# BetaCage: an ultra-sensitive screener for surface contaminants

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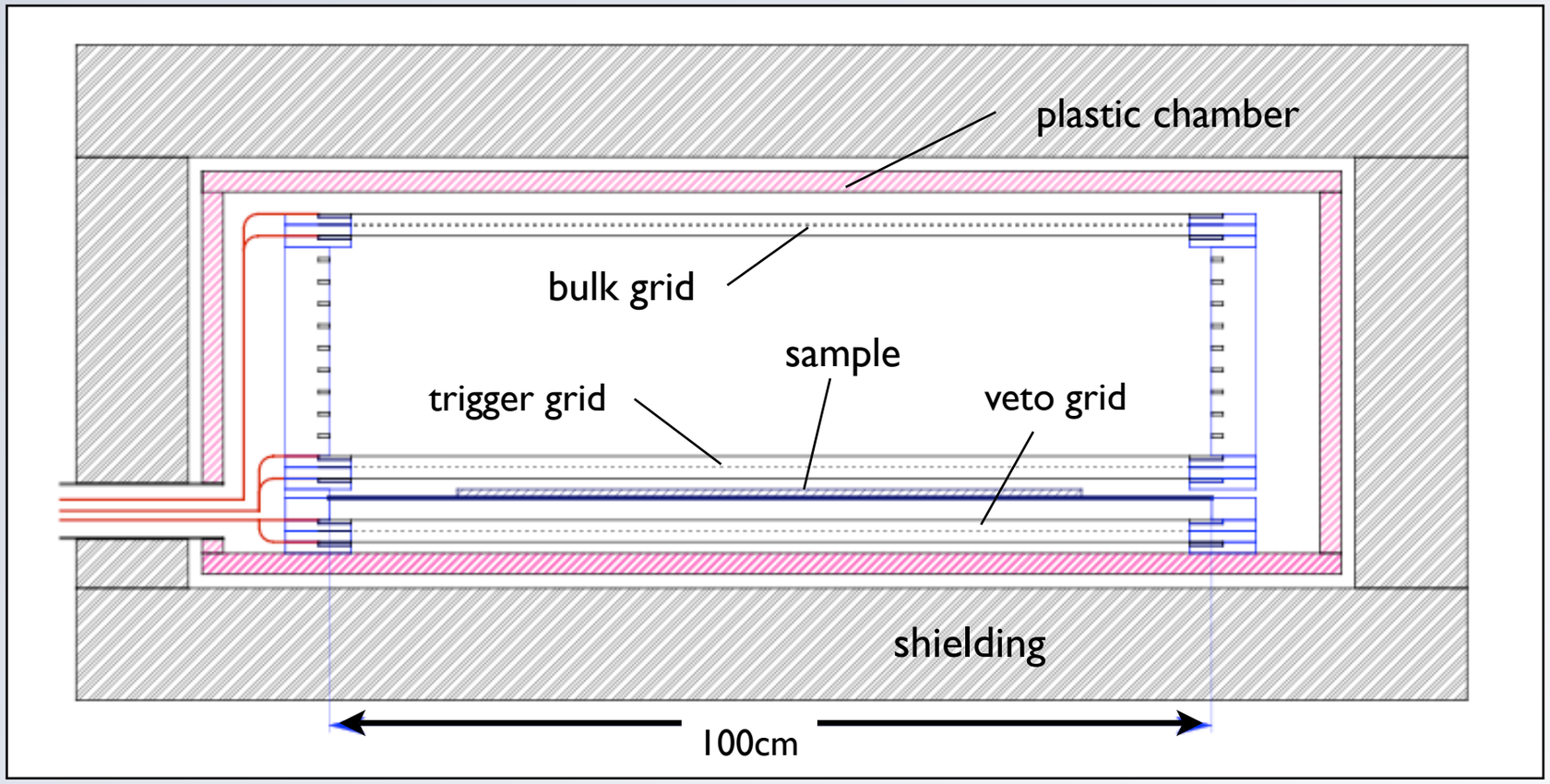
# Motivation

- CDMS limiting background is betas from surface contamination
  - Requirement for SuperCDMS SNOLAB (~100kg Ge) is ~ $2 \times 10^{-5}$ cm$^{-2}$ keV$^{-1}$ day$^{-1}$
- Challenges with traditional counting
  - Energy thresholds
  - Backscattering
  - Long integration time to achieve high sensitivity with small counting areas
  - Some isotopes probed only by beta emission

| **Method** | **Applicable Isotopes** |
|---|---|
| ICP-MS (1 ppb) | $^{40}$K $^{48}$Ca $^{50}$V $^{87}$Rb $^{92}$Nb $^{98}$Tc $^{113}$Cd $^{115}$In $^{123}$Te $^{138}$La $^{176}$Lu $^{182}$Hf $^{232}$Th $^{235}$U $^{238}$U $^{236}$Np $^{250}$Cm |
| ICP-MS (1 ppt) | $^{10}$Be $^{36}$Cl $^{60}$Fe $^{79}$Se $^{93}$Zr $^{94}$Nb $^{97}$Tc $^{99}$Tc $^{107}$Pd $^{126}$Sn $^{129}$I $^{135}$Cs $^{137}$La $^{154}$Eu $^{158}$Tb $^{166m}$Ho $^{208}$Bi $^{208}$Po $^{209}$Po $^{252}$Es |
| $\gamma$ (HPGe) | $^{40}$K $^{50}$V $^{60}$Fe $^{60}$Co $^{93}$Zr $^{92}$Nb $^{94}$Nb $^{93}$Mo $^{98}$Tc $^{99}$Tc $^{101}$Rh $^{101m}$Rh $^{102m}$Rh $^{109}$Cd $^{121m}$Sn $^{126}$Sn $^{125}$Sb $^{129}$I $^{134}$Cs $^{137}$Cs $^{133}$Ba $^{138}$La $^{145}$Pm $^{146}$Pm $^{150}$Eu $^{152}$Eu $^{154}$Eu $^{155}$Eu $^{157}$Tb $^{158}$Tb $^{166m}$Ho $^{173}$Lu $^{174}$Lu $^{176}$Lu $^{172}$Hf $^{179}$Ta $^{207}$Bi $^{208}$Bi $^{232}$Th $^{235}$U $^{238}$U $^{236}$Np $^{241}$Pu |
| $\alpha$ | $^{210}$Pb $^{208}$Po $^{209}$Po $^{228}$Ra $^{227}$Ac $^{232}$Th $^{235}$U $^{238}$U $^{236}$Np $^{241}$Pu $^{250}$Cm $^{252}$Es |
| $\beta$/ppt MS | $^{10}$Be $^{36}$Cl $^{79}$Se $^{97}$Tc $^{107}$Pd $^{135}$Cs $^{137}$La $^{154}$Eu $^{209}$Po |
| $\beta$ only | $^{3}$H $^{14}$C $^{32}$Si $^{63}$Ni $^{90}$Sr $^{106}$Ru $^{113m}$Cd $^{147}$Pm $^{151}$Sm $^{171}$Tm $^{194}$Os $^{204}$Tl |

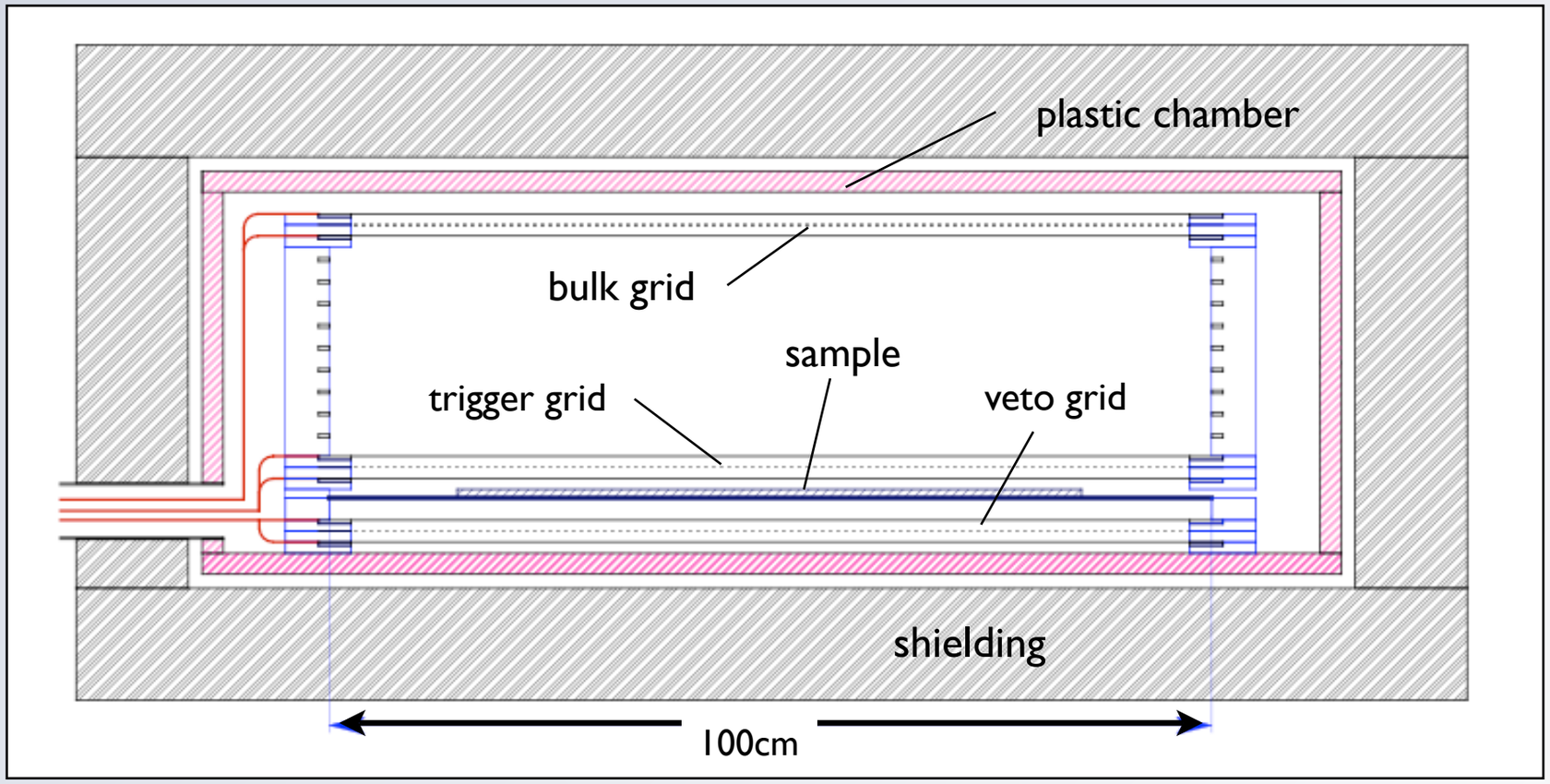
# BetaCage

- Time Projection Chamber
  - Neon + Methane (quench)
  - Trigger, Veto MWPCs for rejection of through-going electrons
  - 40cm drift region (optimized for <200 keV electrons)
  - Position information to define fiducial volume and reject self-background
- 1 $m^2$ counting area
  - Rapid turnaround for measuring samples



# BetaCage

- Ultraclean materials
  - Counted plastics for support structure, chamber
  - Stainless Steel sense wires
  - Assembly in glovebox, in radon suppressed cleanroom
- Underground + Shielding
  - Minimize external gamma background to ~1 dru Ge equivalent



# Backgrounds and Sensitivity

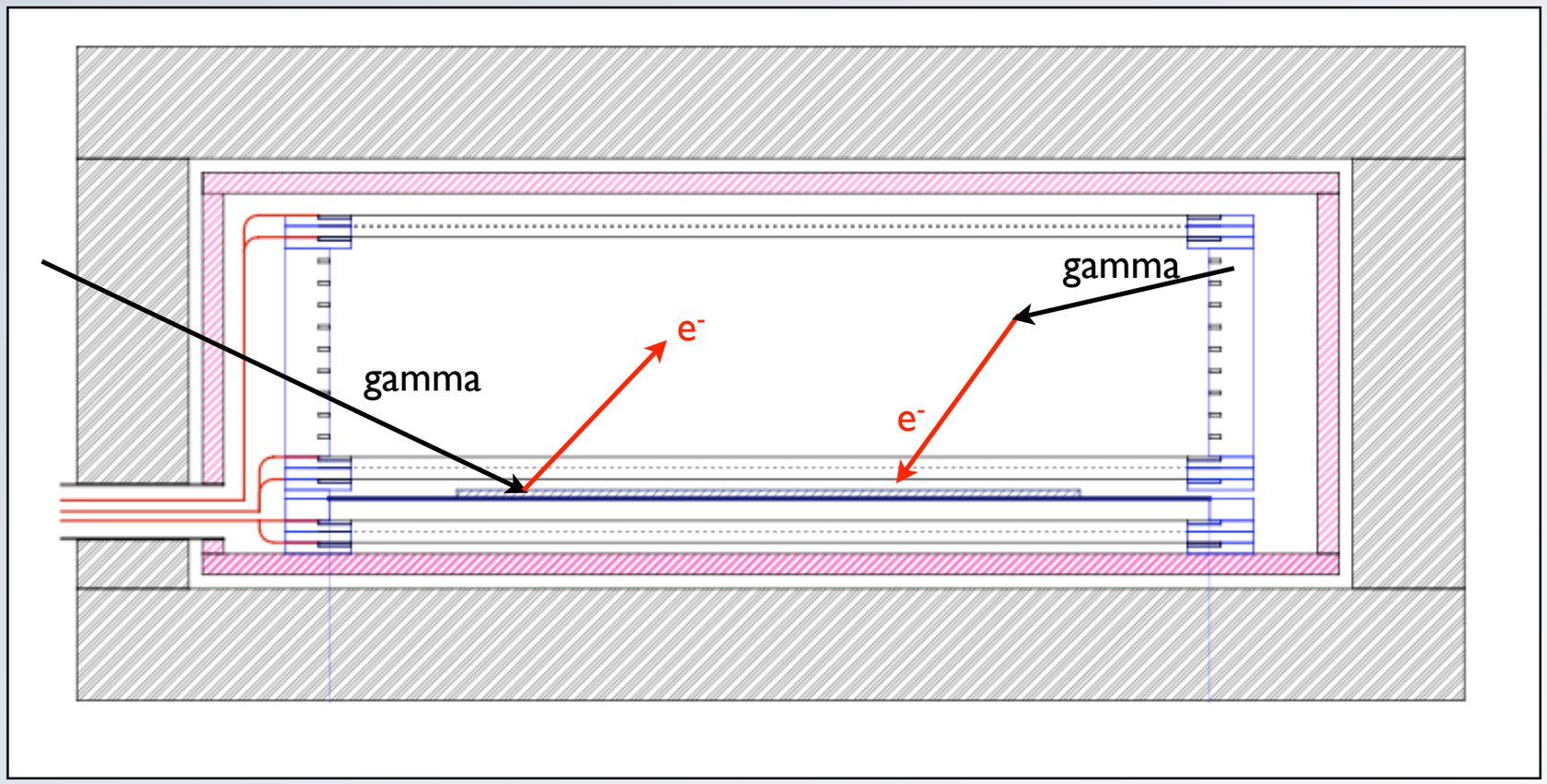
- Primary background from gammas (~$3 \times 10^{-5}$ $cm^{-2}$ $keV^{-1}$ $day^{-1}$)
  - Interact in gas, resulting in electron triggers
  - Interact in sample, resulting in electron triggers
- Wire, $^{14}C$ backgrounds (<$10^{-6}$ $cm^{-2}$ $keV^{-1}$ $day^{-1}$)

**Sensitivity**

***$10^{-5}$ $cm^{-2}$ $keV^{-1}$ $day^{-1}$***

**Resolution**

***10-20% FS (200 keV)***

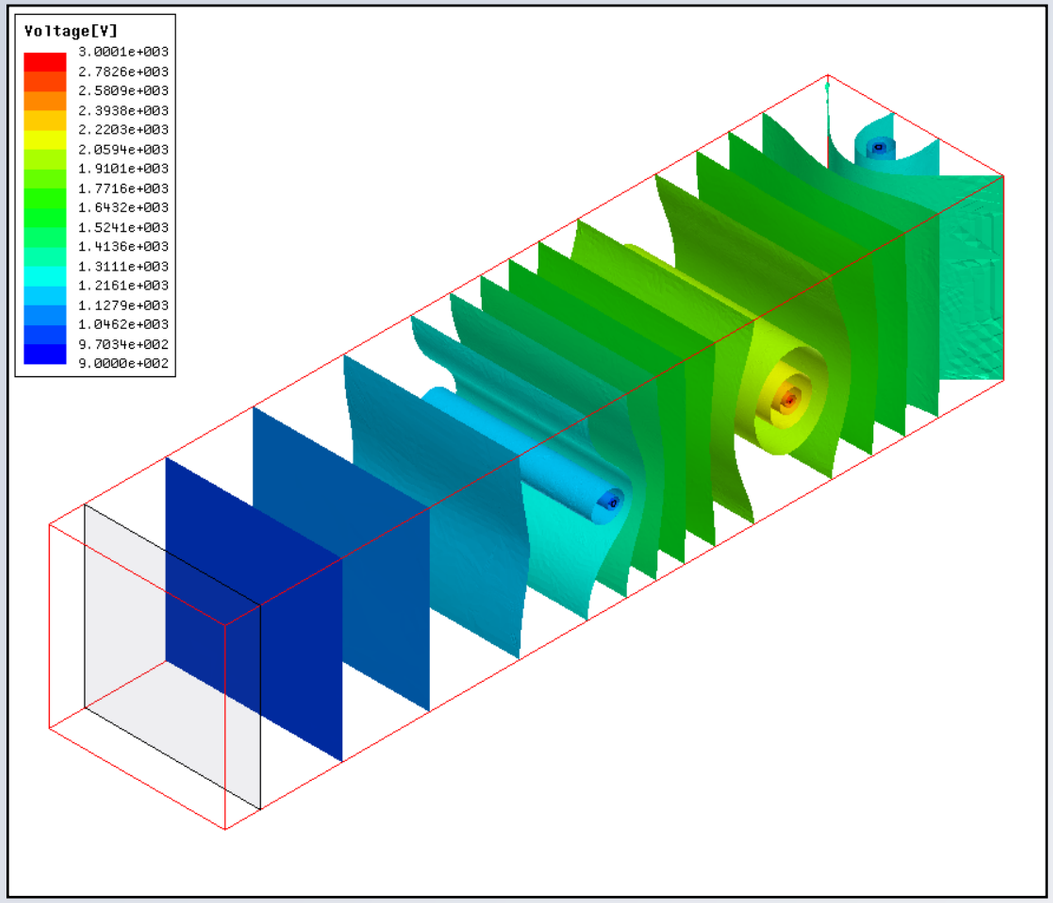


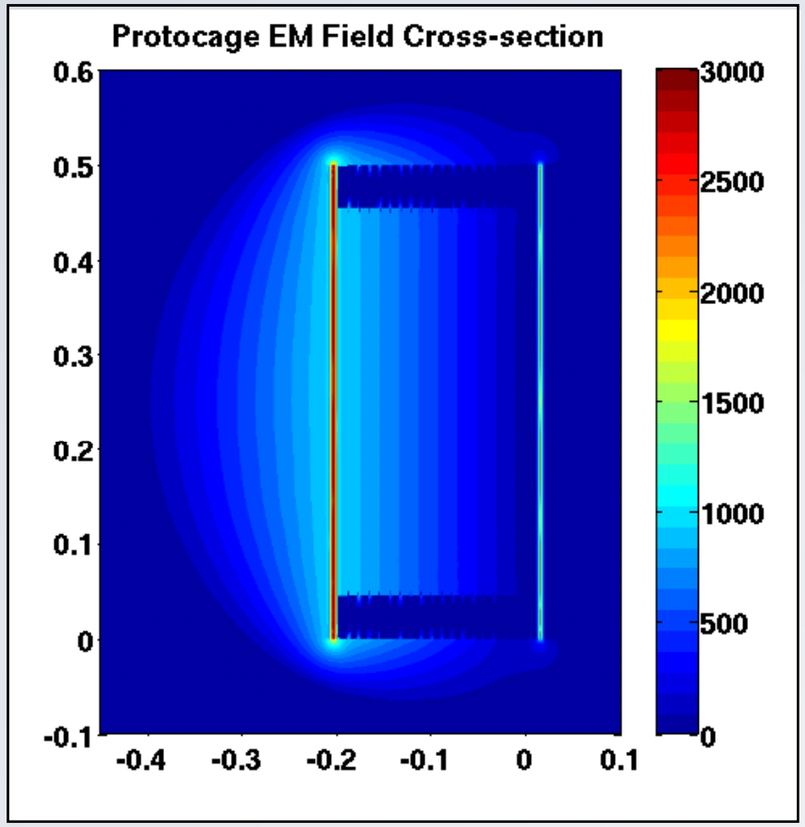
# Prototype development

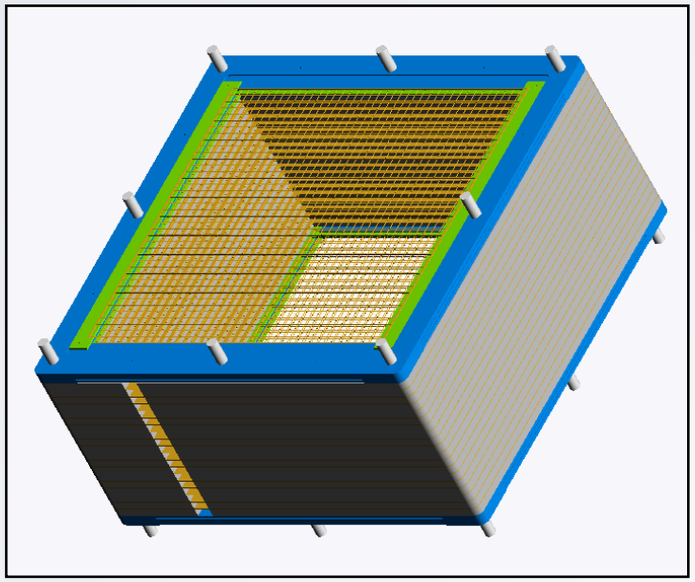
- Proof of principle
  - 50cm x 50cm x 20cm ($^{14}C$ beta endpoint 156 keV contained)
  - Designed without careful attention to radiopurity
  - Use cheaper & better characterized P-10 (90% Argon + 10% Methane)
- Goals
  - Learn to construct MWPCs
  - Study functionality with radioactive sources
  - Determine position resolution and rejection capability
  - Measure drift properties of Neon

# Prototype status

- EM simulations & overall design
  - Wire properties (diameter, pitch, spacing)
  - Field cage and drift times
  - Gain $10^4$-$10^5$

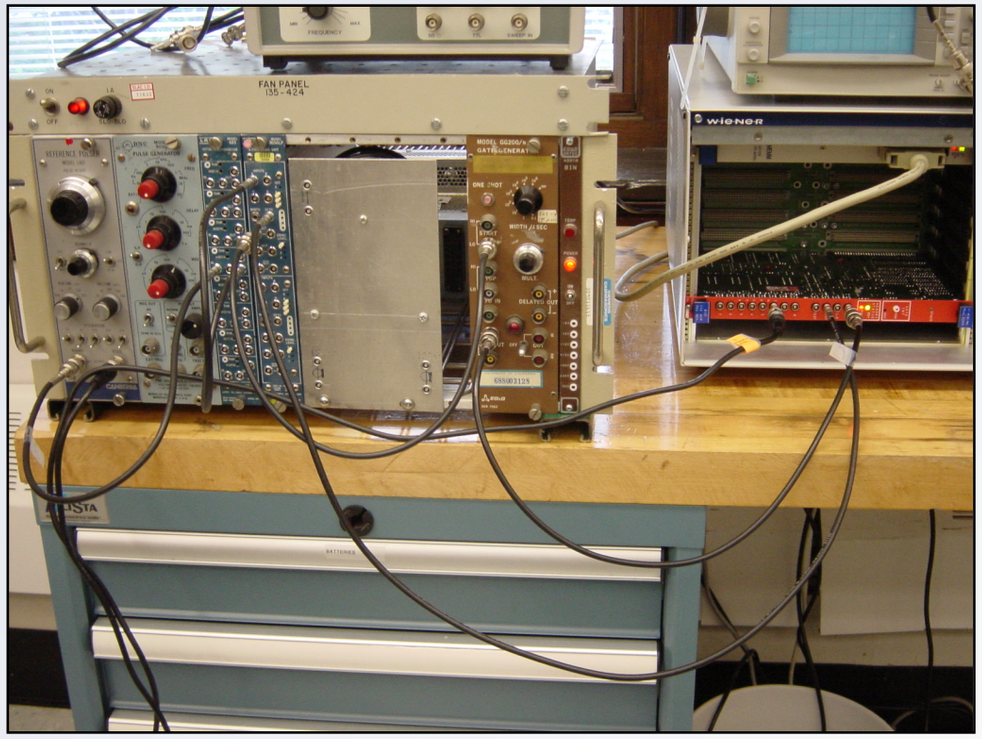


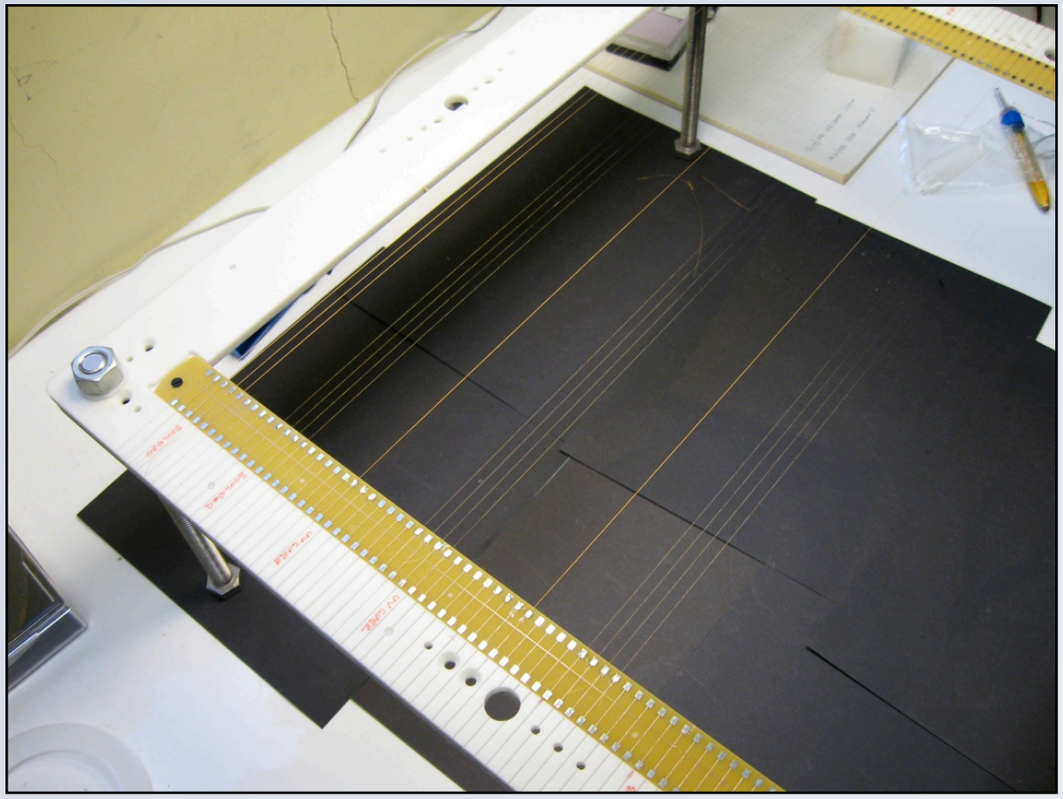
# Prototype status

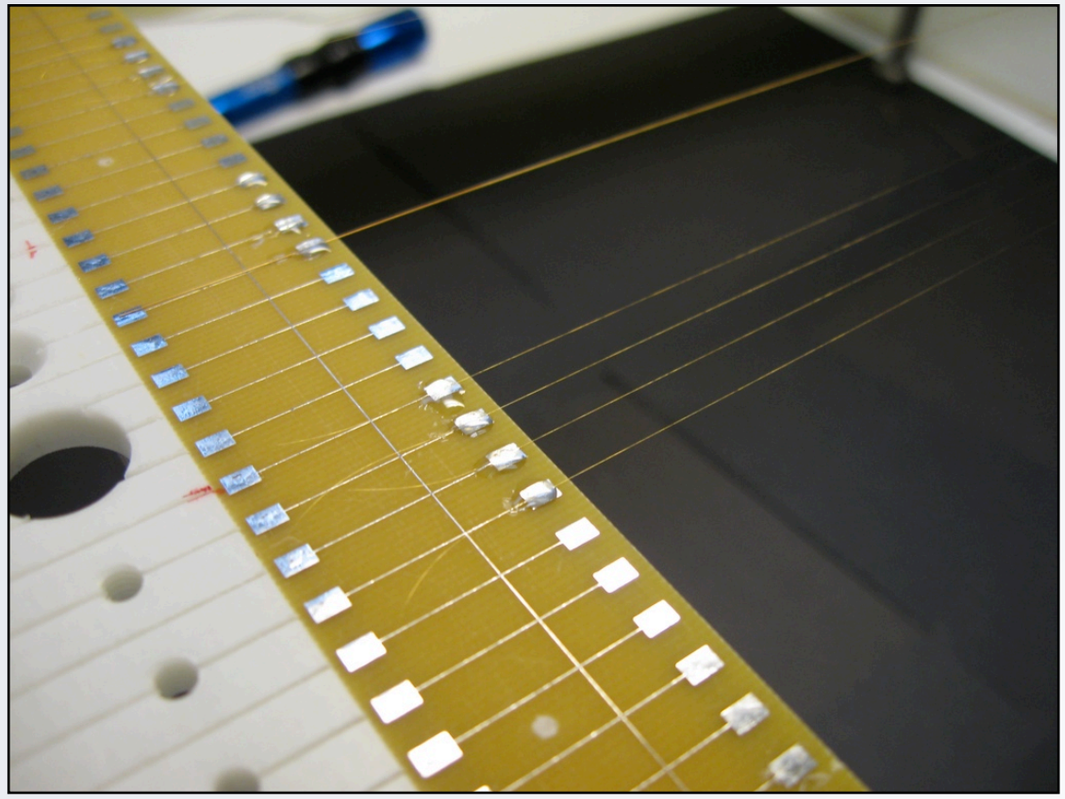
- Gas handling
- HV supply, filtering
- Basic DAQ



# MWPC Construction

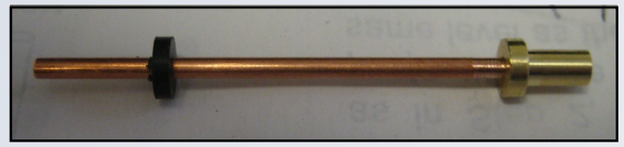
- Layered wire planes
  - Wire attachment with solder, epoxy, silver paint
  - Stresses in plastic hard to relieve
  - Mechanical tolerance required by gain variation constraints couldn't be met.

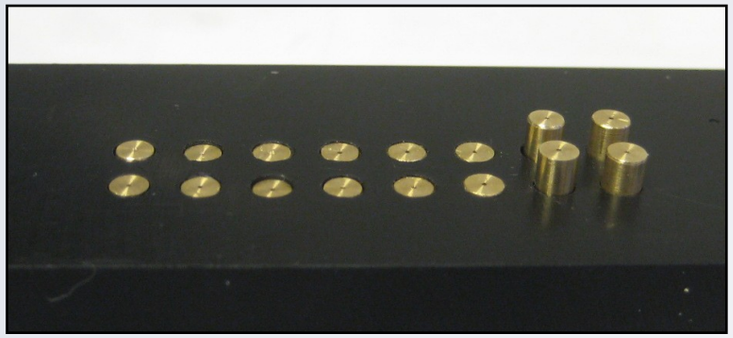


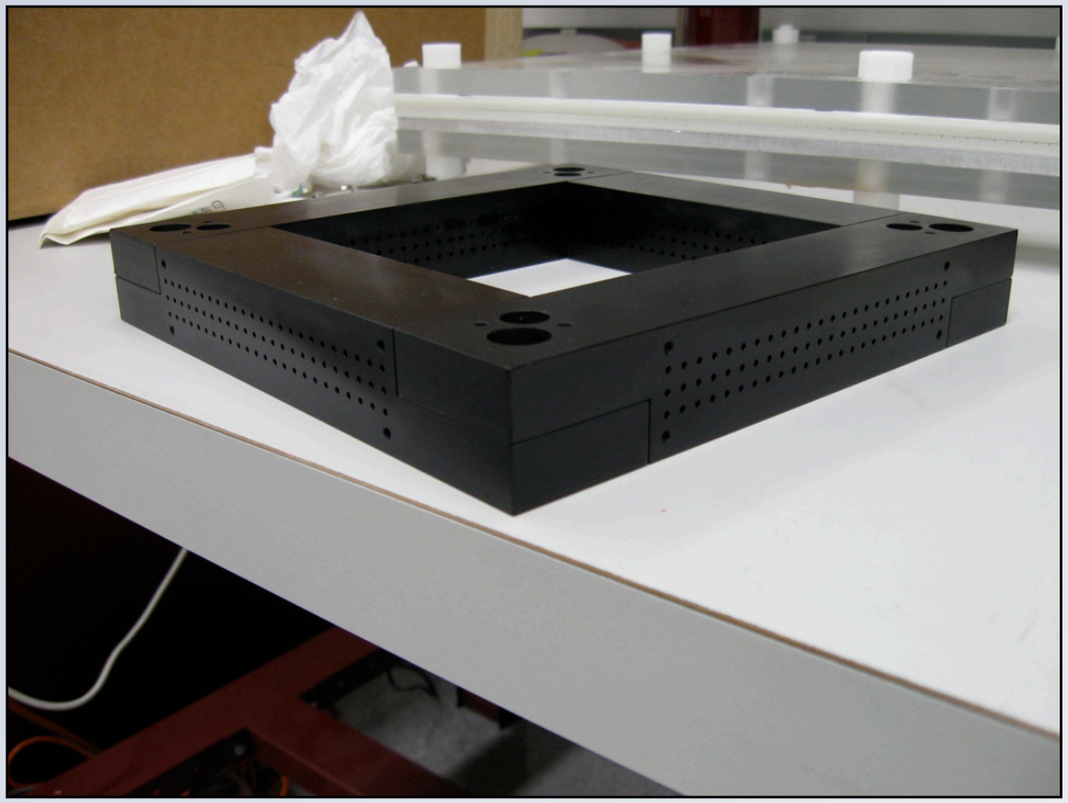


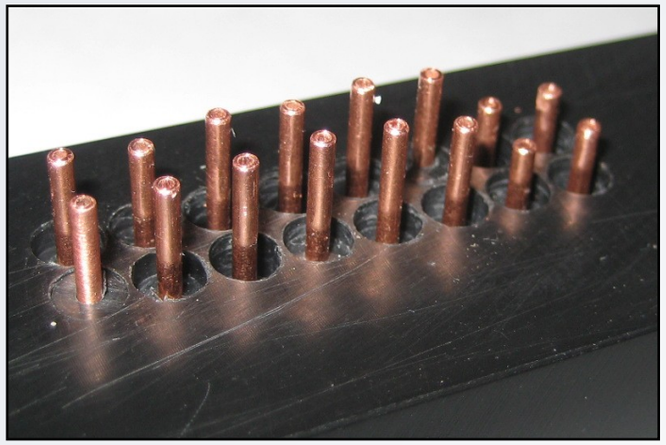
# MWPC Construction

- "Block" MWPC
  - Single MWPC assembled from 4 "blocks"
  - Wire attachment with precision crimped feedthrus
  - Annealing and machining cycles allow 50 micron precision in wire positioning

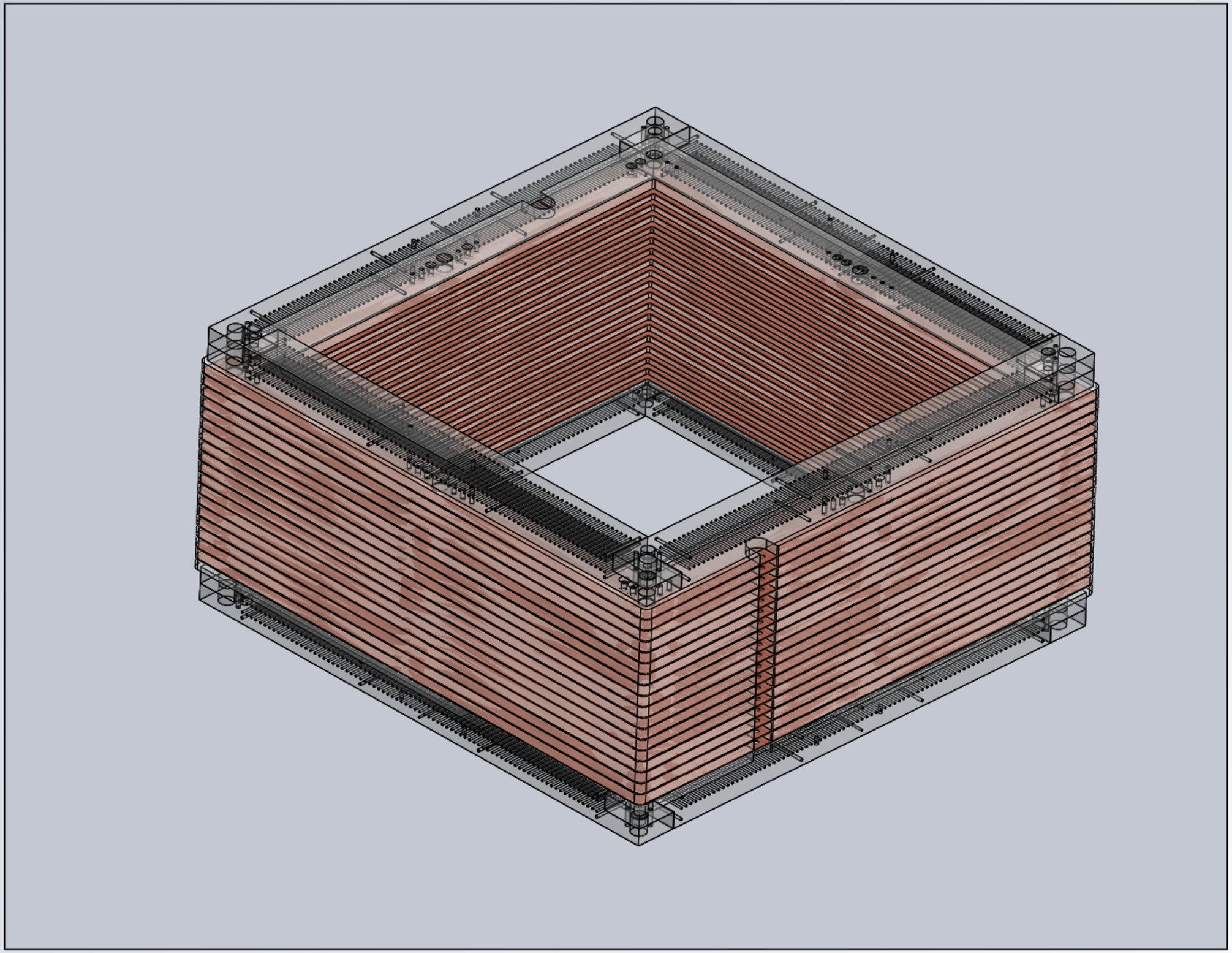








# Updated design

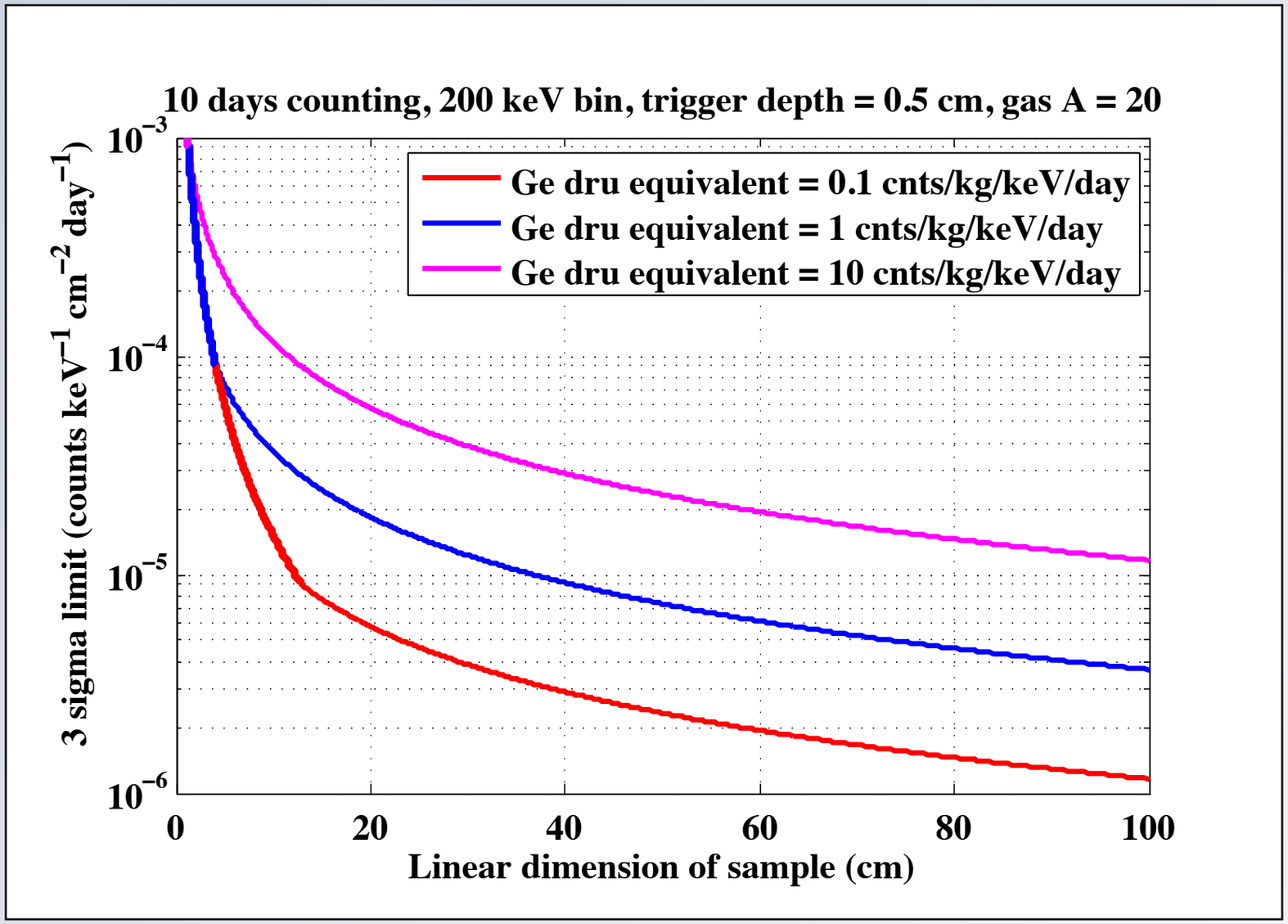


# Current Status and Future Plans

- Waiting in queue at Alberta machine shop to begin MWPC fabrication
- Full system simulation with tracks, pulse signal and noise being implemented
- Transition to multi-channel MIDAS DAQ
- Anticipate full characterization run with sources in Winter 2010-2011
- Begin capital purchases for BetaCage fab in Spring 2011

# Backup slides

# BetaCage Sensitivity



# Cleanroom at Syracuse