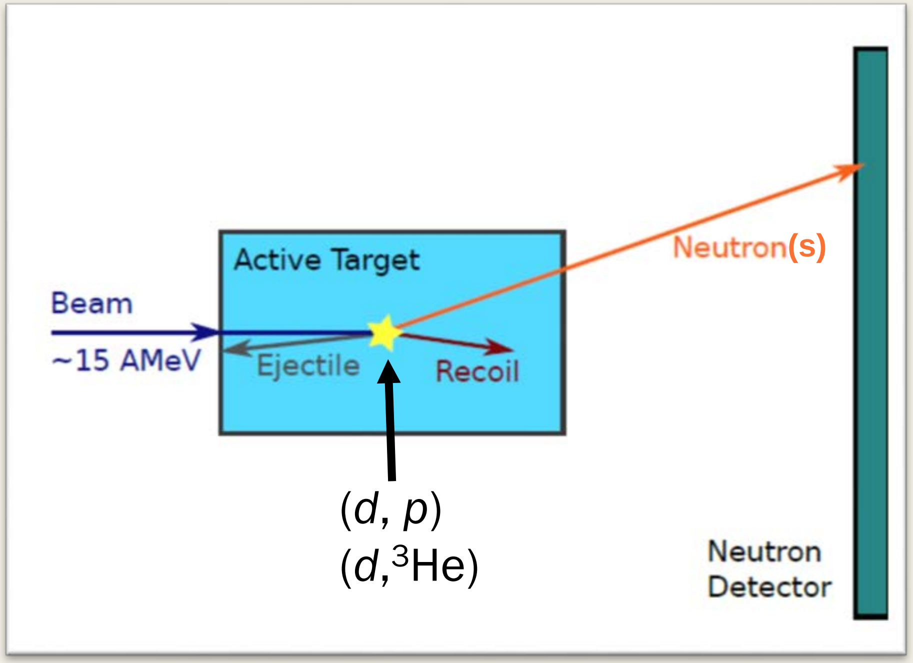
# NEUTRON SPECTROSCOPY AT TEXAS A&M

CENTAUR Neutron Detector Workshop

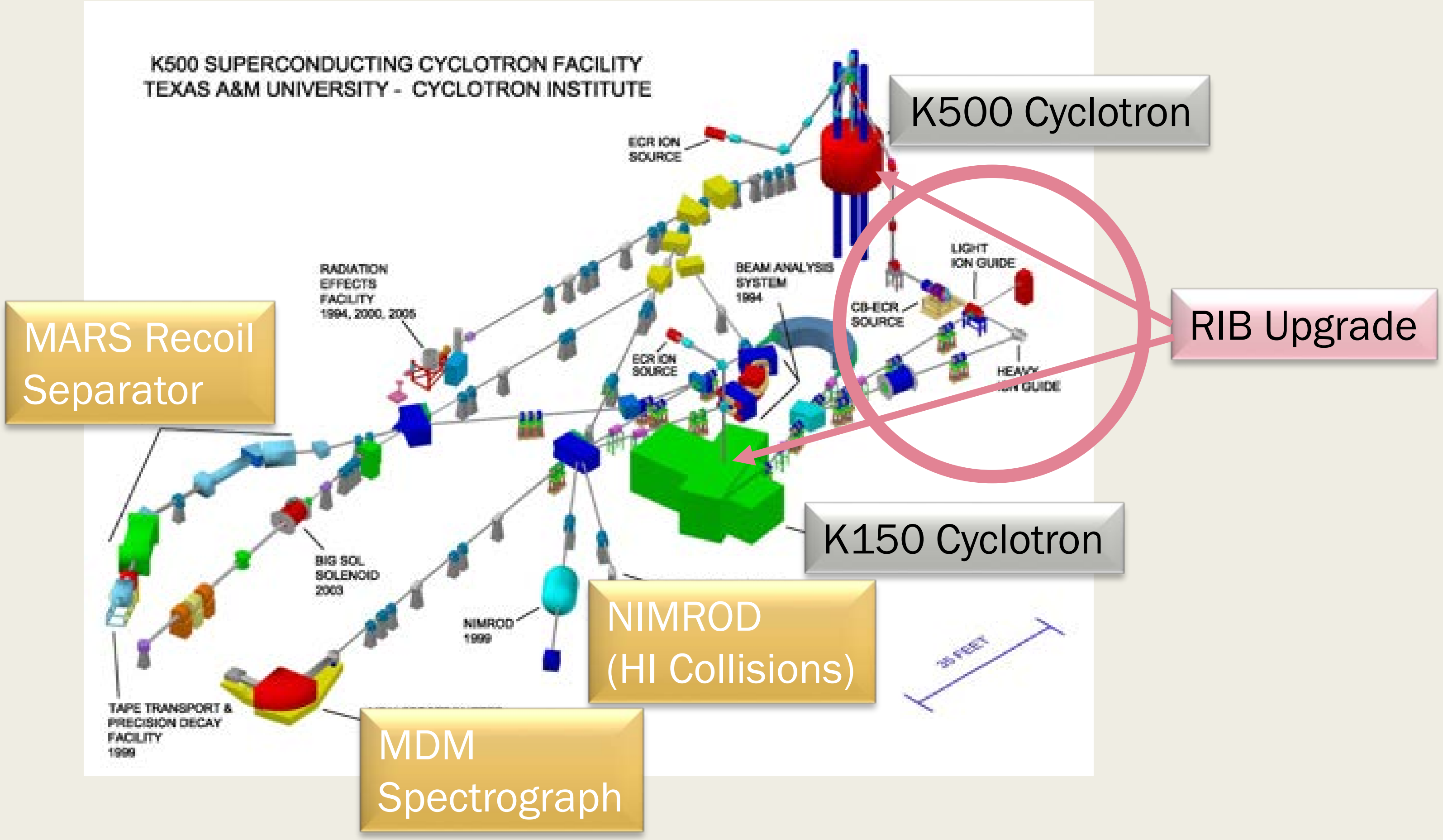
May 11, 2018

# Primary Goal (Broadly Defined)

- Combine the Texas Active Target (TexAT) w/ large-area neutron array for decay & reaction studies in "complete kinematics"
- Targeted experiments
  - *Decay spectroscopy of n-rich nuclei*
  - *(d,n) measurements*
- Other potential applications
  - *β-delayed neutrons*
  - *HI collisions*
  - *etc…*



# Texas A&M Cyclotron Institute



# Projected Beam Intensities

**a) Neutron Rich Products**

| Isotope | Energy Range MeV/u | Intensity pps |
|---|---|---|
| $^{9}Li$ | 13-45 | $1.7\text{-}3.4\times10^{6}$ |
| $^{11}Li$ (8.6ms) | 9-35 | $0.4\text{-}0.8\times10^{4}$ |
| $^{12}Be$ | 16-45 | $2.7\text{-}5.5\times10^{6}$ |
| $^{14}Be$(4ms) | 12-40 | $0.4\text{-}0.8\times10^{4}$ |
| $^{38}S$ | 9-36 | $2.5\text{-}5.0\times10^{5}$ |
| $^{40}S$ | 8-32 | $0.5\text{-}1.0\times10^{5}$ |
| $^{42}S$ | 7-29 | $1.8\text{-}3.6\times10^{3}$ |
| $^{44}S$ | 7-26 | $0.9\text{-}1.8\times10^{2}$ |
| $^{42}Ar$ | 9-39 | $3.3\text{-}6.6\times10^{5}$ |
| $^{44}Ar$ | 7-38 | $0.9\text{-}1.8\times10^{5}$ |
| $^{46}Ar$ | 6-35 | $1.8\text{-}3.6\times10^{4}$ |
| $^{48}Ar$ | 6-32 | $0.9\text{-}1.8\times10^{2}$ |
| $^{62}Fe$ | 13-38 | $1.9\text{-}3.8\times10^{4}$ |
| $^{60}Cr$ | 10-32 | $0.5\text{-}1.0\times10^{3}$ |

- Transfer + decay studies feasible for dripline nuclei w/ $Z < 5$.
- Extend program to FRIB + RIA12 for heavier masses ($Z \sim 8$)??

# Neutron Array – Requirements

*Primary*

- TOF resolution
- Position resolution
- Efficiency

*Secondary*

- Brightness (pulse height resolution)
- n-$\gamma$ discrimination

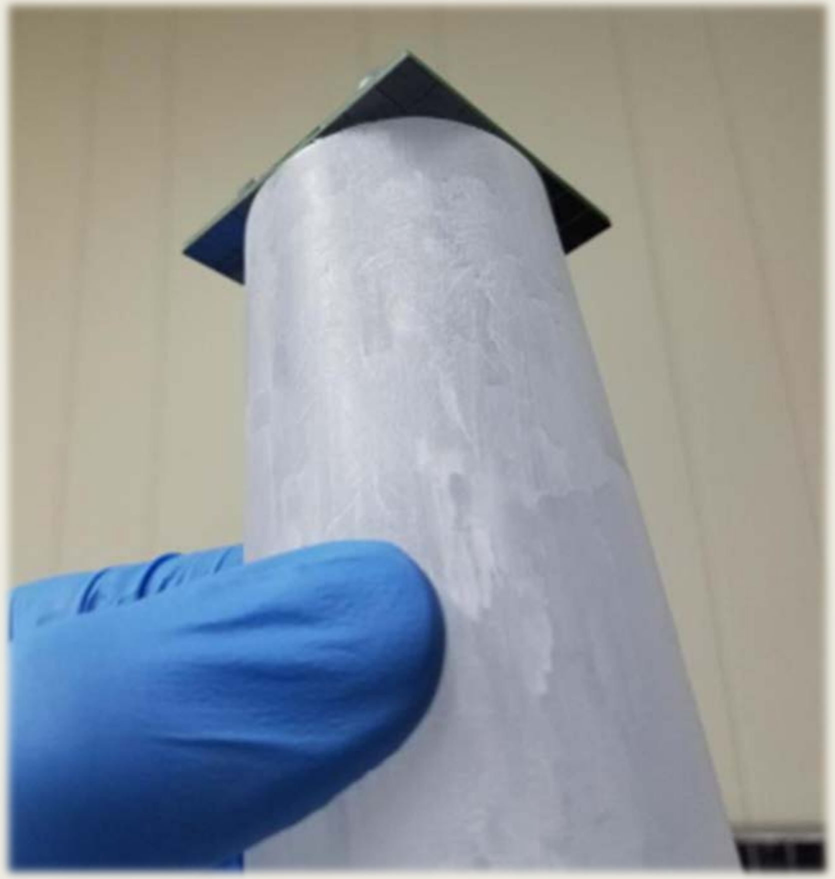
# p-Terphenyl (Proteus, Inc.)

*The Good*

- Fast timing plastic
- PSD down to keV thresholds
- Brightness (27,000 photons/MeV!)

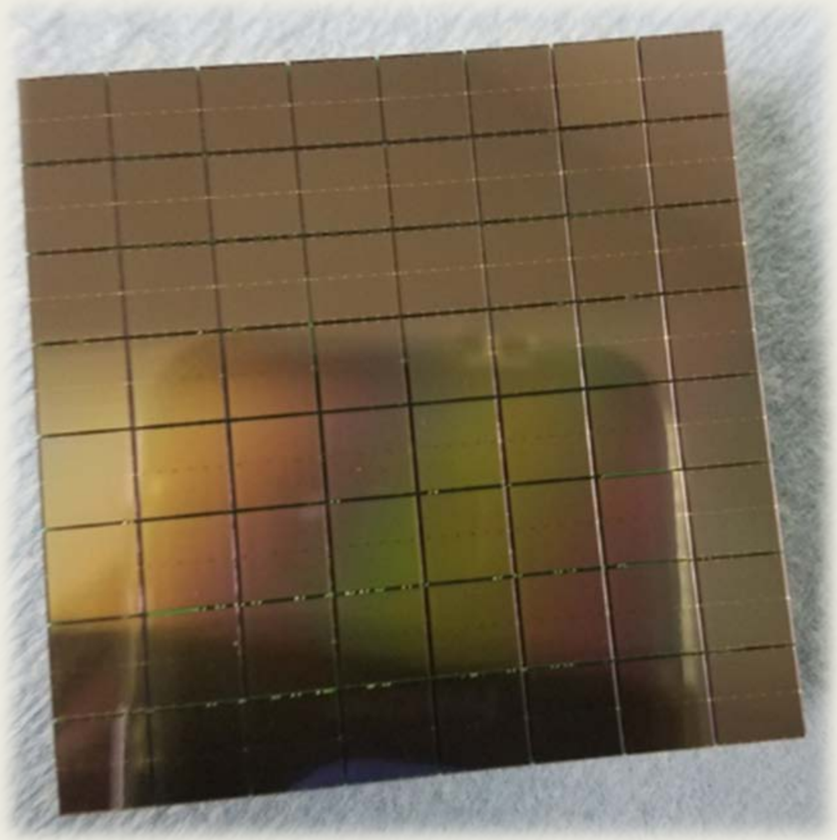
*The Bad*

- Limited fabrication geometries
  - *Cylindrical (max: 5 cm x 10 cm)*
- Cost ($2k/cylinder)
- Limited (slow) production capability



# Silicon Photomultipliers (SiPMs)

- Small footprint (compact array, less dark scattering)
- Operation in magnetic fields
- Pixlelation → sub-cell position determination
- Low cost (~$25/pixel in large volumes)



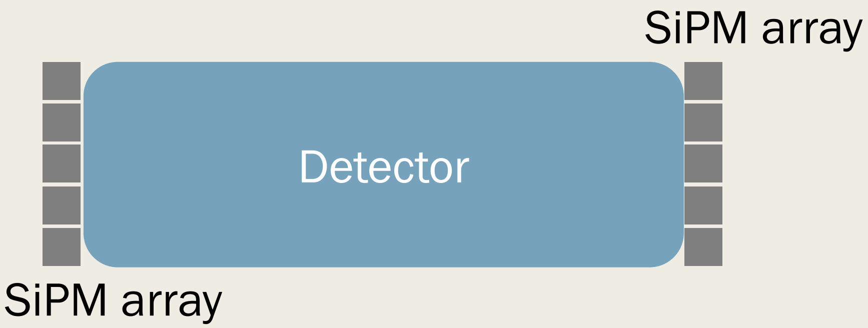
Sens-L ArrayJ 60034-64p
(8x8 array of 6 mm pixels)

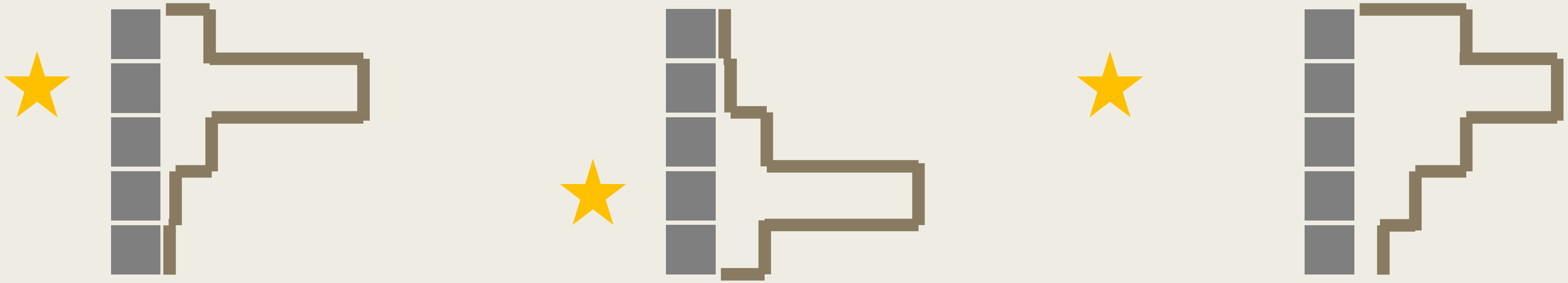
# Position Resolution

- Better determination of flight path → energy resolution from TOF
- Determination of opening angle for complete neutron momentum (invariant mass)
- 1n vs. 2n discrimination (more later)
- Methods to improve
  - *Smaller detectors*
  - *Readout methods w/ good sub-cell sensitivity*

# Light Sharing with SiPM Arrays

- Analyze centroid (*x*/*y*) and width (*z*) of distribution of light intensity on SiPM array
- Similar methods widely employed for PET (w/ inorganic scintillators)
- Brightness of p-Terphenyl may be essential for this to work



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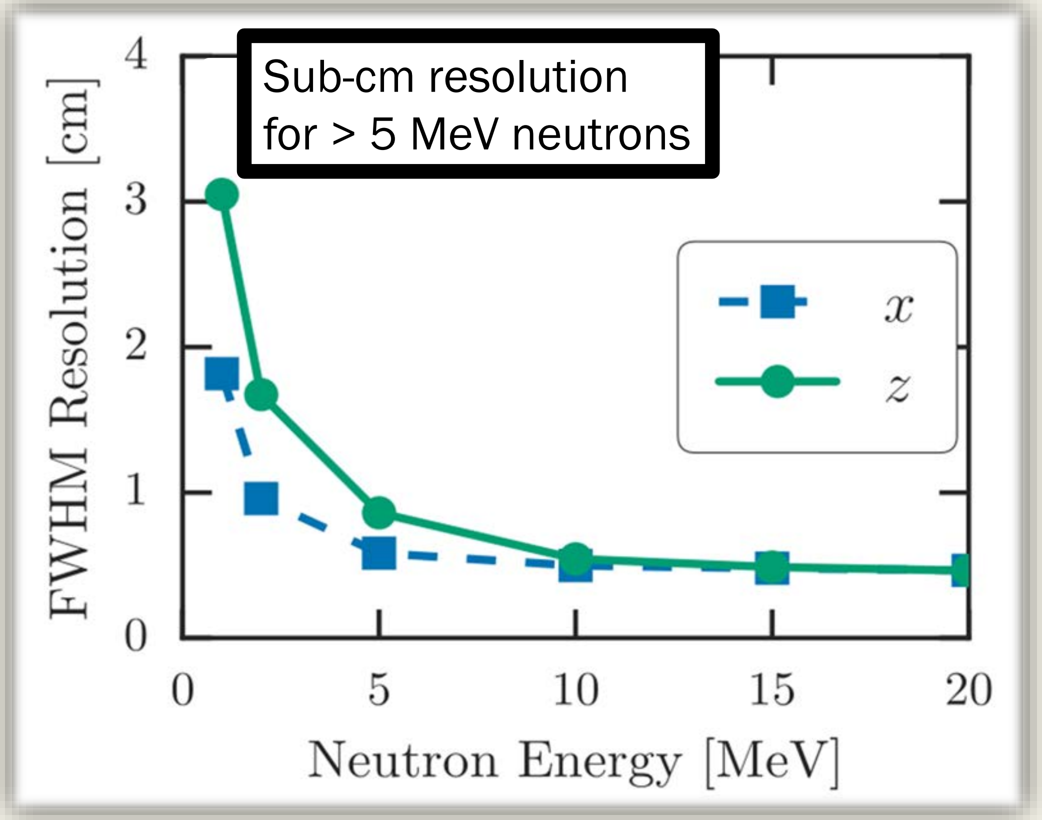
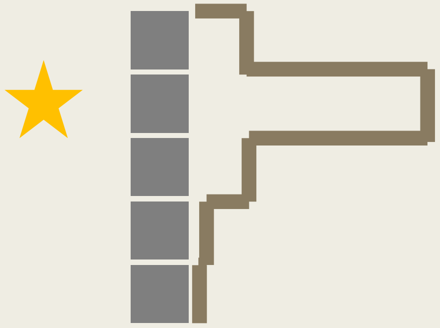
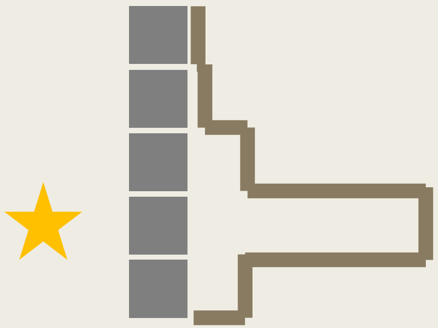
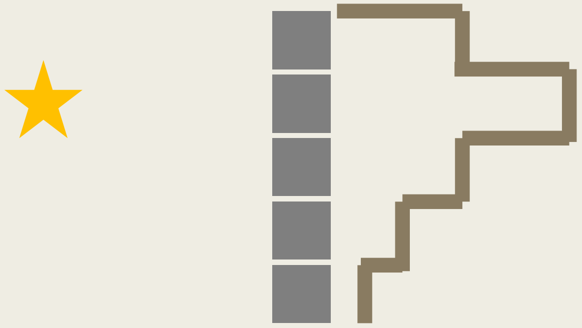


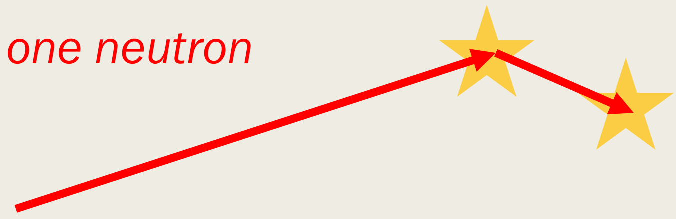



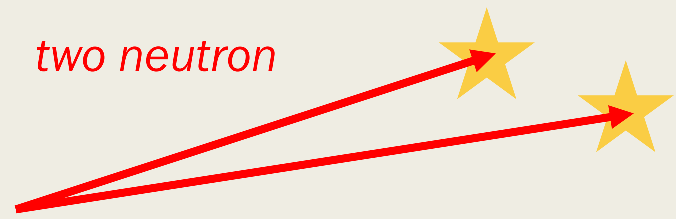


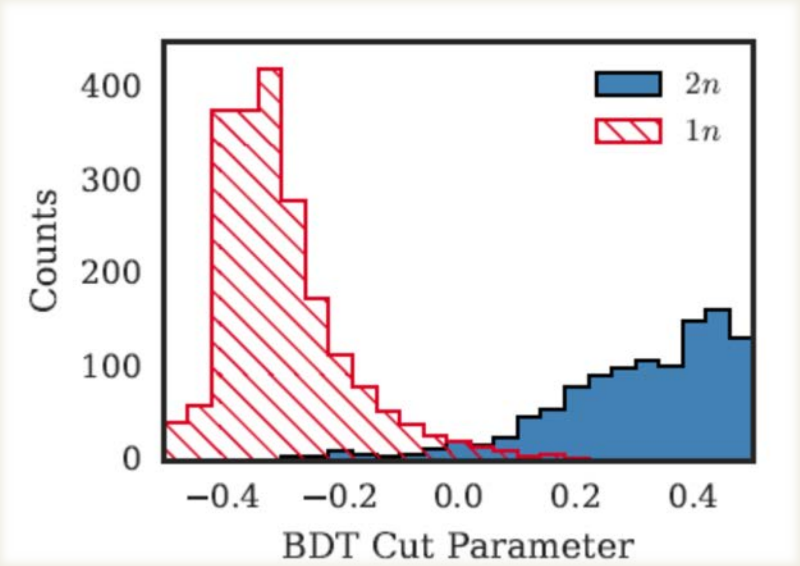


# One vs. two neutron discrimination

- Significant problem for 2n measurements with close-packed arrays
- Traditional methods – kinematic causality cuts
- Better pixilation → use tracking algorithms to distinguish?
- Machine learning?
  - *Simulation work indicates boosted decision trees (BDT) can be very effective.*
  - *95% efficiency for real 2n events, 5% 1n contamination*
  - *Possibility to try w/ existing data sets?*



# Where are we now?

- Early stages… noise a major issue
- Beginning work on designing noise filters, bias stabilizers etc. (lots of good documentation & advice from Sens-L)
- But no need to re-invent the wheel – suggestions / advice / collaboration from those who have been here already are most welcome.