

## ESS Science Symposium on Neutron Particle Physics at Long Pulse Spallation Sources

( about 50 participants)

Workshop **conclusions**

**Stefan Baessler**



1

## What are we doing?

Response from Dirk Dubbers:

“



”

As opposed to:

“

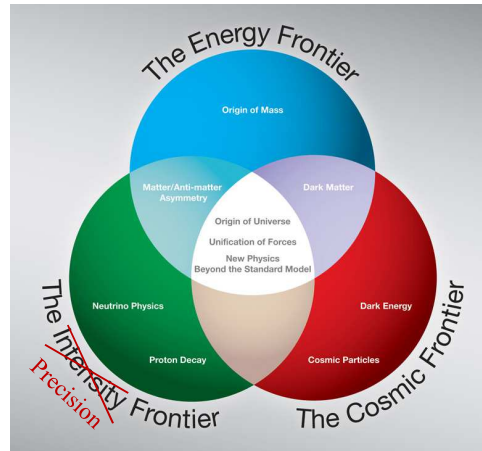


”

2

## US version of the response

Fermilab's view:



David MacFarlane, Director of Particle Physics and Astrophysics division, SLAC

“The Intensity Frontier involves many diverse lower-energy precision experiments; and its discovery potential, being less direct, is therefore harder to understand.”

3

## Theoretical motivation for fundamental physics with neutrons

Bill Marciano:

### Outline

- 1.  $T_n, g_A, V_{ud}$  & CKM Unitarity  
(Future Goals: Theory & Experiment)  
*Main Topic of this talk*
- 2. Neutron Electric Dipole Moment  $P$  &  $T$  Viol.  
(A Higgs Boson  $\rightarrow \gamma\gamma$  Connection?)
- 3. Neutron-Antineutron Oscillations  $|\Delta B|=2$   
(Are Neutrons Majorana Particles?)  
Dark Matter may also be Majorana! (Example)

Mike Snow:

[...]

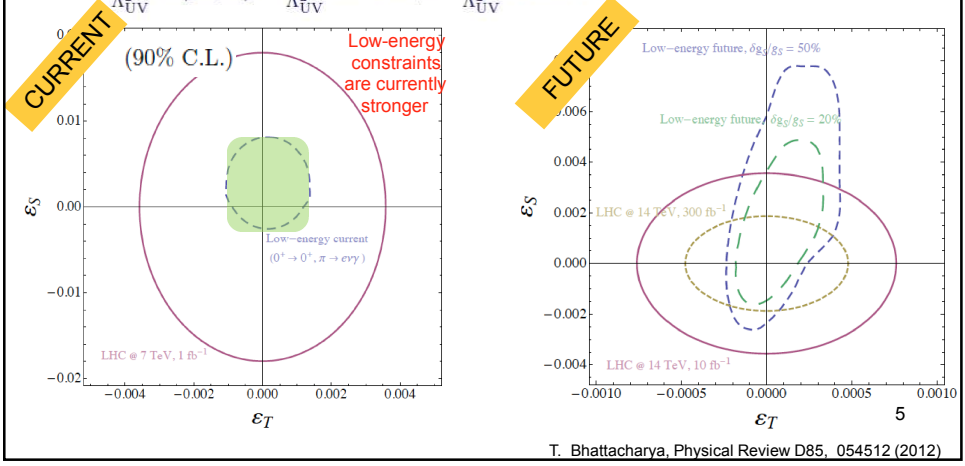
- Tests of quantum mechanics/entanglement/information
- NN weak interactions
- Neutrons and gravity (gravitational bound states, transitions, etc.)
- Search for weakly coupled new forces with mm-Angstrom ranges

4

## New physics in Effective Field Theory description

A. Singer: Description of new physics in a EFT picture:

$$\mathcal{L}_{\text{BSM}}^{\text{ET}} = \mathcal{L}_{\text{SM}}^{\text{ET}} + \frac{c^{(5)}}{\Lambda_{\text{UV}}} (\bar{\ell} \Phi) (\bar{\ell} \Phi) + \frac{c_{0F}^{(6)}}{\Lambda_{\text{UV}}^2} f G_{\mu}^{\nu} G_{\nu}^{\rho} G_{\rho}^{\mu} + \frac{c_{2F}^{(6)}}{\Lambda_{\text{UV}}^2} \bar{q} \sigma^{\mu\nu} u \Phi G_{\mu\nu} + \frac{c_{4F}^{(6)}}{\Lambda_{\text{UV}}^2} \bar{q} \Gamma q \bar{e} \Gamma e + \dots$$



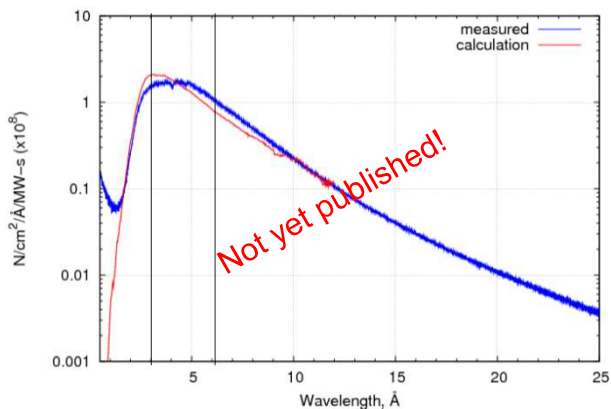
## Tools we possibly want:

- Cold neutron beamline(s)
- UCN source in beam and/or in-pile
- Through-going beam tube(s) for experiments
- More efficient (colder) moderator

This is all nice to have, but asking for everything assumes there is no limit on manpower, money, time in the community (be careful what you ask for!):

## Properties of cold beamline

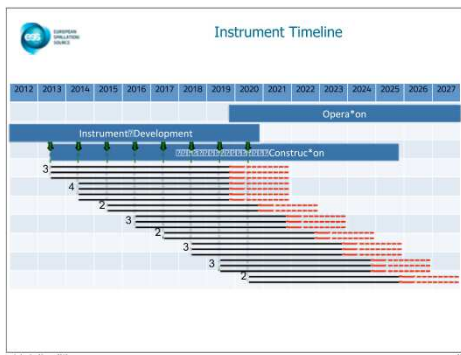
- Average flux about the same as strongest reactor beams
- Time structure gives (about) neutron de-Broglie wavelength  $\lambda = h/m_n v$   
(Note: Need to discuss overlap)
- Time structure might help to tell signal from background
- SNS: near- to-perfect agreement between expected and measured performance



7

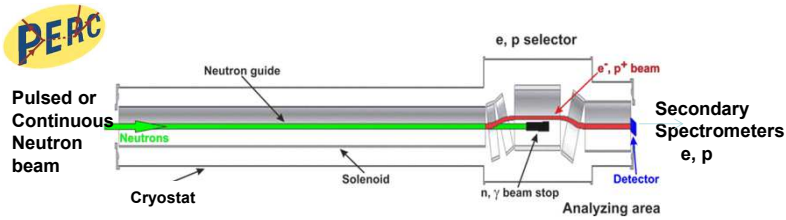
## Properties of cold beamline (2)

- Much higher fast neutron component in background  
More serious “instrument” shielding than at reactors  
For npdgamma: Data during flashed not analyzed, but no persistent detector saturation observed
- Standard: Combined Thermal/cold beam. Do we want thermal component?
- Shorter construction phase than for other ESS-”instruments”



8

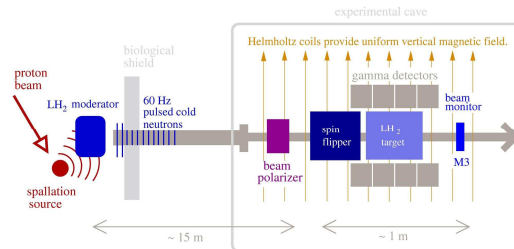
## Experiments, potentially for ESS (1)



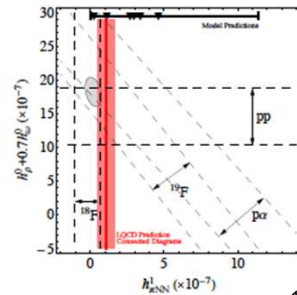
- Clear theoretical motivation
- Funding (about) in hand
- C. Klauser: Factor 5 statistical advantage to FRM-2 (preliminary, maybe more)
- T. Chupp: Polarization analysis in polarized neutron beta decay experiment (advantages: of pulsed beam: in situ-monitoring, potentially more precise measurement)
- (-) PERC is just being built at FRM-2

9

## Experiments, potentially for ESS (2)



- Npdgamma is running at SNS, looks like it will be systematics limited, and therefore can “just” be moved to SNS (see Scott Wilburn’s talk)
- Theoretical motivation might change, depends on SNS result and progress in Lattice-QCD
- (-) Not clear who will do ESS-npdgamma and who will fund the necessary modifications (E.g., the move to SNS required a rebuild of the LH2 target due to different hydrogen safety requirement)



10

## Other experiments, potentially for cold beamline @ ESS

More experiment proposals:

- Neutron Spin Rotation (n-4He, n-H2) (benefit: statistics, systematics) and ndtgamma look for weak hadronic interaction physics (as npdgamma) (M. Snow)
  - Neutron beam lifetime (benefit: systematics) (F. Wietfeldt)
  - nnbar (Theoretical motivation, but proposal @Project-X, not @ESS. See Y. Kamyshev. Problem: Coexistence with 21 scattering elements?)
  - Spin-rotation measurements with Ramsey apparatus in cold beam to search for new physics. (see F. Piegsa's talk)
- 
- UCN source (superfluid He, O. Zimmer et al., M. Pendlebury et al.) developed for cold beam (see next slides)

11

## Experiments with UCN

Typically “flagship” experiments

- Neutron electric dipole moments (strong theoretical motivation, to the consequence that there are already half a dozen ongoing EDM searches).
- Neutron lifetime in bottle
- Gravitationally bound states (quBounce –T. Jenke, GRANIT – P. Brax )
- Eventually nnbar in huge bottle (A. Young)
- Interferometric experiments (A. Frank)
- ...

Physics case beyond (my) doubt

Expression of interest for UCN @ ESS are needed.

12

## • UCN source concepts for ESS

Sources: “In beam”: M. Pendlebury, O. Zimmer

“In pile”: presentations for UCN sources at other spallation facilities (LANL, PSI, FRM-2, KEK, missing: TRIGA: Mainz), but not for ESS

“In-pile (B)”: Source could be in through-going tube

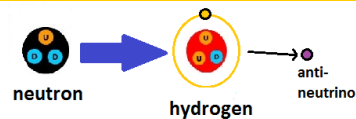
If maximum UCN production rate is desired, in-pile source are favored. If maximum UCN density (in not-too-big volume) is desired, in-beam is better/easier (for comparison, see O. Zimmer’s talk).

Path forward:

- Need expressions of interest of experiments to built/moved to ESS
- Decide on the type of UCN source
- If “in-beam”, cold neutron beam optimization should be a compromise between cold neutron experiment and UCN needs. What is the advantage of ESS to other strong CN beams?
- If “in-pile (through-going tube)”, need to be part of community proposal.

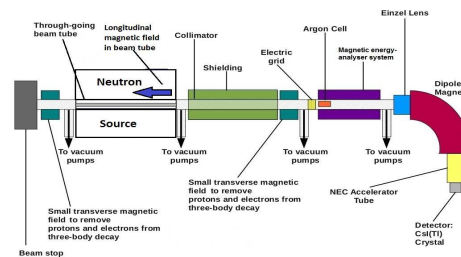
13

## Through-going tube for other experiments



J. McAndrews, **Bound beta decay**

- Population of atomic hydrogen hyperfine states is sensitive to new physics (V+A, S, T)
- Need expressions of interest to go to ESS
- Need goals for tube (position, diameter)  
(in particular: is it the same tube as for “in-pile” UCN source?)



Other uses for through-going tube in traditional nuclear physics: nuclear fission, gamma spectroscopy

14

## Relevant ESS Policy decisions

(Looks light a detail, but might turn out costly)

- Decision on Magnetic field requirements:
    - LANCSE: Wild west
    - SNS: < 50 mGauss at neighbor instrument (that would probably kill PERC@ESS, but good for low field experiments like Spin-Echo / EDM)
    - ILL, FRM-2: no fixed policy
  - Background requirements (unlike for many scattering instruments, fundamental physics demands are often much more demanding for detectors than for people):
    - fast neutron flash (problem for safety, and if detectors would remain dead afterwards
    - Signal **and** beam-related background are time-dependent, need policy for neighbors (instrument might be more sensitive than people)
  - Space: Length (optimization for PERC seems reasonable), height, preparation space+crane, beamline at edge allows for place to the side.
- Possible infrastructure wishes for which experiments can make a case:
- |   |   |  |    |
|---|---|--|----|
| <ul style="list-style-type: none"> <li>• Central facility for polarized He3</li> <li>• Central facility for LHe (+recovery)</li> <li>• Climatisation</li> </ul>                 | } | <p>Needed by many experiments @ ESS<br/>(in my view)</p>   |    |
| <ul style="list-style-type: none"> <li>• Humidity/vibration control</li> <li>• Stainless steel as opposed to standard steel in floor</li> <li>• Pit below instrument</li> </ul> | } | <p>Need expression of interest<br/>from experiments that move<br/>to ESS to make a good case</p> | 15 |



## ESS target opportunities for NPP

(F. Mezei)

Decisions are made by the ESS STC on the basis of proposals!

- NPP beam line: In principle funded, but good proposal needed!
- $\phi$  20-25 cm through going tube at about 50 cm below moderator: good case study needed, funding could be found for keeping an upgrade opportunity open
- Smaller through going beam closer? Does it make sense?
- Moderator development for more long wavelength neutrons: ongoing work. Case study for what would be helpful (e.g. 9 Å? > 20 Å?)



## Summary of the summary

Work is cut out:

- Need to write convincing proposal (within 6 months) to ESS
- So far, only Torsten was named as volunteer
- Need to agree on contents
- Details (beamline design) can be worked out later. ESS funded Postdoc(s) position for detailed design, to be filled soon.

Thank the organizers (Torsten, Guillaume, Peter, Angelika, Josephine)

**Have a safe trip home!**



17