Radioactive Sources in DUNE

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DUNE Calibration Task Force

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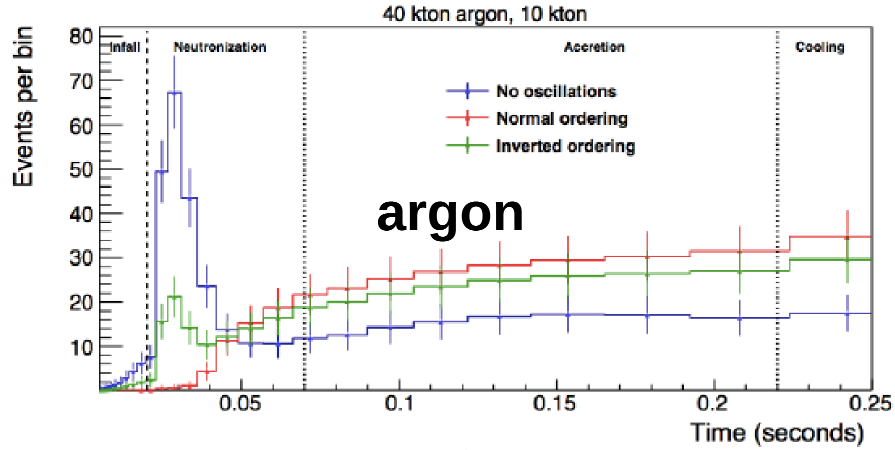
Advantage of Supernova Neutrinos with DUNE

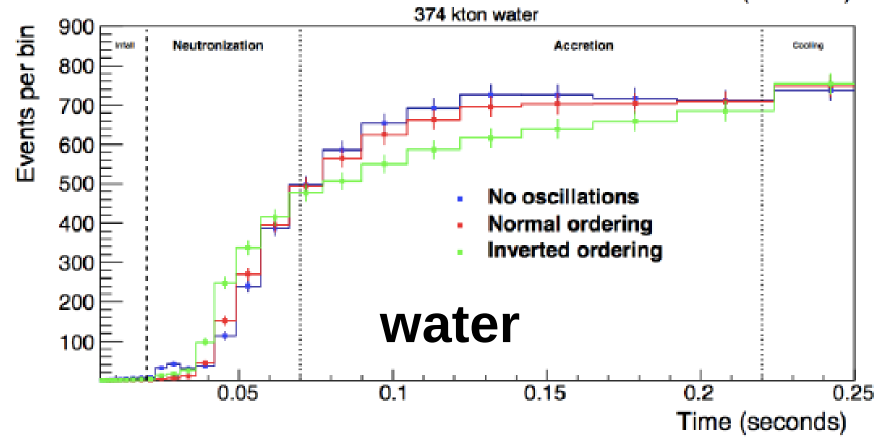
Same supernova model, other future large detectors

- neutronization burst much more visible in LAr
- time profile varies by hierarchy, differently for different detectors

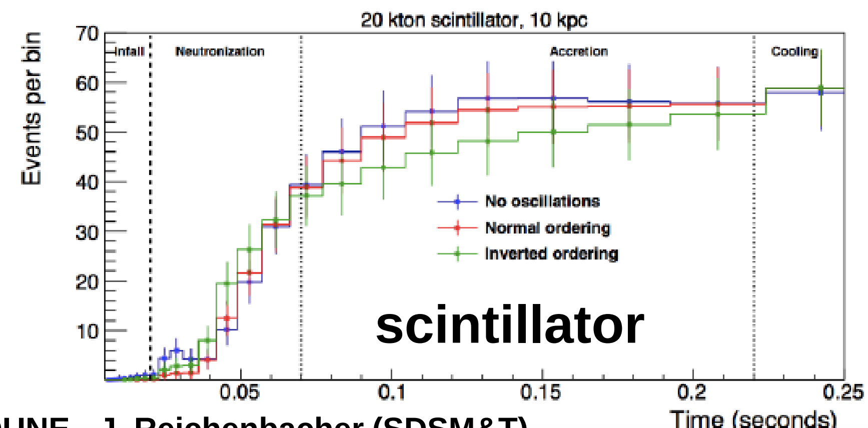
⇒ ***<u>We need LAr SNB detector!</u>***



ν_e

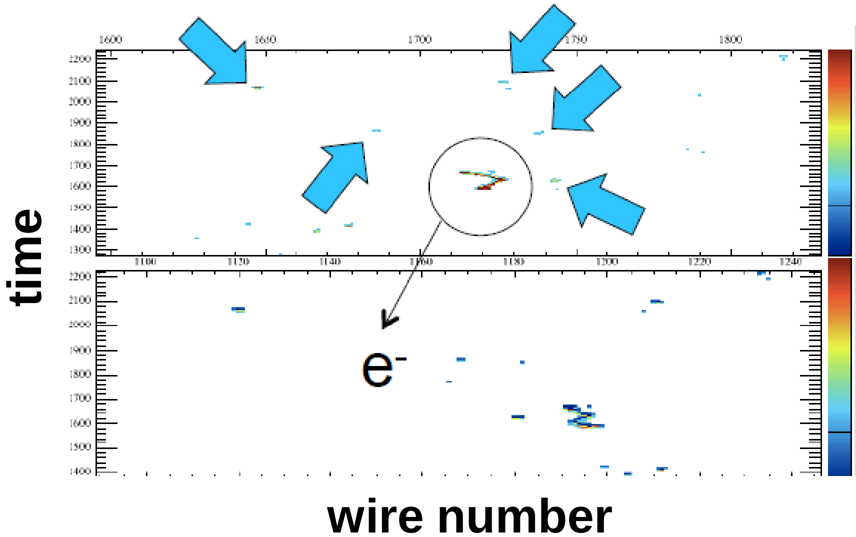


$\bar{\nu}_e$



$\bar{\nu}_e$

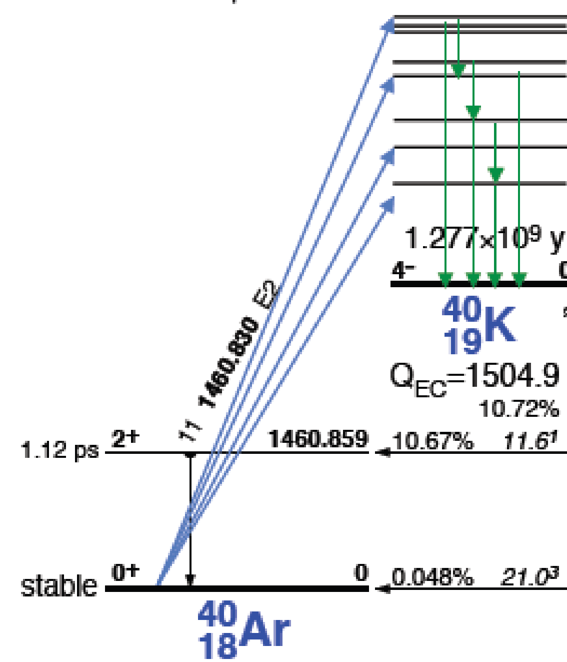
Can we tag ν_e CC interactions in argon using nuclear deexcitation γ's?



Charged-current absorption:

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

(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!

MARLEY: **M**odel of **A**rgon **R**eaction **L**ow-**E**nergy **Y**ields

- **Goal:** determine whether "every little thing gonna be all right" for SN neutrino physics in LArTPCs
- Event generator for SN ν on ^{40}Ar
- Current version focuses on generating ν_eArCC events

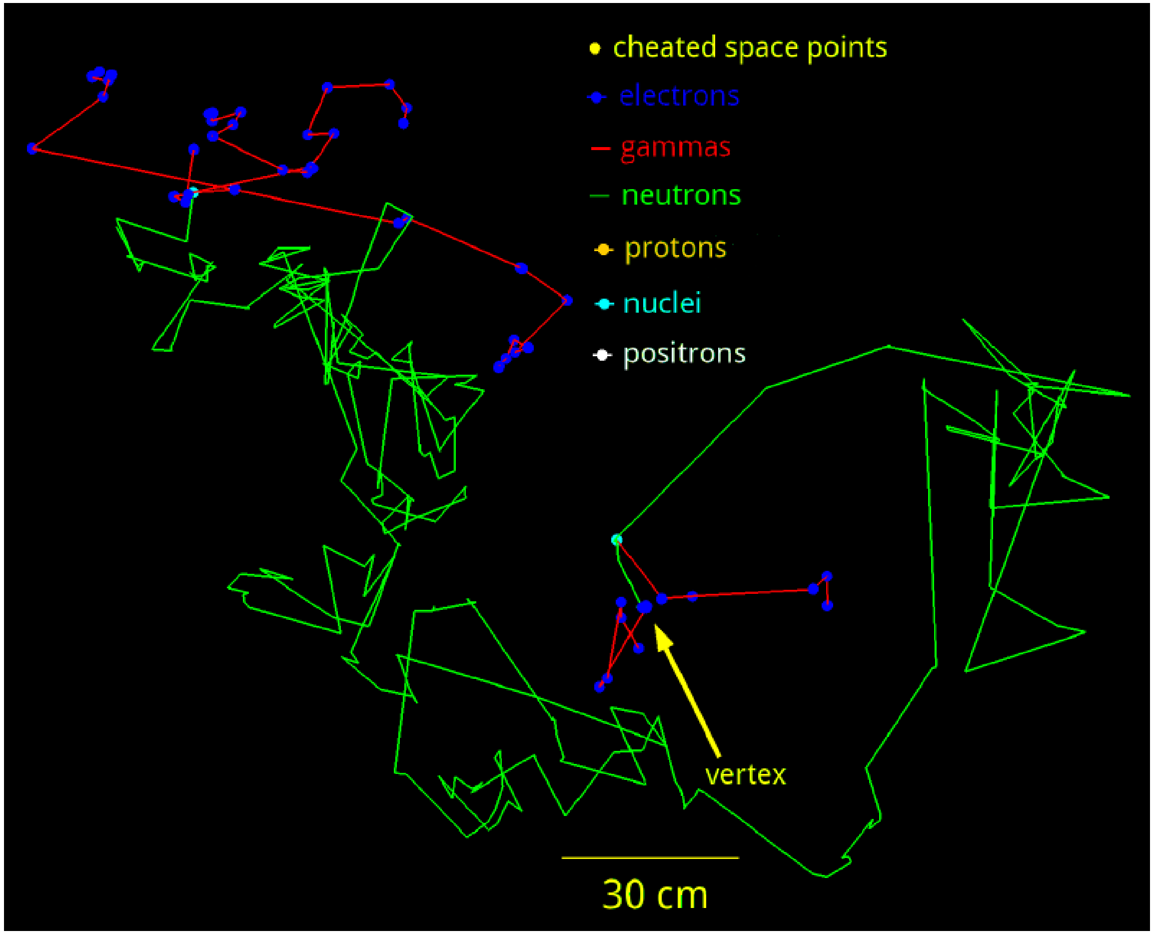
R. Svoboda,
S. Gardiner,
C. Grant & E. Pantic

Example neutron event (true trajectories)

- E_ν = 16.3 MeV
- e^- deposited 4.5 MeV
- No primary γs from vertex
- ^{39}K deposited 68 keV
- n deposited 7.6 MeV (mostly from capture γs)
- Total visible energy:

  12.2 MeV
- Visible energy sphere radius:

  1.44 m
- Neutrons bounce around for a long time!



-> need to control u/g neutron background!

External radioactive source 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]

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[b]*CTI, 810 Innovation Drive, Knoxville, TN 37932, U.S.A.*

smaller design with Cf-252

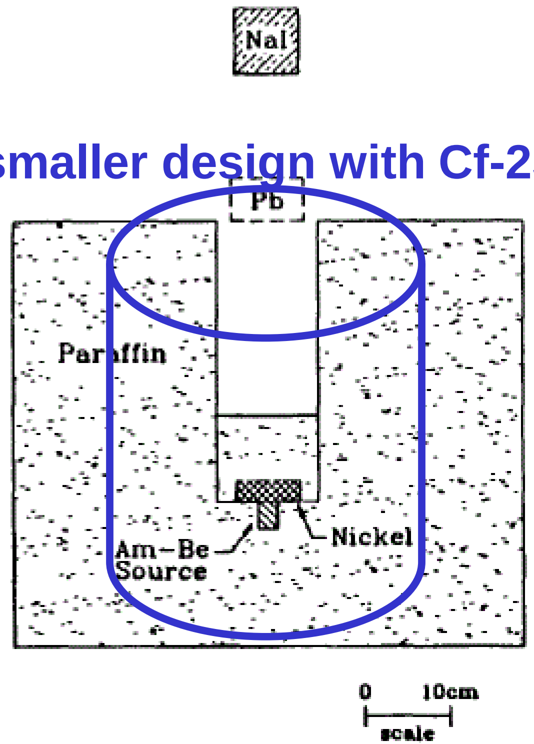


Table 1 - Thermal (n,γ) Rates from natural Ni taken from ref. [3]

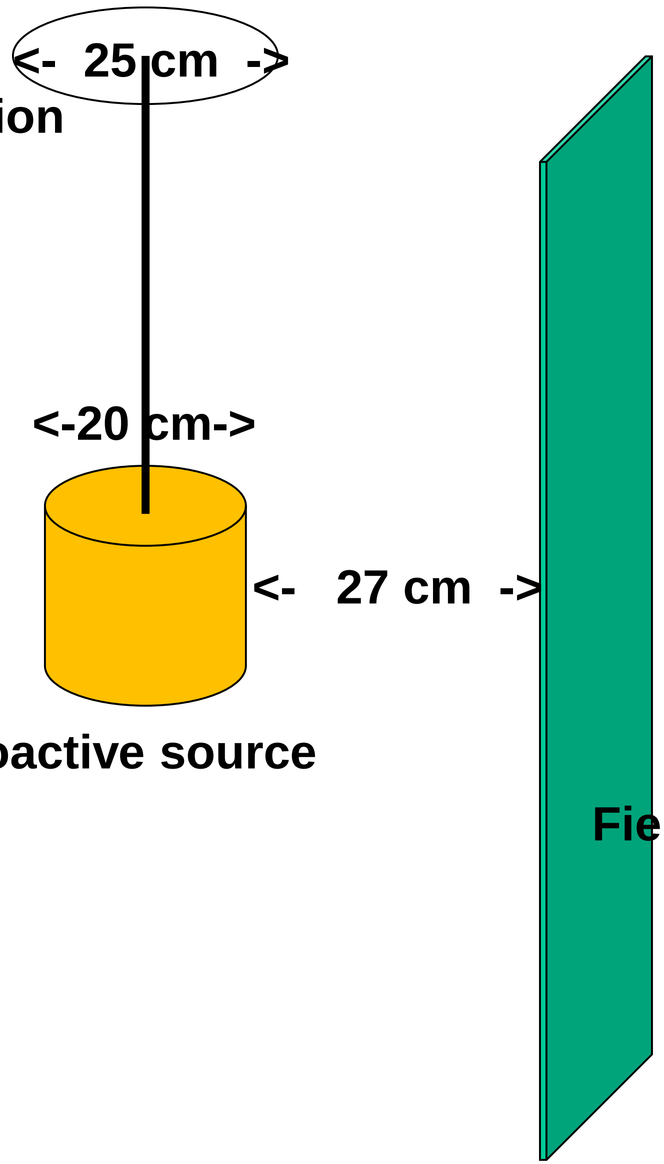
Gamma Energy (MeV)	Rate (photons/100 captures)
8.997	26
8.532	11
8.119	2.5
7.817	6
7.528	4
7.22	0.4
7.05	0.6
6.839	9
6.58	2
6.34	1
6.10	1.3
5.99	0.4
5.82	3
5.70	0.6
5.31	1.3

[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 20 cm diameter feedthru

Safety distance of deployed radioactive source wrt. FC

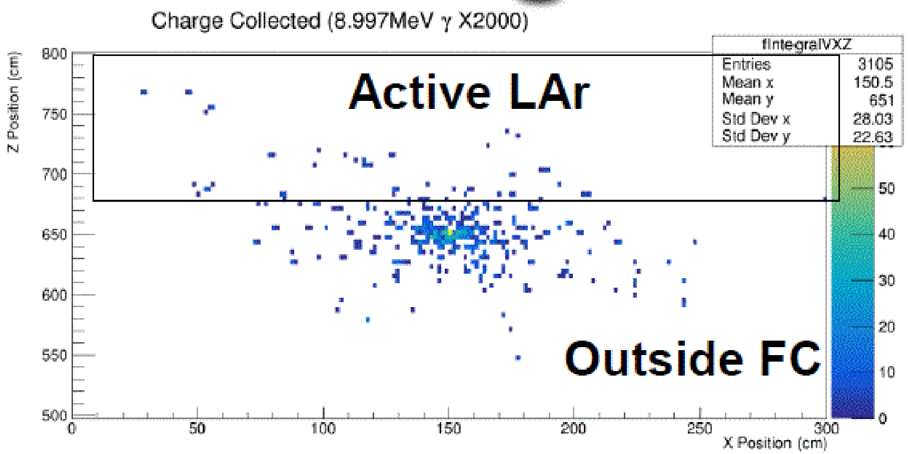
318.66 mm - (250 mm diameter / 2) + ~80 mm shrinkage = 273.66 mm

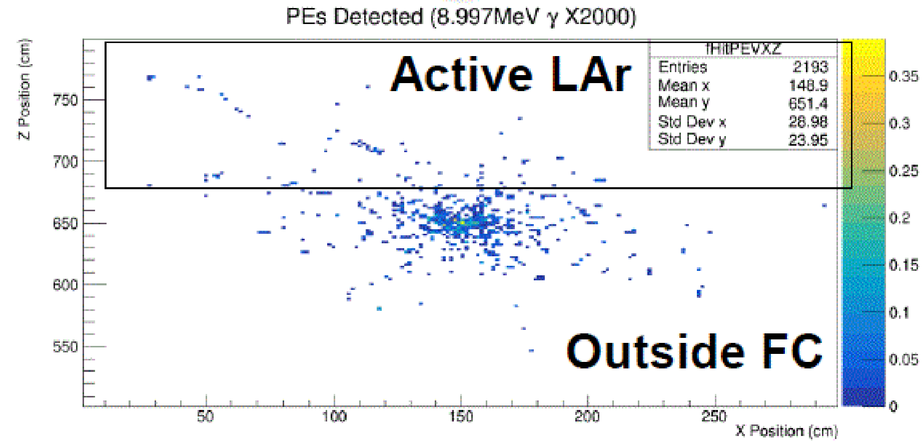


(Same 27 cm distance of source thru FTs on top of FC)

Plan First Radioactive Source Deployment inside a Cryostat

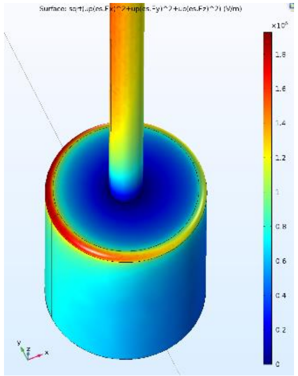
charge Source at half-drift **light**





Field cage:

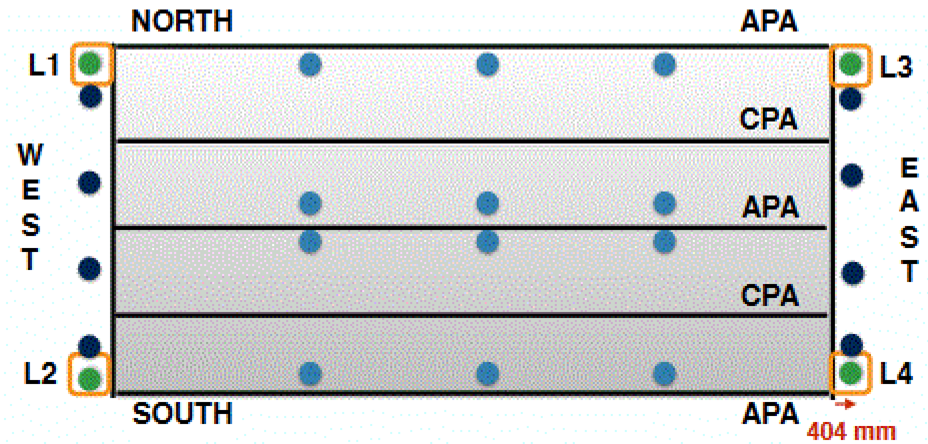
Dust samples for HV studies (Stock & Haiston)



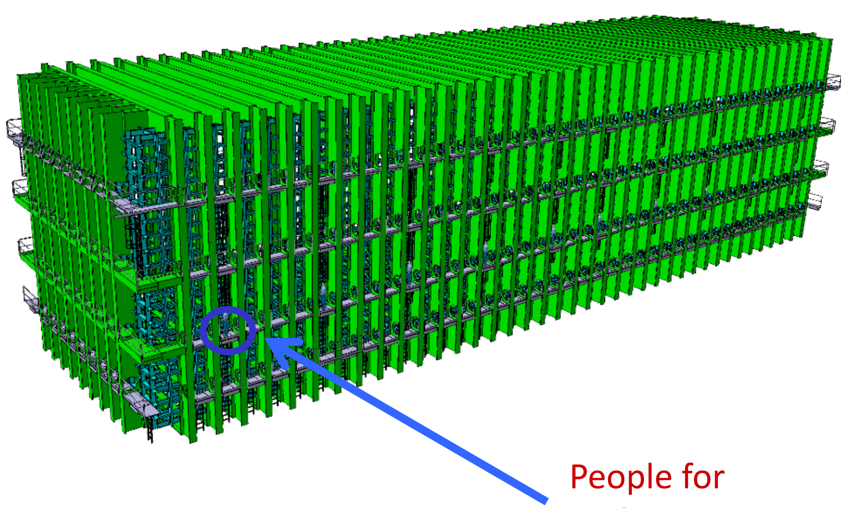
FEA sim (Bo YU)

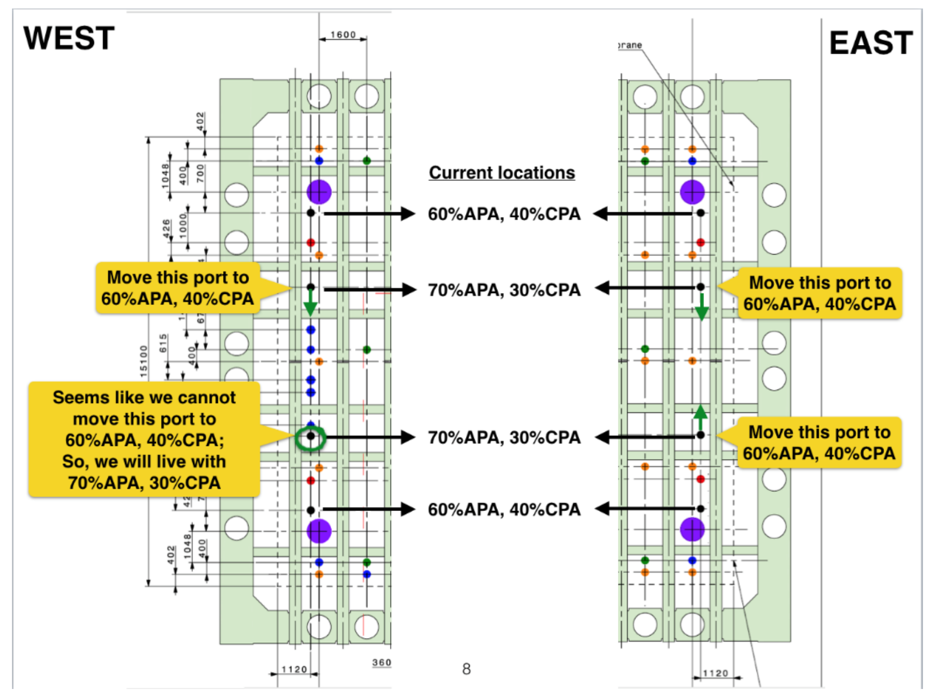
^{58}Ni(n,γ) source to be deployed vertically outside field cage (Haiston & Reichenbacher)

Plan First Radioactive Source Deployment inside a Cryostat



Planned feedthrough penetrations





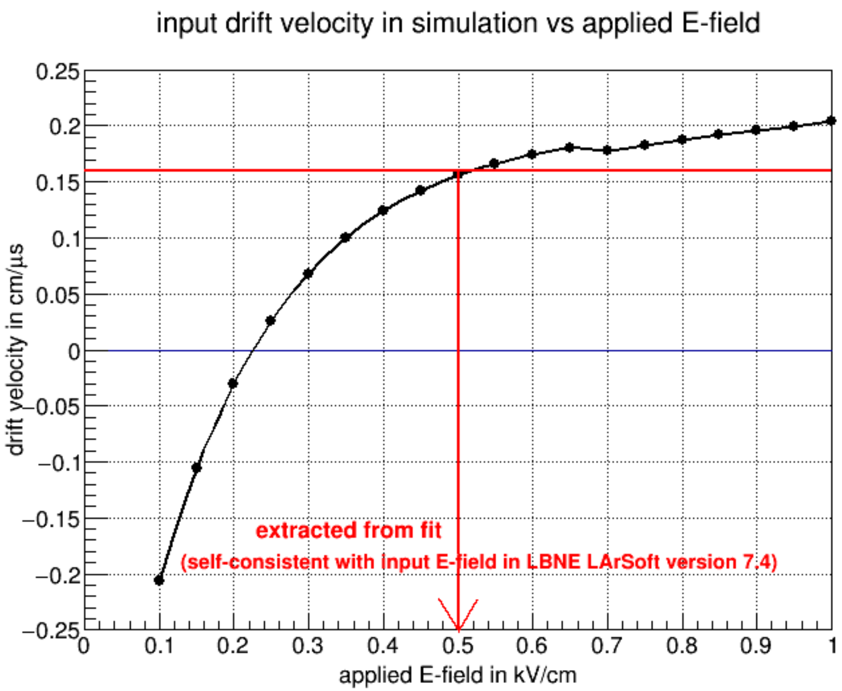
Double Chooz Calibration Deployment System inside Glove Box:

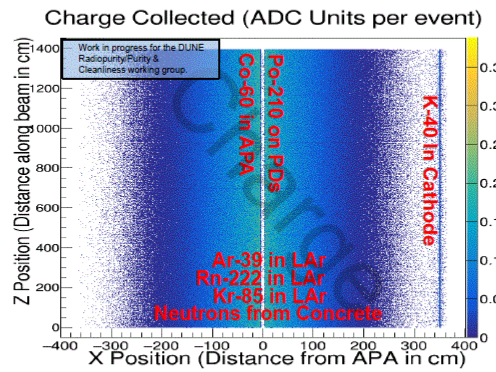
Automated fishline system for target deployments:

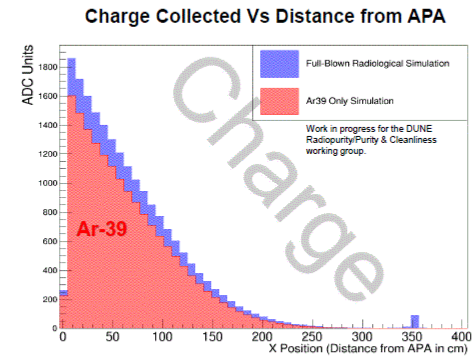
+/-2 mm precision over 7 m

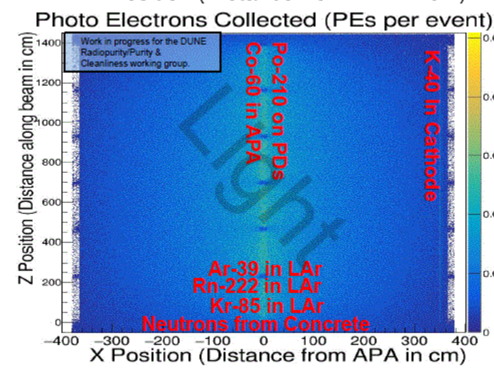
-> 2 systems available in Jan 2018

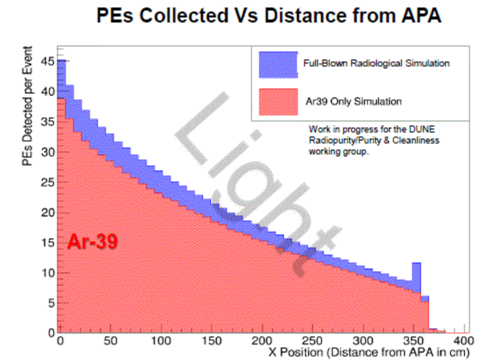
Summary discussion for immediate tasks











Do we really achieve our HV goal and e-lifetime? What's the electronic noise?

What's the detection efficiency for low-energy gamma's (in various scenarios)?

How does the detection efficiency depend on the Reco/HitFinder?

Are penetration locations sufficient?

Can we discriminate radiologicals?

…

Backup Slide: 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.