External Radioactive Calibration Sources in DUNE Far Detector

Juergen Reichenbacher,
Jason Stock & James Haiston

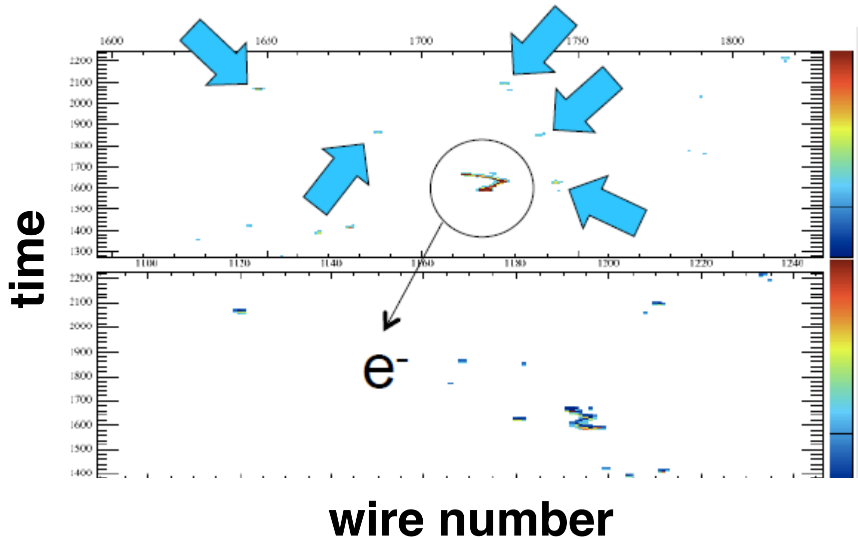
DEEP UNDERGROUND NEUTRINO EXPERIMENT

SOUTH DAKOTA SCHOOL OF MINES & TECHNOLOGY

DUNE Calibration Workshop
Fermilab, 15-Mar-2018

Radioactive Calibration Sources Mostly Critical for SNB ν's

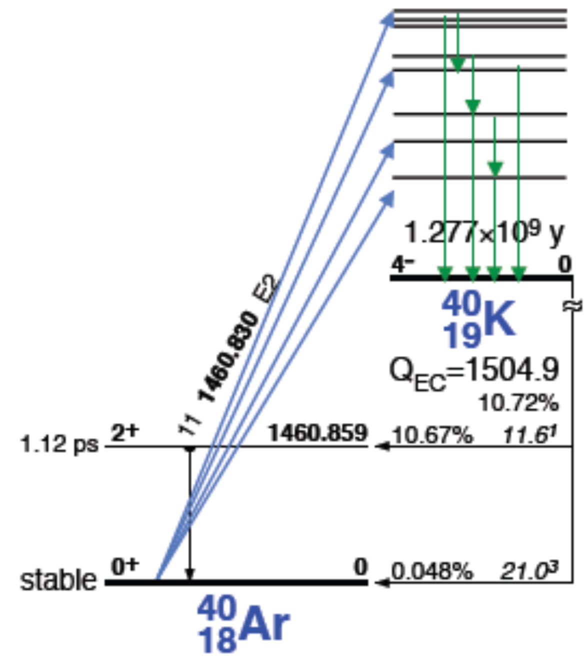
Can we tag ν_e CC interactions in argon using nuclear deexcitation γ's?



Charged-current absorption:

$$\nu_e + {}^{40}\text{Ar} \rightarrow {}^{40}\text{K}^* + e^-$$

(g.s. to g.s. is 3rd forbidden transition)



⇒ ***Always get at least one gamma to collect!***

⇒ ***Calibrations with radioactive sources essential for probing detection efficiency!***

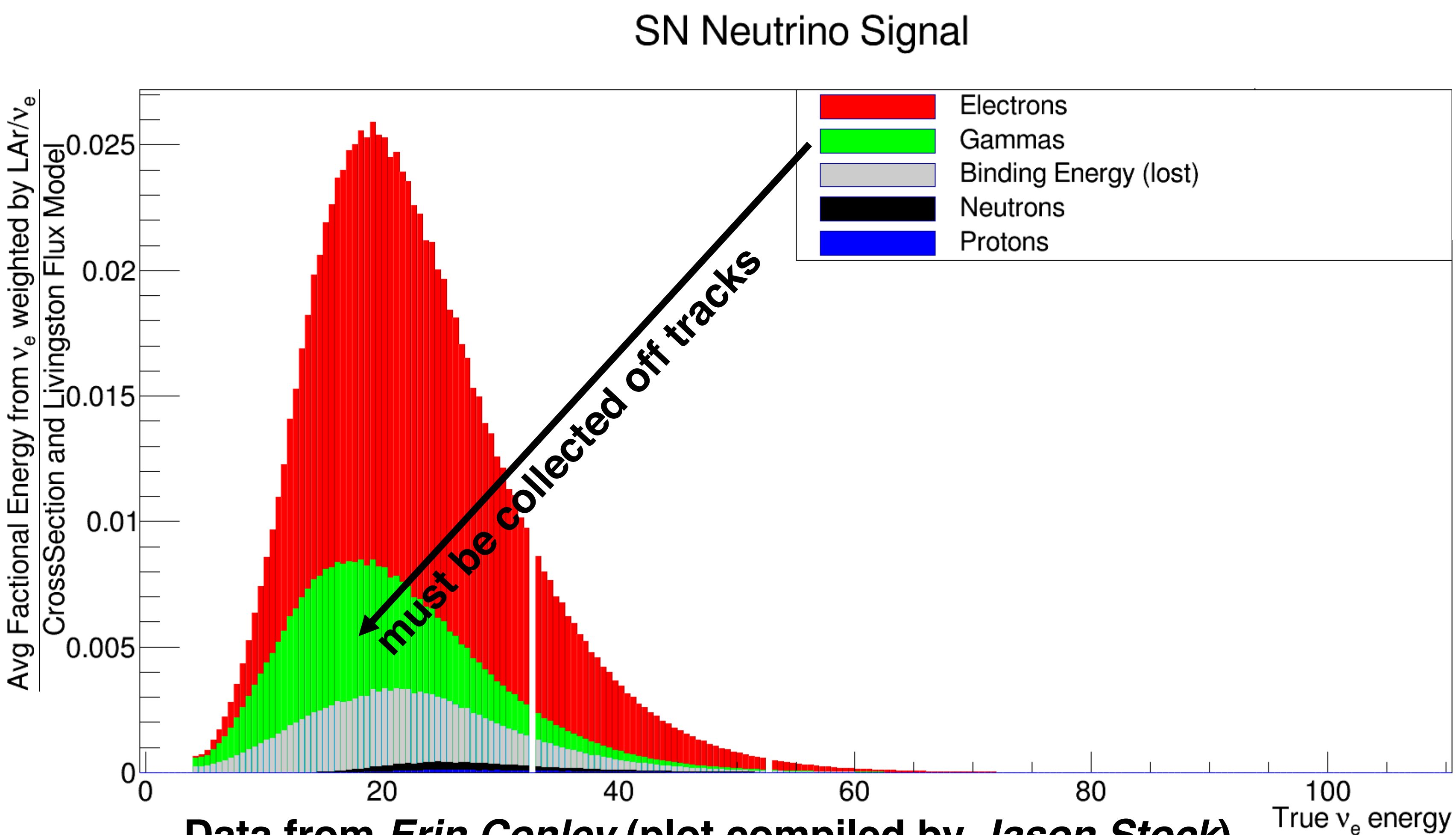
⇒ ***Task Force Leaders for this: Reichenbacher, Scholberg and Svoboda***

20 MeV ν_e , 14.1 MeV e^-, simple model based on R. Raghavan, PRD 34 (1986) 2088

Improved modeling based on ^{40}Ti (^{40}K mirror) β decay measurements in progress

Direct measurements (and theory) needed!

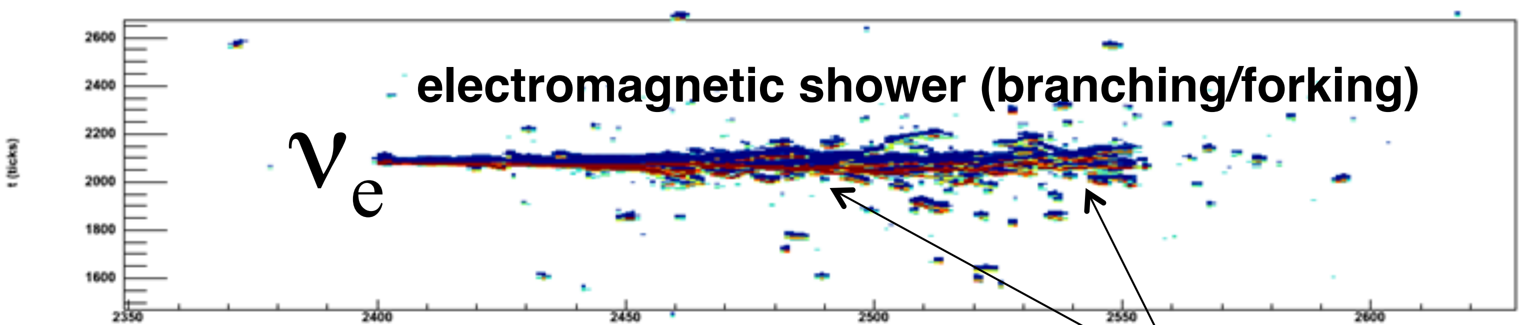
Computed Supernova ν_e Detection in LAr



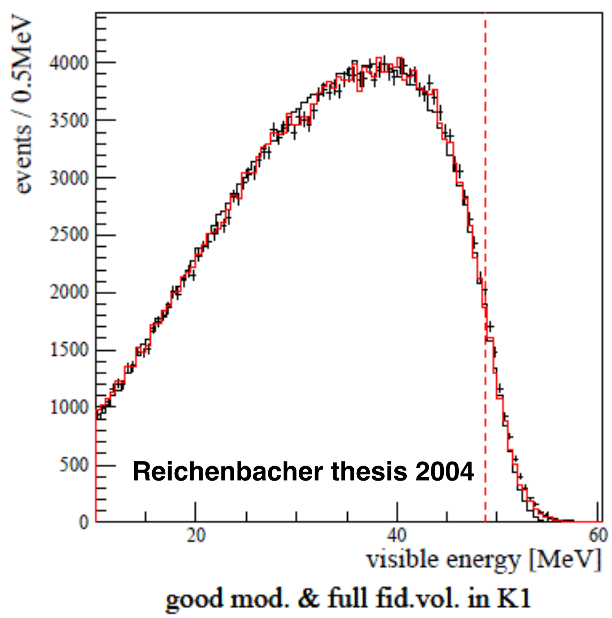
Data from *Erin Conley* (plot compiled by *Jason Stock*)
Uses MARLEY Model (*Steven Gardiner* et al)

=> Need to collect γ's to do meaningful spectral SNB physics!

Low-Energy EM Response also Relevant for outliers of EM Showers…



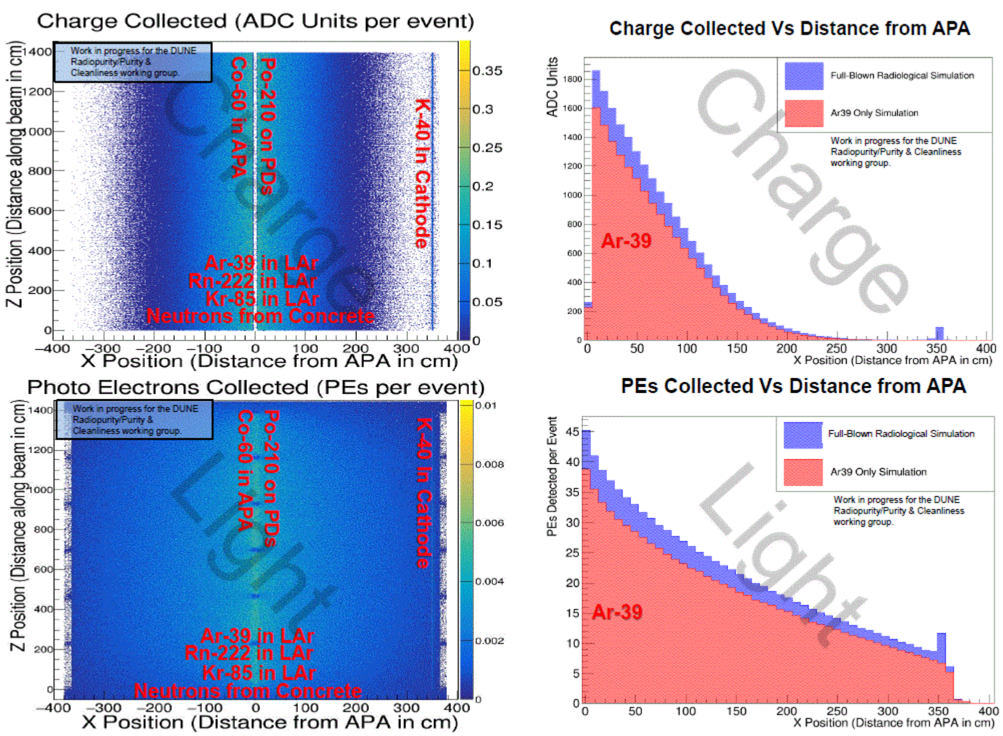
low-energy gammas
Vs. electronic noise

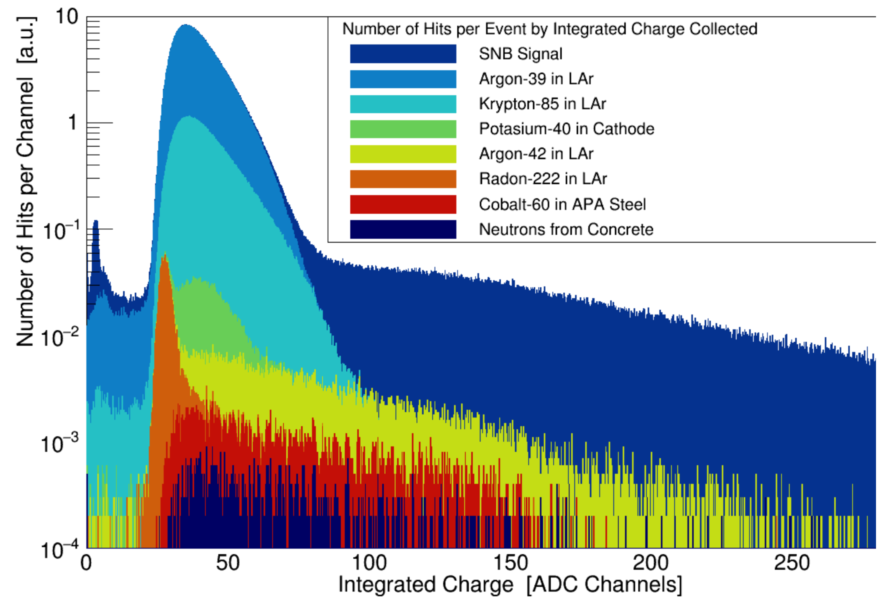


… and Michel energy spectrum!

Radiological Background in DUNE

- **Full-blown radiological model is condensed into one LArSoft producer file and provides input for SNB, DAQ simulations, cosmogenics, atmospheric ν's, ndk etc.**

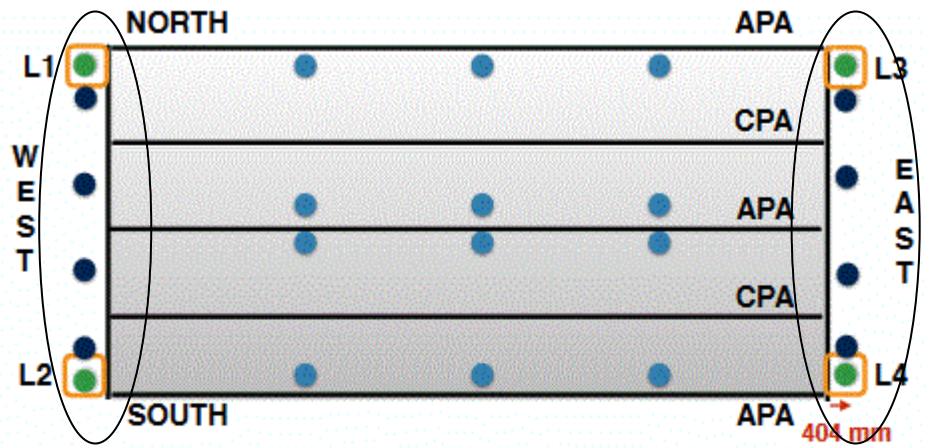




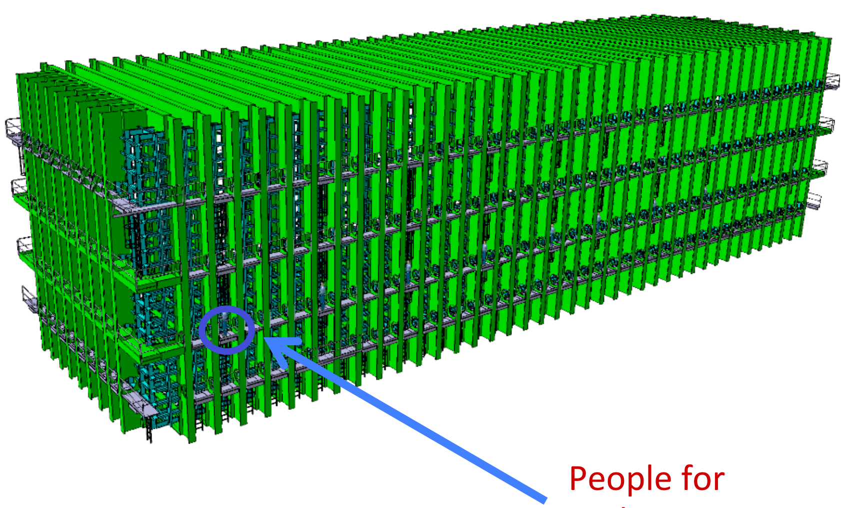
Jason Stock & Reichenbacher

-> Requirements set correctly as detector components are subdominant (ProtoDUNE first LArTPC to see Ar-42?)

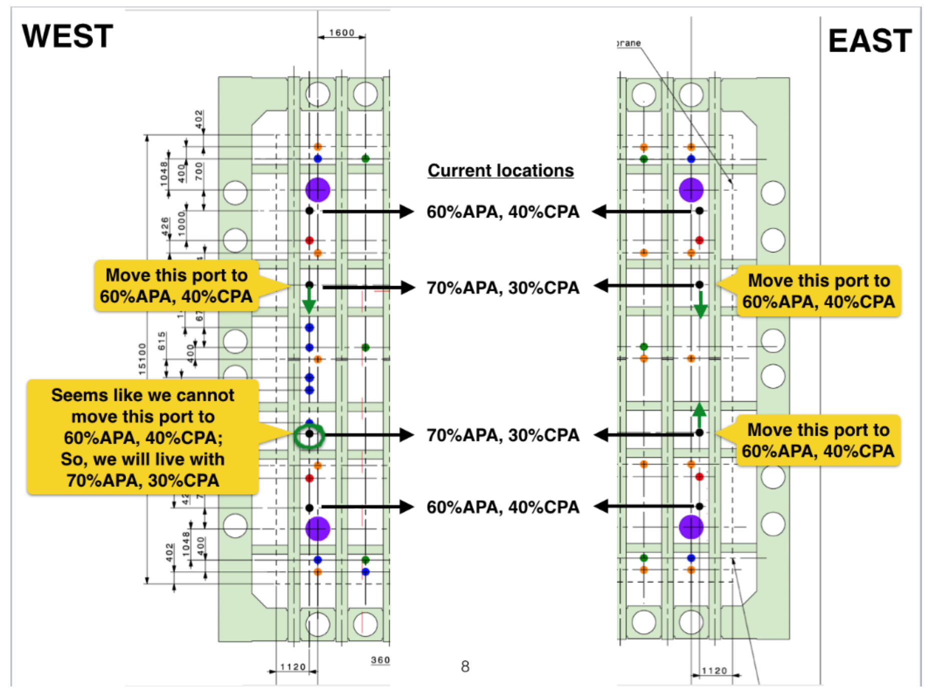
Plan First Radioactive Source Deployment inside a Cryostat



Planned feedthrough penetrations



FTs for external radioactive source deployments are at 60% to 70% of full drift length away from APA



Isolate External Source Deployment System in Glovebox on Top of Cryostat FTs

Automated fishline system for target deployments:

+/-2 mm precision over 7 m

-> 2 systems available from Double Chooz in Jan 2018

Concept of 9 MeV gamma Source for Deployments

$^{58}Ni(n,\gamma)^{59}Ni$

TRI-PP-96-7
Apr 1996

A 7–9 MeV isotopic gamma ray source for detector testing

Joel G. Rogers[a*], Mark S. Andreaco[b], and Christian Moisan[a]

[a]*TRIUMF, 4004 Wesbrook Mall, Vancouver, B.C., Canada V6T 2A3*
[b]*CTI, 810 Innovation Drive, Knoxville, TN 37932, U.S.A.*

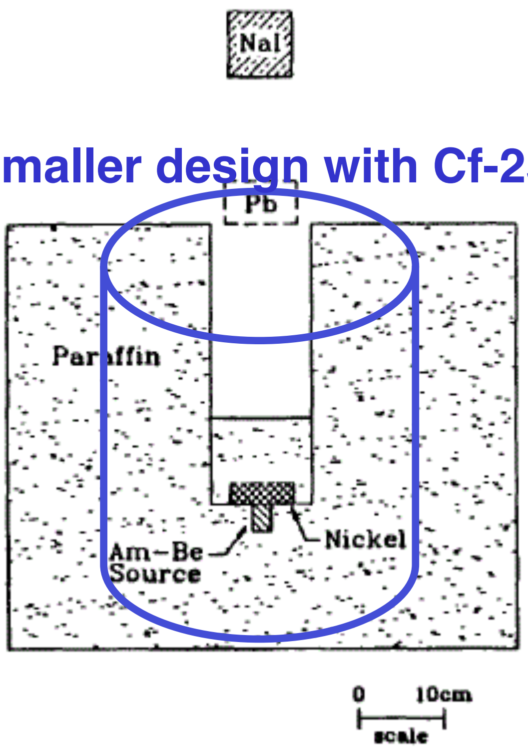


Table 1 - Thermal (n,γ) Rates from natural Ni taken from ref. [3]

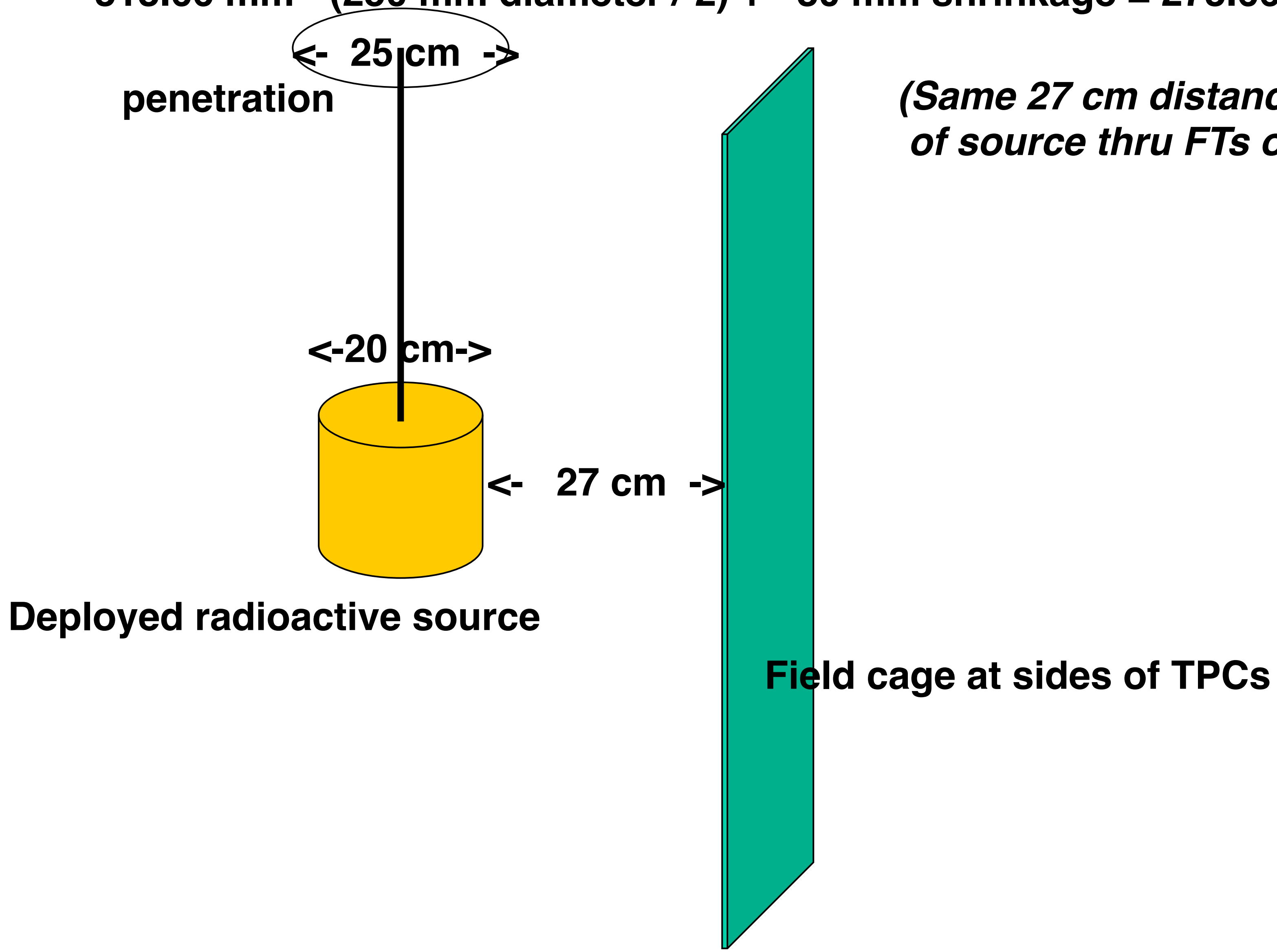
Gamma Energy (MeV)	Rate (photons/100 captures)
8.997	26
8.532	11
8.119	2.5
7.817	6
7.528	4
7.22	0.4
7.05	0.6
6.839	9
6.58	2
6.34	1
6.10	1.3
5.99	0.4
5.82	3
5.70	0.6
5.31	1.3

[3] E. Troubetzkoy and H. Goldstein, "A compilation of information on gamma ray spectra resulting from thermal neutron capture", USAEC Report, ORNL-2904 Oak Ridge National Laboratory, 1960.

Using Cf-252 (or even better AmLi) would significantly reduce size of source, such that it would fit a 25 cm diameter feedthru

Scheme of Vertical Deployments: Safety distance of deployed radioactive source wrt. FC

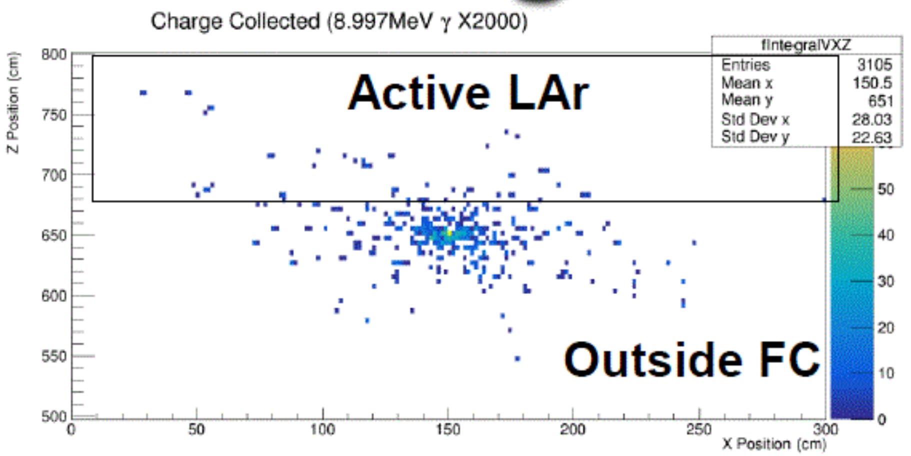
318.66 mm - (250 mm diameter / 2) + ~80 mm shrinkage = 273.66 mm

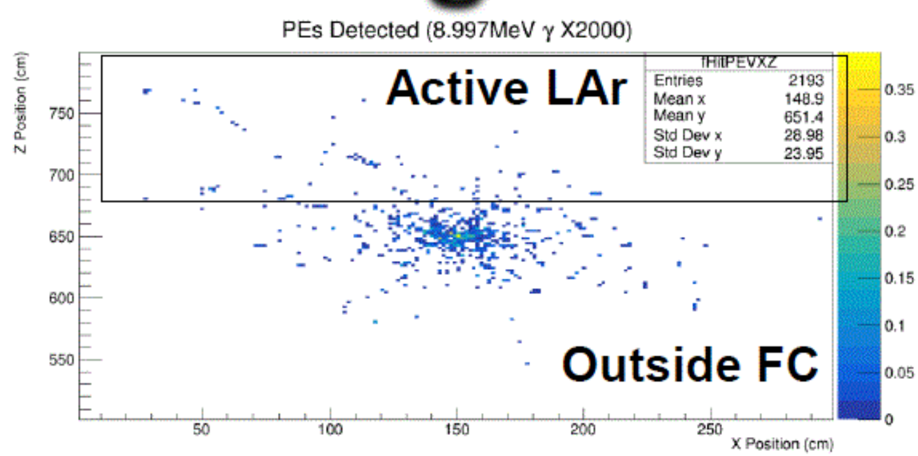


(Same 27 cm distance of source thru FTs on top of FC)

First Radioactive Source Deployment inside a Cryostat

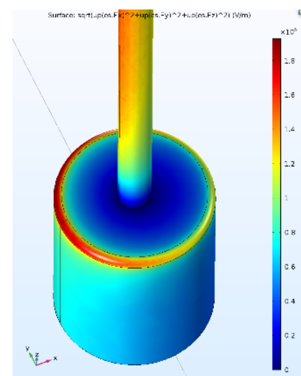
charge — **Source at half-drift** — **light**





(Stock & Reichenbacher)

Field cage:



FEA sim (Bo YU)

Known position of source in x:
=> average time difference between light and charge validates electron-lifetime and E-field

Known source strength:
⇒ low-energy detection efficiency & low signal vs electronic noise

^{58}Ni(n,γ) source to be deployed vertically outside field cage (Haiston & Reichenbacher)

First Deployment Plan

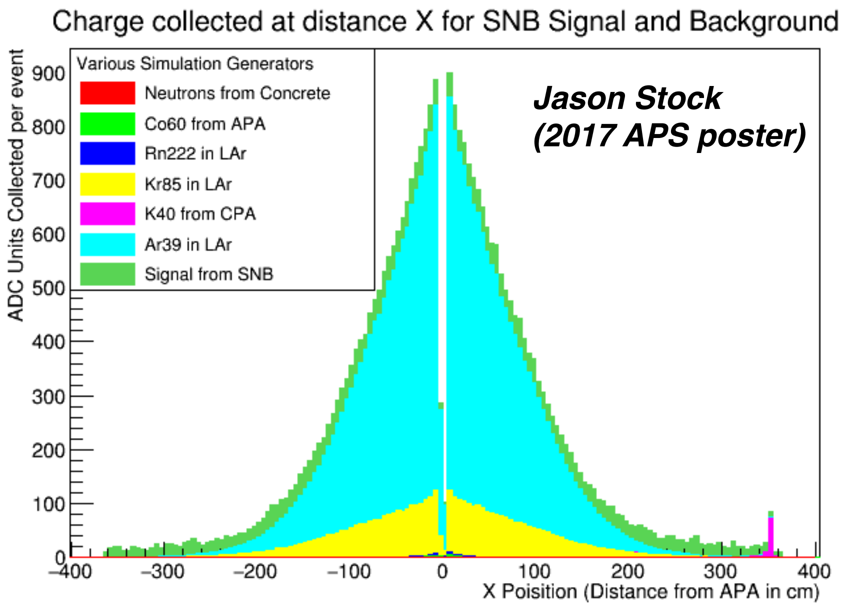
1. Dummy source deployment (within 2 months of the commissioning)
2. Present to TB on the dummy source deployment and get sign off/green light for the real source deployment (1 to 2 weeks)
3. First real source deployment (within 3-4 months of the commissioning)
4. Second real source deployment (within 6 months of the commissioning)
5. Assuming things will be reasonably stable, radioactive source will be deployed every half a year. Ideally, a deployment before a run period and after the run period are desired so you have at least two data points for calibration.
   This is important since you need to know if the state of the system has changed before and after the physics data run.
6. If stability fluctuates due to electronics changes at a particular location, one would want to deploy the source at that location once a month or more often depending on how bad the stability is.

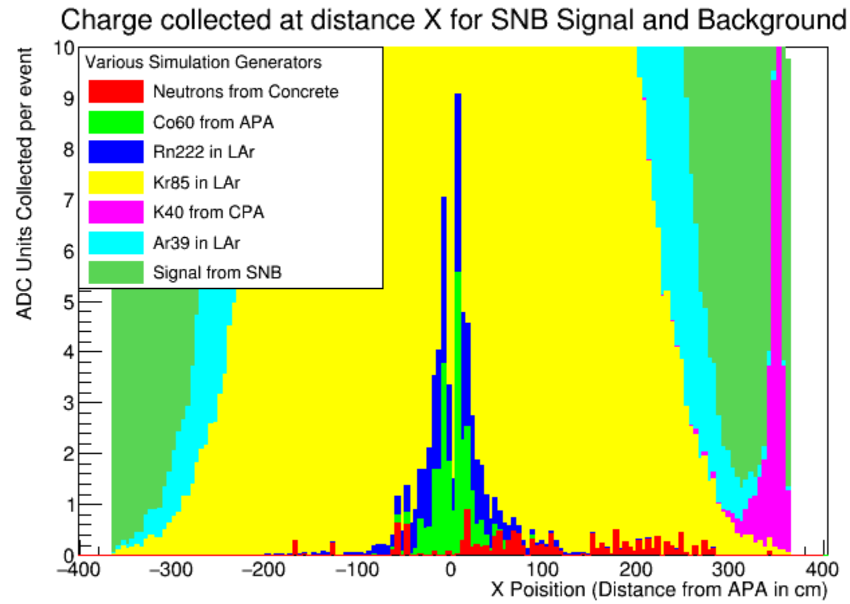
In terms of how long it takes to deploy:

1. few hours (e.g. 8 hours -> one work day u/g) for one FT position
2. parallel deployment (one port to another) takes 2 days or so.
3. Full calibration campaign (with only one shared system) — at least a week.

(DATA and TRIGGER rates pending sims and TBD at this workshop)

BACKUP: Injected Thoron & Internal "fixed" Sources



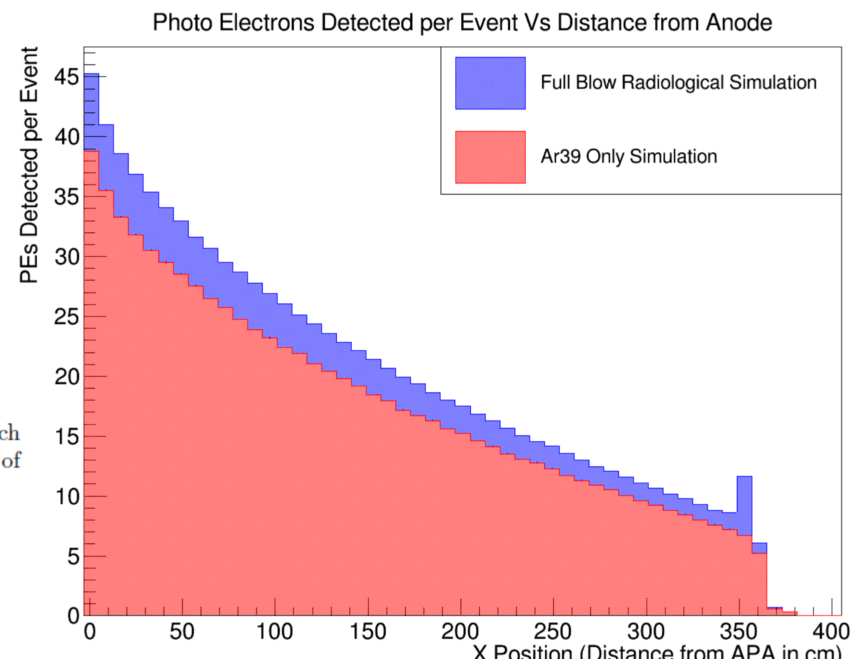


-> SNB events require at least some track-reco to stick out of background! (no simple trigger)

-> Could spike local points on cathode & FC (electroplating isotopes dissolved in nitric acid and final seal with thin Teflon layer)

Use Thoron (-> Tl-208) or beta sources

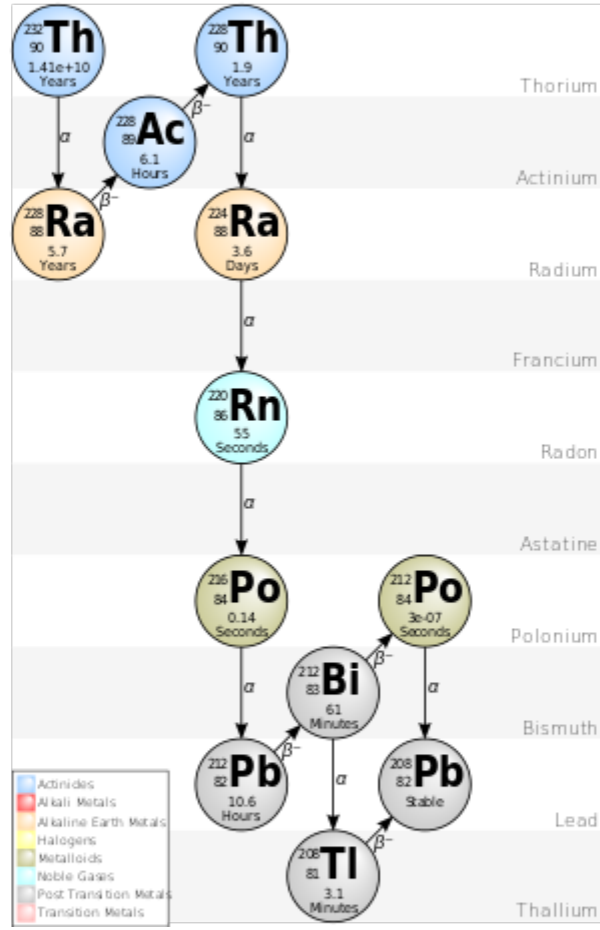
' β-sources with relatively high end point energies, such as for example ^{144}Ce (halflife of 284 d, daughter ^{144}Pr with $\beta- < 2.99$ MeV) or ^{106}Ru (halflife of 368 d, daughter ^{106}Rh with $\beta- < 3.54$ MeV). '



BACKUP: Injected short-lived radioactive sources: Detector Uniformity

⇒ **ensure uniform detector response:**
purity and electron lifetime
(employ purity monitors)

⇒ **impact of complicated flow pattern**
checked with fluid dynamic simulation
(employ RTDs)



Tl-208 gamma of 2.615 MeV
and beta with endpoint energy of up to 1.8 MeV

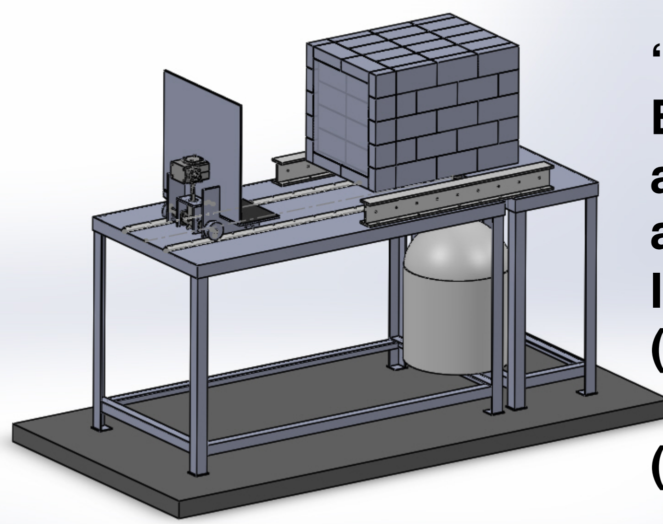
γ-Screening of External Source Strength and of Critical DUNE Detector Parts

- **Received samples from 1 barrel of copper getter and mol sieve from ProtoDUNE (*from David Montanari & Stephen Pordes*)** **-> could introduce Rn-222 into LAr!**

- **Samples will be pre-screened with Ge-detector at SDSMT and underground at SURF with low-background counter (*Kevin Lesko / LBNL*)**

- **We have 50 barrels, i.e. 50 samples. Do we want to test them all? See 1st results…**

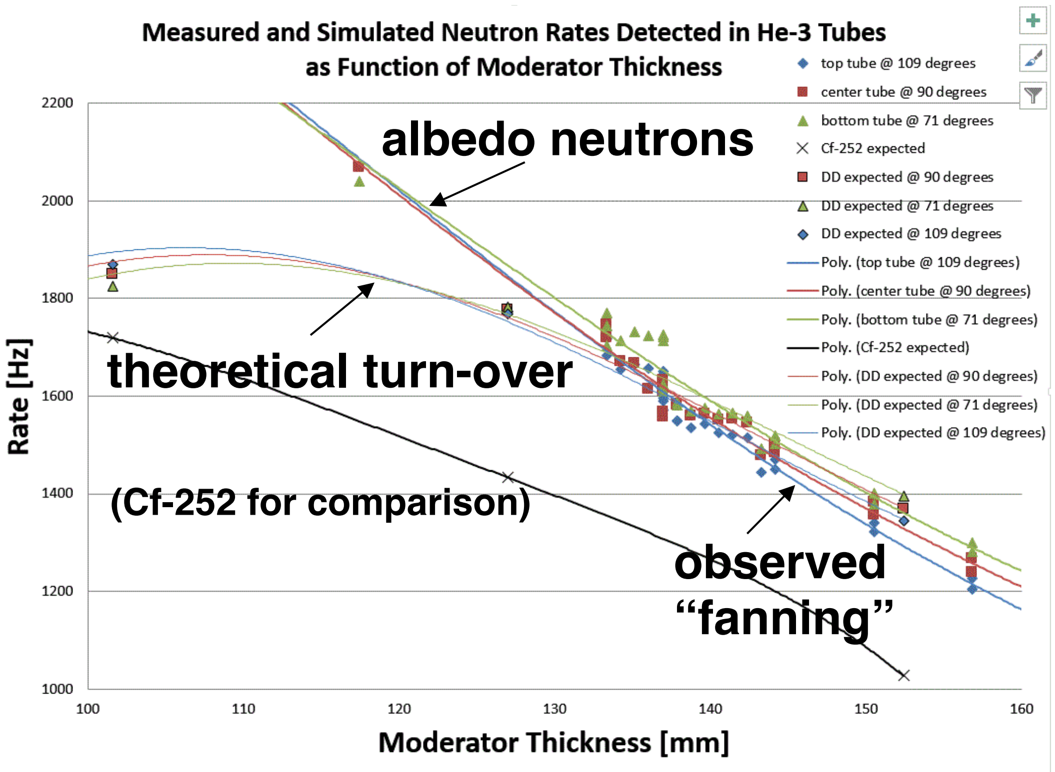
- **Pre-screener "Rabbit" at SDSMT is 2 blocks from logistics center in Rapid City**



"Rabbit" BEGe γ-detector at SDSMT allowing for large samples (12"x12"x12")

(*James Haiston*)

SDSMT Neutron Telescope Measures Angular Dependent Neutron Energy Emitted by DD-Gun

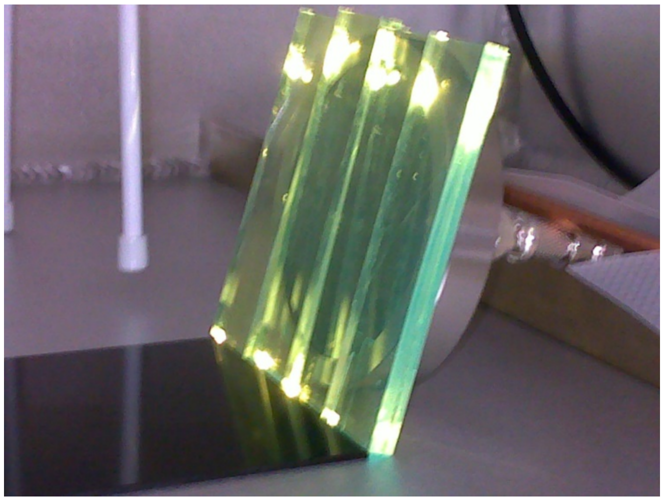
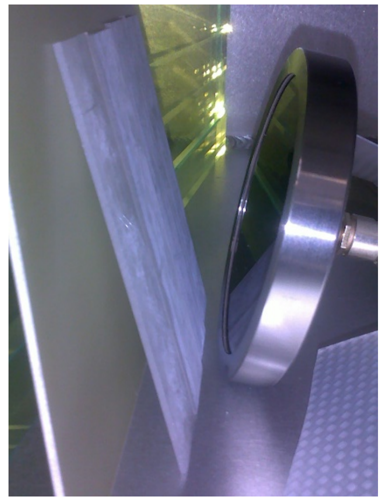
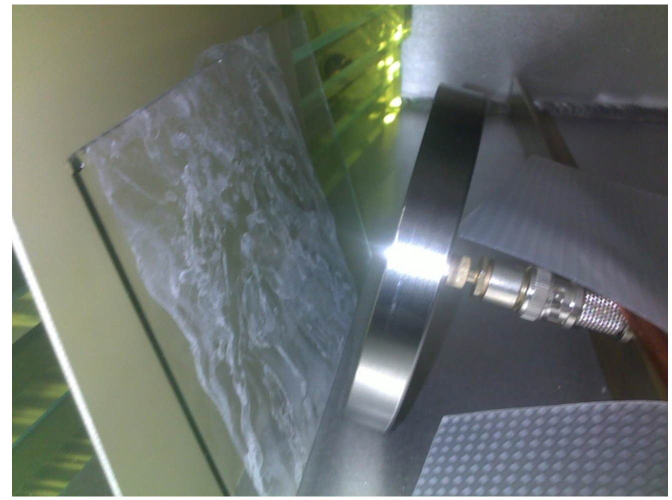


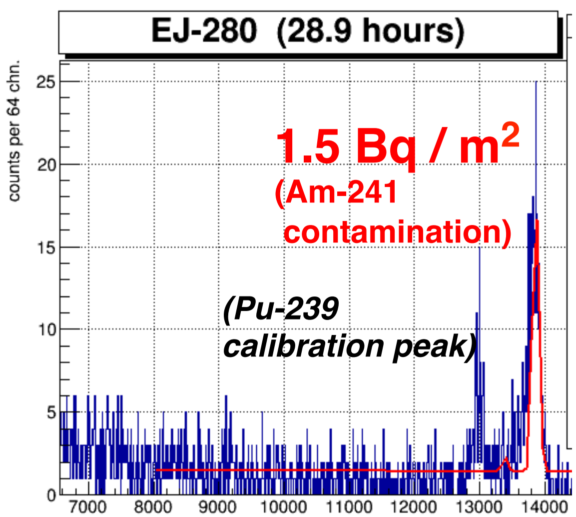
⇒ **Energy shift of ~100 keV observed at 70° and 110° degrees (compared to 90°)**

(by varying thickness of PE moderator foil in steps of few hundred micrometers)

BACKUP:
Importance of Surface α-Screening of DUNE PDs

Quality control (QC) by α/β−screening with AlphaBACH at SDSMT:



Quality Assurance (QA) much less stringent than for dark matter experiments, but still 1000x below NRC swipe sample sensitivity (yet 1000x above AlphaBACH sensitivity)

-> will screen PDs from ProtoDUNE for QC (α's could produce lots of light in LAr)