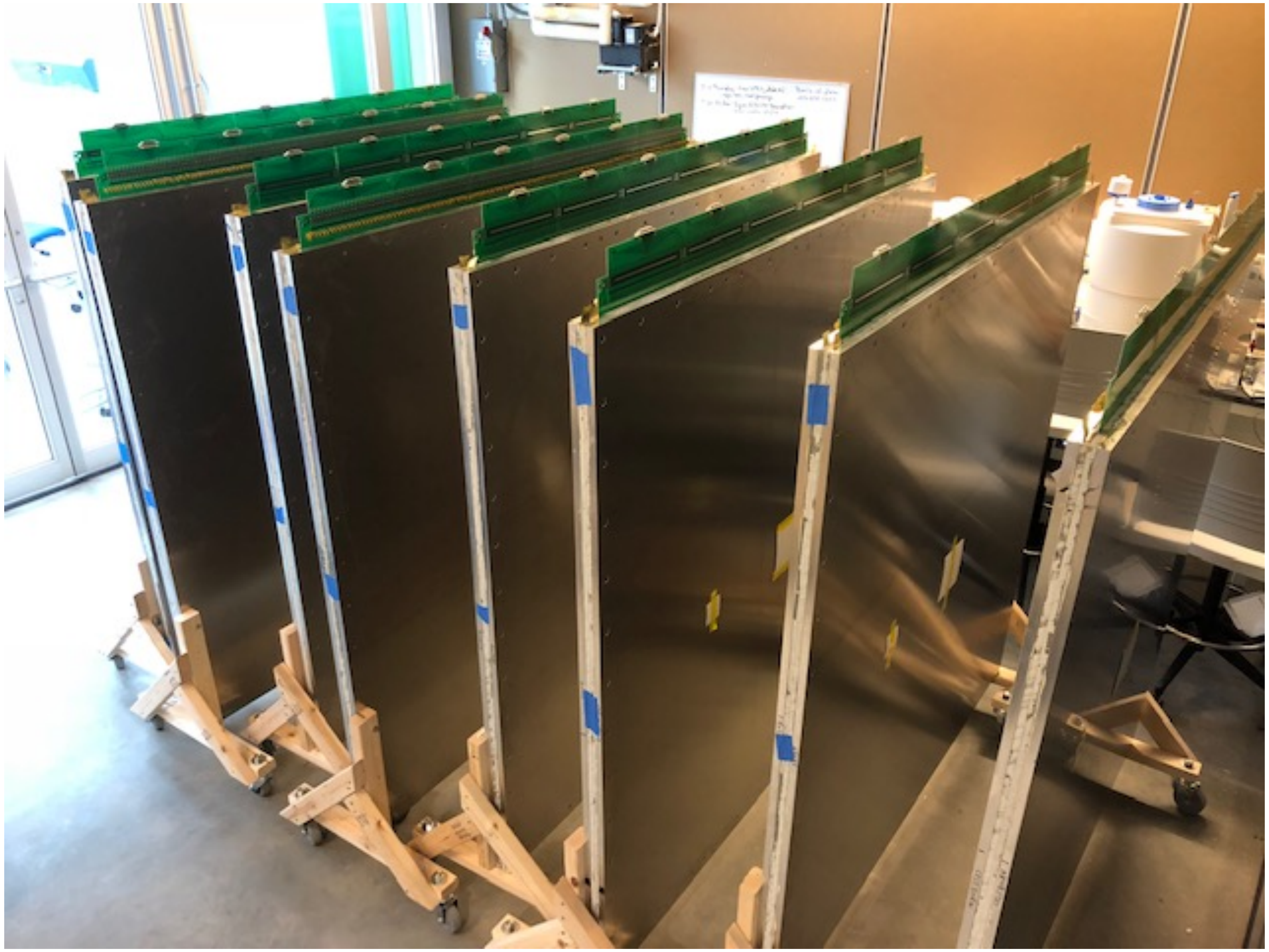
- **Design for detector and shielding installation in Hall D**



Dark Room and Platform Modification



- **Muon chamber contruction and testing**



Sense wire pitch: 1 cm

Wire to cathode plane distance: 1 cm

Sensitive area: 60 x 60 in^2

Number of channels: 144

Operating voltage: +1800 V

Gas mixture: Ar:CO_2 90:10

Approximate operating gain: 10^5

- **Muon chamber contruction and testing**

✓Early 2018 beam test in Hall D during GlueX running established that chambers can operate in this environment

- **TOF trigger studies for CPP**

TOF trigger modifications	Old TOF +	Old TOF + 1.7 rad.len. shield 60x60cm +	New TOF with DIRC installed	New TOF, no DIRC
	Feb. 2019	Feb. 2019	Dec 2019	July 2020 ?
"Default": at least 4 TOF hits, at least one hit per plane	320 kHz	175kHz	28kHz	?
Signal threshold increased to ~50mV	250kHz	105kHz	19kHz	?
At least 2 hits per plane	270kHz	135kHz	22kHz	?
All above plus R >18cm and cos θ <0 cuts	160kHz	55kHz		?

+ platform was 1.2 m downstream, and DIRC partly installed

✓A test run with the DIRC removed and the TOF in the nominal position can tell us what to expect for CPP run conditions, and allow us to optimize TOF paddle grouping in the trigger word. A lead shielding option during the test run would be useful.

- **Development of MVA tools for the analysis of:**
  i. $\gamma p \rightarrow e^+e^-(p)$ Bethe-Heitler events (CPP background)
  ii. $\gamma p \rightarrow \pi^+\pi^-(p)$ low-t, low-s events ($\sim$ CPP signal)

Analysis restricted to low-t: both tracks go into the TOF and FCAL

Detection of recoil proton not required

MVA is trained on: $e^{\pm}$ tracks from the simulation, and
$\pi^{\pm}$ tracks from $\gamma p \rightarrow \pi^+\pi^- p$ data

✓ Andrew Schick will present results on e/π separation for CPP at an upcoming working group meeting.

- **Update on theoretical calculations**

✓ 2008, the first "modern" (i.e. reliable) dispersion theory calculation for the polarizability effect in $\gamma\gamma \to \pi^+\pi^-$ by Pasquini et al., Phys. Rev. C 77, 065211 (2008).

✓ 2016 Dai and Pennington publish a dispersion analysis for pion polarizabilities from $\gamma\gamma \to \pi\pi$ data based on their global analysis of $\gamma\gamma \to m^*m$ data, Phys. Rev. D 94, 116021 (2016).

✓ ~7 years ago the Mainz Prisma Cluster of Excellence establishes calculation of hadronic light-by-light contribution to muon g-2 as a high priority, calculations of $\gamma^*\gamma^* \to \pi\pi$ are a key ingredient to this. Marc Vanderhaeghen and collaborators have calculations for $\gamma^*\gamma^* \to \pi\pi$: arXiv:1909.04158 **[hep-ph],** arXiv:1901.10346 **[hep-ph]** and arXiv:1810.03669 **[hep-ph]**. CPP, along with NPP and the neutral pion lifetime and form factor, provide a constraint, test, and input for HLBL calculations