Workshop Introduction and Meeting Goals

David Hertzog

University of Washington

GORDON AND BETTY MOORE FOUNDATION

Purpose of this meeting: a mostly “in person” event!

- Articulate the Science cases for a RPD measurement program
  - LFUV, π–beta and V_{ud}, exotic searches, … BSM motivations …
  - THANK YOU to our many theory friends who will present and who have helped launch this program!
- Review experiences from experts on recent RPD experiments
  - Lessons learned and how to overcome pitfalls.
  - PIENU and PEN have an enormous vault of experiences. We must first **LEARN**
- Launching PIONEER to the next level with 1st in-person meeting of most of the participants
  - A lot has been done remotely, virtually, and so on
  - It’s time to interact and discuss as a real collaboration does – in person as much as possible (we know, it’s not totally possible)

Beyond these more obvious comments, what would we *really* like to accomplish or get out of this Workshop?

- On the experimental physics side:
  - Identify Key Performance Parameters (KPPs)* and begin to assign values
    - Beam: dP/P; pi purity; intensity; spot size
    - Stopping target: (x,y,z) “resolution”; Energy dynamic range; Timing response;
      - Practical stuff: allowed cabling thicknesses for various phases; cross talk acceptance;
    - Calorimeter options: resolution needed; pileup / rate capability; triggering options
      - Practical stuff: supports, thicknesses of wrappings; #channels; calibration method
    - Triggering, Digitization; DAQ:
      - digitization speed and depth for Calo and ATAR; triggering options for tail triggers and others
      - Practical stuff: #channels; platform choices (too soon?); building up test stands for groups to use
    - Cylindrical Tracker: (z,phi) resolution; speed of response; thickness maximum;
      - Practical stuff: footprint to surround ATAR but avoid Calo

* This language is not accidental. We will have to use it in funding proposals and in general reports on progress

KPPs … example expanded (from nEDM collaboration)

Performance Parameters:

KPP (Key) = Threshold KPP
NPP (Nominal) = Objective KPP
UPP (Ultimate) = Ultimate KPP

DO NOT WORRY ABOUT THESE ENTRY NAMES OR VALUES; IT IS ONLY THE SPIRIT OF THIS EXERCISE THAT WE SHOULD EXAMINE

Their "design goals" … much like our Proposal goals

Table 1. Experimental design goals for the key parameters that influence the statistical uncertainty.

Quantity	Definition	Value
P_{UCN}	UCN production rate	0.31 UCN/cc/s
N_0	Number of UCNs in each cell at t=0	4.5×10^5
V_{cell}	Measurement cell volume	3000 cc
τ_β	β-decay lifetime	880 s
τ_3	UCN-^{3}He absorption time	500 s
τ_{cell}	UCN-wall absorption time	2000 s
$\|E\|$	Electric field	75 kV/cm
T_m	Measurement time	1000 s
T_f	Cold neutron fill time	1000 s
T_d	Dead time between cycles	400 s
P_3	^{3}He initial polarization	0.98
P_n	UCN initial polarization	0.98
τ_P	^{3}He & UCN depolarization time	20,000 s
ε_3	Detection efficiency for UCN-^{3}He capture	0.93
ε_β	Detection efficiency for β-decay	0.5
$\dot{N}_B$	Non β-decay background rate	5 Hz

Now, map to RANGEs of achievable values

Description of Scope	KPP	NPP	UPP
Magnetic Field Gradient $\langle \partial B_i / \partial x_j \rangle_{vol}$ [μG/cm] [A]	0.5	0.25	0.1
Magnetic Shielding Factor at 0.01 Hz [A]	1×10^4	5×10^4	7.5×10^4
UCN Wall Loss Time [B]	100	1000	2000
⟨Photoelectrons⟩ per n-^{3}He Capture [C]	6	20	20
SQUID Noise [fT / √Hz] [D]	20	10	1
Electric Field [kV/cm] [E]	10	40	75
^{3}He ABS Flux [s^{-1}] | Signal-to-Noise Ratio [F]	1×10^{14} | 20	1×10^{14} | 50	1×10^{14} | 100
^{3}He Injection Volume Temperature [mK] [G]	350	320	300
8.9 Å Neutron Flux [n/Å/cm^2/s/MW] [H]	2×10^6	6×10^6	6×10^6
8.9 Å Neutron Polarization [%] [H]	80	90	98
Estimated Sensitivity [10^{28} e-cm] [I]			

This last line that I am hiding is experimental sensitivity given achieving all the values above in each column

The nEDM folks then did a fantastic exercise of developing analytical expressions for how the final sensitivity would depend on any combination of achieved KPP values. What matters most

PIONEER examples (Phase 1) … let's just have 2 steps

	KPP (lowest)	UPP (Ultimate)
Beam flux @ 65 MeV/c	200 k/s	300 k/s
dP/P (%)	2.5	<2
$\Delta X \times \Delta Y$ (FHWM, mm^2)		10 x 10
$\Delta X' \times \Delta Y'$		±10°
Muon contamination		
Electron contamination		
ATAR parameters		
X,Y pitch		
Z thickness		
Timing resolution (ns)		
Energy dynamic range		
CALO parameters		
Resolution at 69 MeV		

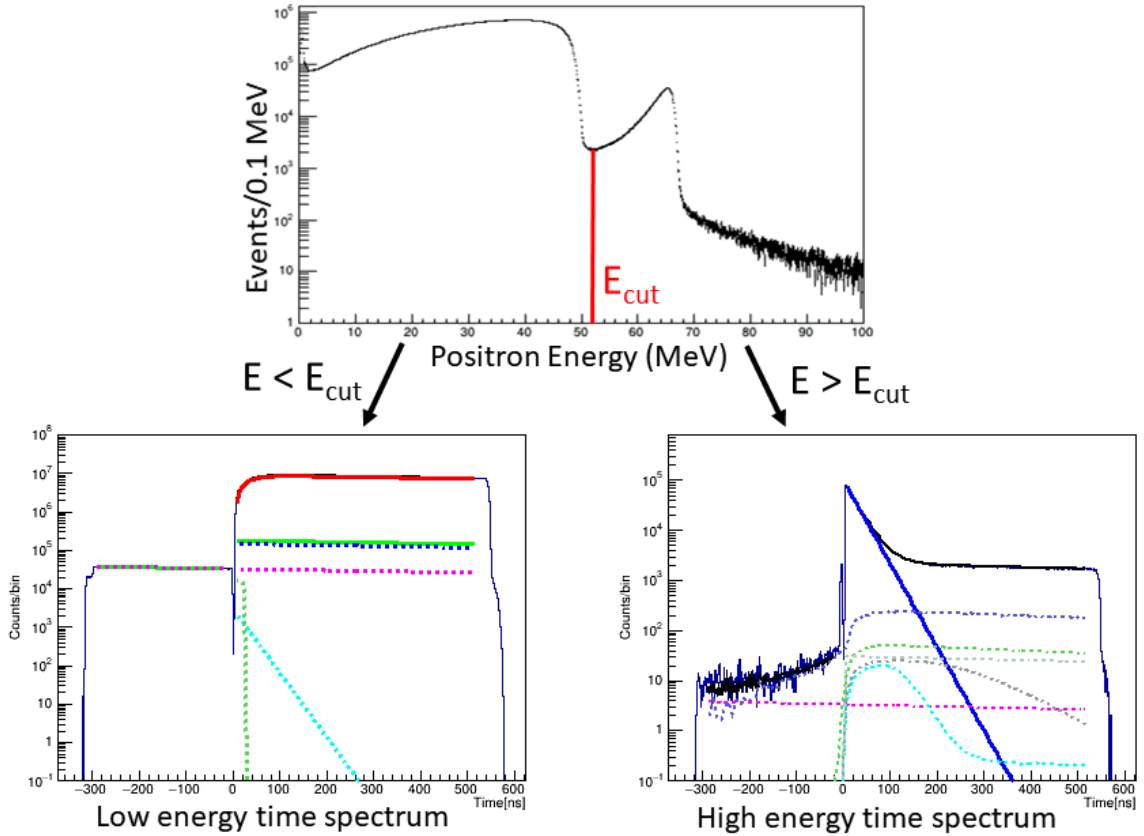
AND SO ON … TO BE FILLED IN

This week, we will hear reports on individual system progress… no coupling yet, nor implications on the final result sensitivity

- 1st beam tests at PSI
- Many ATAR development efforts and measurements
- How to go from MEG II LXe experience to a PIONEER-ready design and needed R&D
- Crystal calorimeter options, using PEN CsI in a hybrid configuration
- Next-gen electronics platform ideas for digitization, triggering, and DAQ
- Simulation platforms to guide designs

How do we assess these given the interplay between all parameters?

- We need to do a pseudo analysis, following PIENU and PEN efforts
- Sim group will discuss plans, run a simulation Bootcamp and establish target dates for realistic productions



Back to practical

- Let’s learn
- Let’s encourage discussion
- Let’s use the breaks to brainstorm
- Let’s formalize our Collaboration

"I have no trouble getting on high horses. Getting off has always been my problem."

Key dates coming …

- December: -- Sim team will talk about external input “due”
- January:
  - Report to PSI
  - Beam time 2023 request (if we want it; discuss after talks)
  - Possible pre-proposal for R&D to NSF (discuss Saturday)
  - Launch major Simulation of events (discuss later)
- Feb – April
  - Submission of …