Brainstorming on
Design-stage issues for Neutrino Decay-at-Rest Experiments at ESS

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ESS allows for 2 types of Decay-at-rest fluxes,

pi/mu DAR (<53 MeV) and KDAR (<300 MeV):

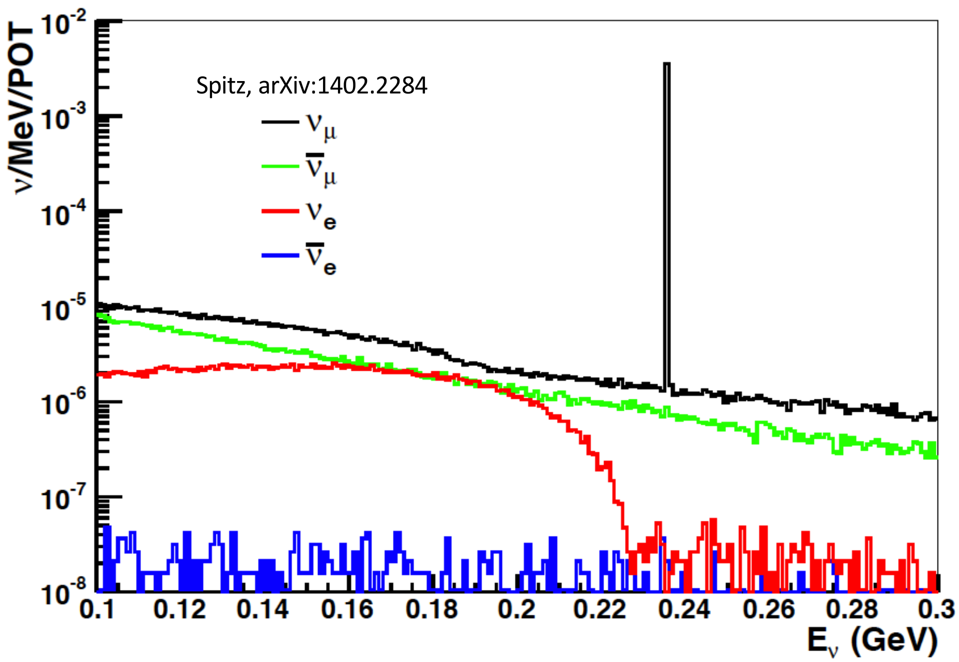


FIG. 1. The neutrino flux from 100-300 MeV provided by the 3 GeV proton-on-mercury JPARC-MLF source. The 236 MeV charged kaon decay-at-rest daughter ν_μ is easily seen.

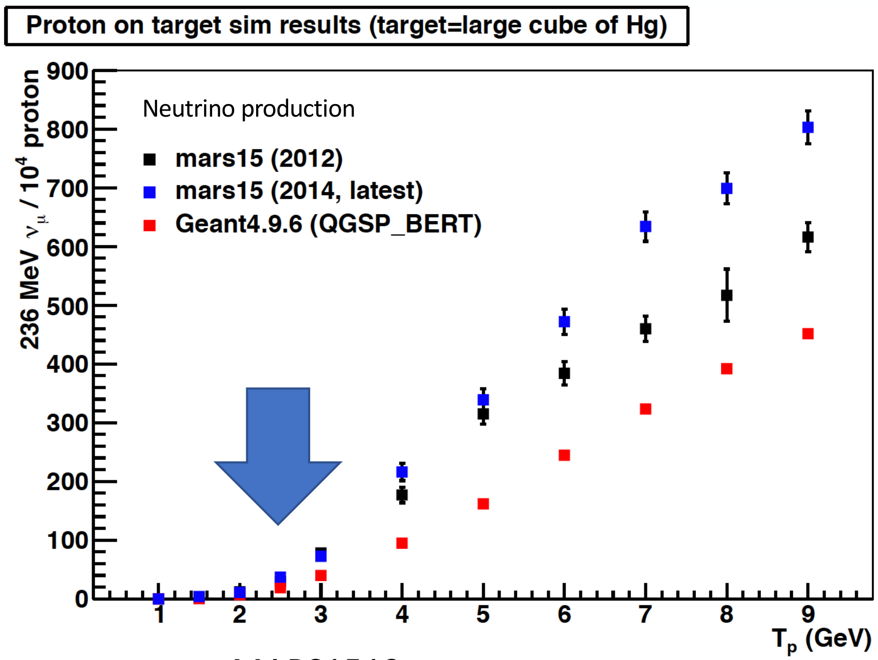
Very few locations that provide DAR fluxes can offer the KDAR flux:

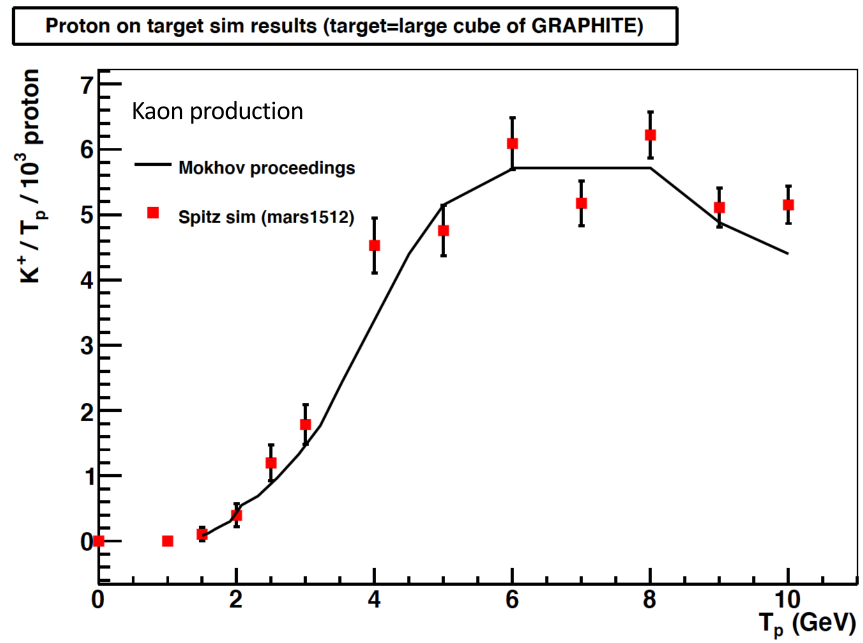
Facility	Proton Energy (GeV)	Power (MW)	Bunch Structure	Rate
LAMPF	0.8	0.8	600 µs	120 Hz
Lujan	0.8	0.08	290 ns (triangular pulse)	20 Hz
ISIS	0.8	0.16	2 x 100 ns	50 Hz
SNS	1.0	1.4 (2.4 w/ STS)	600 ns	60 Hz
MLF	3	1 Not reached Yet	2 x 100 ns (540 ns apart)	25 Hz
CSNS	1.6	0.1	<500 ns	25 Hz
ESS	2.5	5	2.86 ms (~1.3µs with PSR) CRUCIAL	14 Hz
PSI	0.6	1.4	CW	CW
BNB	8	0.032	1.6 µs	5 Hz
PIP-II LINAC	0.8	1.6	CW	CW

The high-intensity sites are MLF and ESS

Most of these sites are already operating,
Do not place neutrino experiments at high priority,
And are not designed with neutrino studies in mind.

MLF is running at 3 GeV protons on target. The ESS plan is for 2.5 GeV protons.
The reduced energy causes substantial reduction of the KDAR rate:





MARS1512:
34 KDAR numu per 10000 POT.

Geant4.9.6 (QGSP_BERT):
20 KDAR numu per 10000 POT

} Large differences in absolute Predicted rate!

What types of experiments benefit from the DAR fluxes?

Examples of Interesting Physics Goals (in no particular order)

→not including CEvENS-specific which you already heard about...

- IBD-based sterile neutrino appearance searches piDAR (LSND motivated)
- KDAR/CCQE -based appearance search (1203.6050)
- KDAR CCQE numu sterile neutrino disappearance searches (KPIPE, 1506.05811)
- numu disappearance with the 20 MeV neutrino from piDAR (upgraded CCM expt)
- Neutrino-electron scattering (NSI measurements complement the CEvENS plan)
- CCQE xsec at 236 MeV (1402.2284)
- Light Dark Matter searches
- Secret neutrino interactions (1911.06342)

Blue = Benefits from KDAR or is KDAR specific

What type of detectors might be used?

Scintillator

High pressure argon TPC

Liquid argon – with (SBN-like) or without (CCM-like) the TPC

The physics case is compelling;
the detectors are relatively straightforward to design and not too expensive.
A good way to start up a "Neutrino Campus" at ESS.

Some Design issues, ideas, and the advantages/disadvantages we would study:

1. Using the thin targets from ESSnuSB is not ideal – a lot of Decay in Flight neutrinos! Reduced DAR Flux

→ Option 1: the ESSnuSB beam dump be built to take the 5 MW beam for long periods to act as the DAR target
  Timing w/r/t ESSnuB running: We can begin running before ESSnuB is fully constructed.
  Or, to run simultaneously, we send the beam through the "target hole" to dump for some spills
  advantage of using ESSnuB area: a single beamline is installed.
  disadvantage: dump will be activated if we do early running.

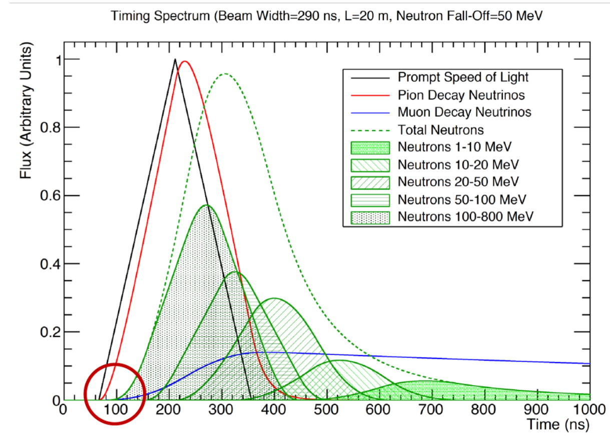
→ Option 2: A dedicated running area – more expensive but might make designing ESSnuSB easier.

2. The DAR target must be able to handle 5 MW -- This will be interesting for those who like high power targetry.

3. Target should be designed to minimize neutron production – this increases the flux and also
   reduces the amount of shielding for the detectors.

4. How well do the experiments need to know the absolute fluxes? (Some need this, some do not)
   What data can we use to get better predictions? Do we need to run a small experiment somewhere
   to make measurements? Can we leverage a better predicted piDAR flux to constrain KDAR?
   Can we do measurements in the beam hall that add constraints? How might those affect the design?

Example design issues, continued



5. Neutron shielding: The piDAR experiments,
   especially will need to be well shielded.
   One can use of the pulse-timing to eliminate neutrons
   but this limits the studies to the fast fluxes
   (eg 20 MeV pion decay)

6. Cosmic-ray shielding: The beam timing is crucial to reducing cosmic backgrounds. Is shielding also needed?
   How far below ground can the target hall be built? Can we build a hill on top of the hall?

7. Detector footprints and space in the target hall:
   Most detectors will have (few meter)^2 footprints.
   Some will want a range of locations from DAR target – few m to 10's of meters.
   Some of us are very interested in proposing a very long experiment (KPIPE)
   Most detectors are likely to want to be located in the opposite direction (upstream) of incoming beam,
   but LDM might prefer to be downstream

Not a complete list, but...

The design questions appear to be tractable and not too expensive to address.
We would like to have design-work for a DAR source incorporated into the proposal.