Future Opportunities for HPNC Measurements using Neutrons

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References for Neutron Beam Properties

NIST NG-C: J.C. Cook, Rev. Sci. Instr. 80 (2009), 023101.

ILL PF1B: H. Abele et al., Nucl. Instr. and Meth. A562 (2006), 407.

SNS FnPB: N. Fomin et al., Nucl. Inst. Meth. A773 (2014), 45; arxiv:1408.0753.

JPARC NOP: Y. Arimoto et al., Prog. Theor. Exp. Phys. (2012) 02B007.

FRM MEPHISTO: J. Klenke, private communication (2014).

ESS ANNI: T. Soldner et al, proposal to ESS STAP (2015).

PIK : A. P. Serebrov et al, Physics of Atomic Nuclei 79, (2016) 293.

Neutron Particle Physics Cold Beams

Facility	Pulsed?	Capture flux density, area [10^9 n/cm^2/s]	Total capture flux [10^{11} n/s]	Comments
ANNI (ESS)	Yes	50, 8 cm x 8 cm	32 (polarized)	ESS under construction, ANNI not yet approved
PF1B (ILL)	No	20, 6 cm x 15 cm	24	
MEPHISTO (FRM II)	No	18, 6 cm x 10 cm	13	Dedicated to n beta decay
NG-C (NIST)	No	8, 11 cm x 11 cm	10	Cold source upgrade in 2022, X (1.5-2.0)
FnPB (SNS)	Yes	4, 10 cm x 12 cm	5	Fully subscribed
NG-6 (NIST)	No	2, 6 cm x 15 cm	2	Now neutron imaging

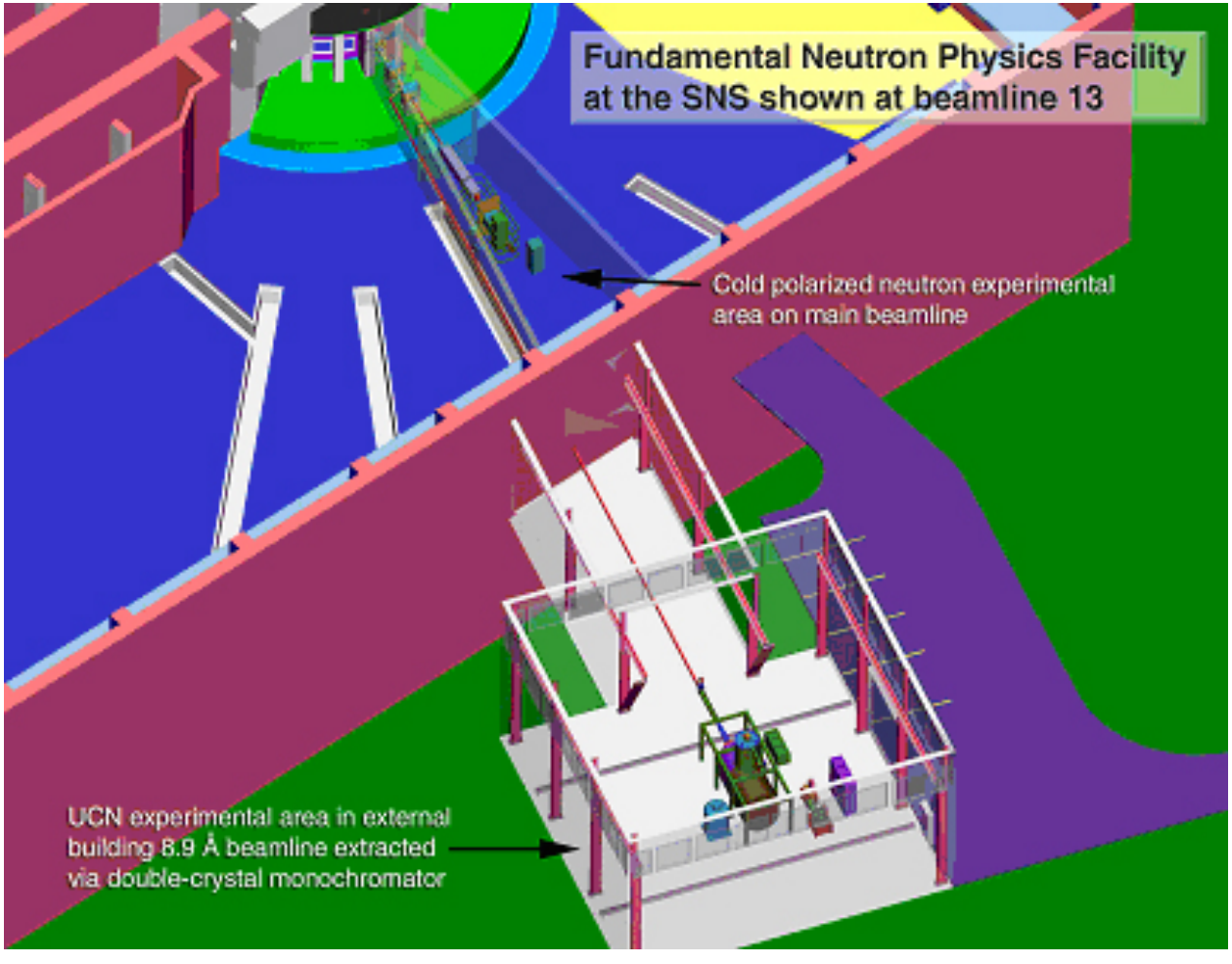
Last three neutron HPV experiments in the US:

2 done at SNS (NPDGamma, n-3He)
1 done at NIST (4He spin rotation)

Last two neutron HPV experiments in Europe:

2 done at ILL (n+6Li, n+10B)

Fundamental Neutron Physics Beamline (FnPB) at Spallation Neutron Source, ORNL



Experiments completed:
NPDGamma
n-3He

Next up: Nab neutron beta decay experiment

In preparation: Neutron EDM experiment in superfluid helium

Opportunity for HPV experiments? NO

Neutron Physics Beamline (FnPB) at Japanese Spallation Neutron Source, JPARC

Experiments completed: angstrom-scale exotic Yukawa

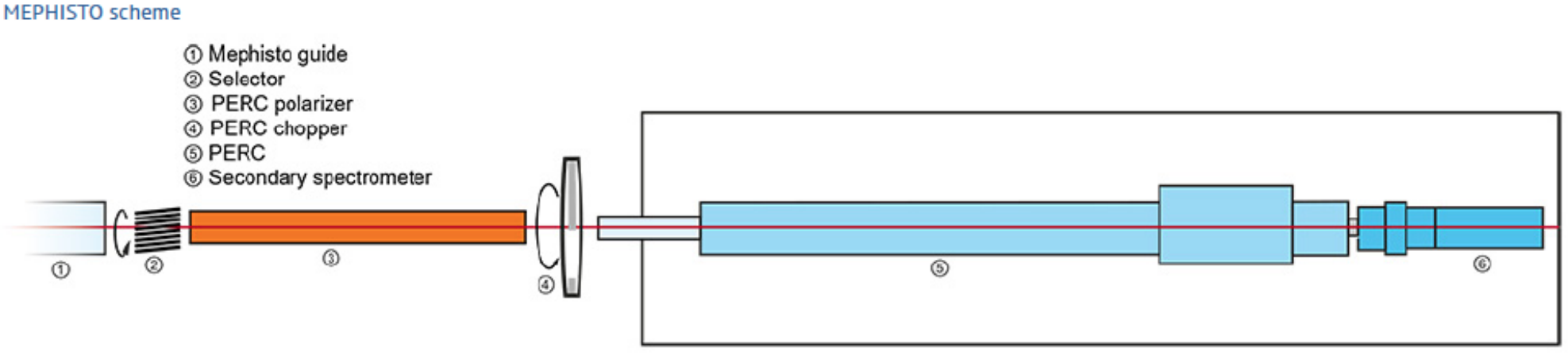
In progress: neutron lifetime measurement (beam, TPC)

In preparation: various experiments in neutron optics/ detectors/UCN

Beam port is split into three separate beams with different optimized properties

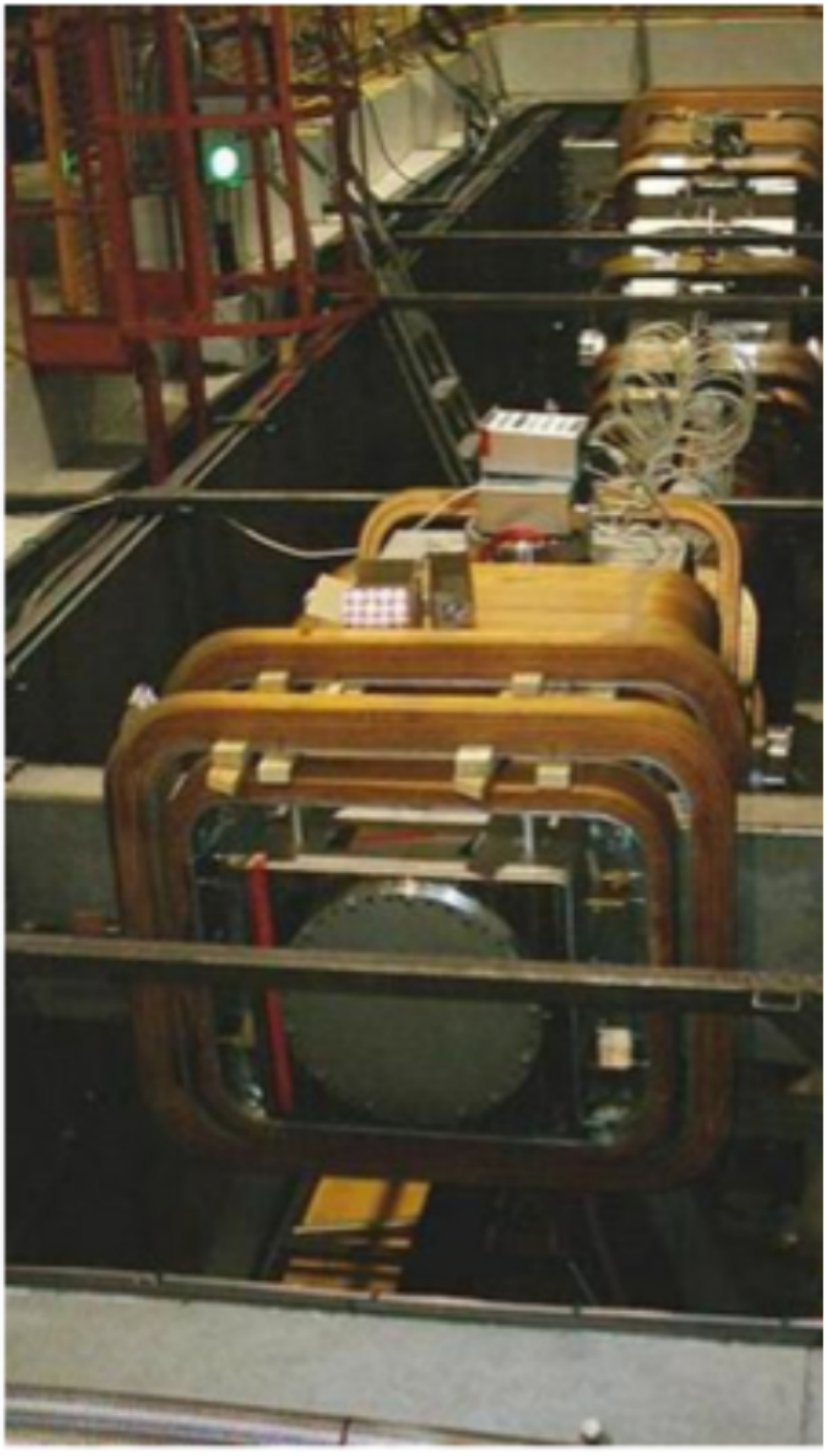
Opportunity for HPV experiments? NO

MEPHISTO at FRM/Munich



Beam (under construction) is devoted to the PERC neutron beta decay spectrometer facility

Opportunity for HPV experiments? NO



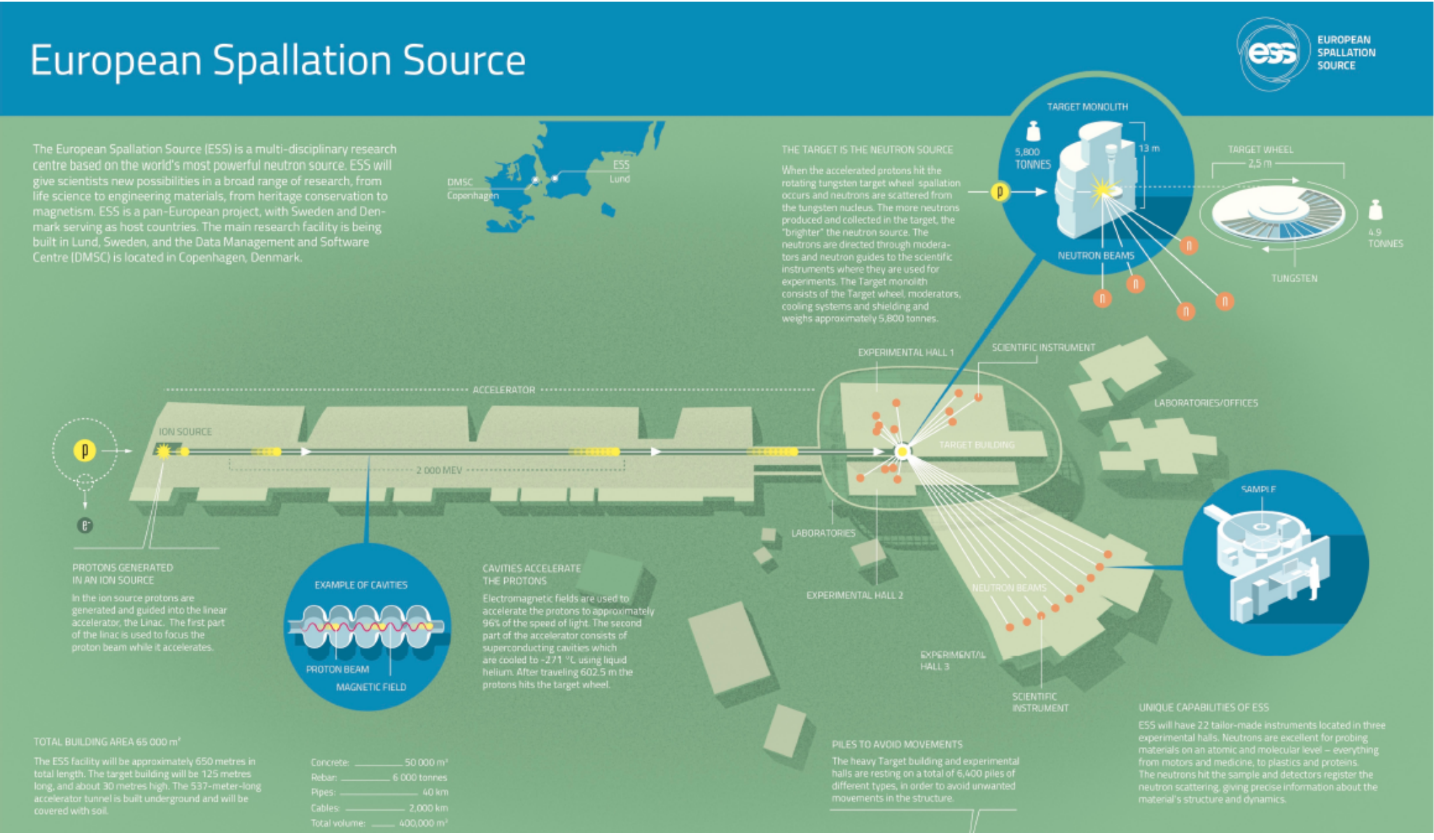
PF1B at ILL

Most intense cold neutron beam in the world

US not a member of ILL (local collaborators needed)

ILL operating time has decreased lately (fuel costs, safety issues)

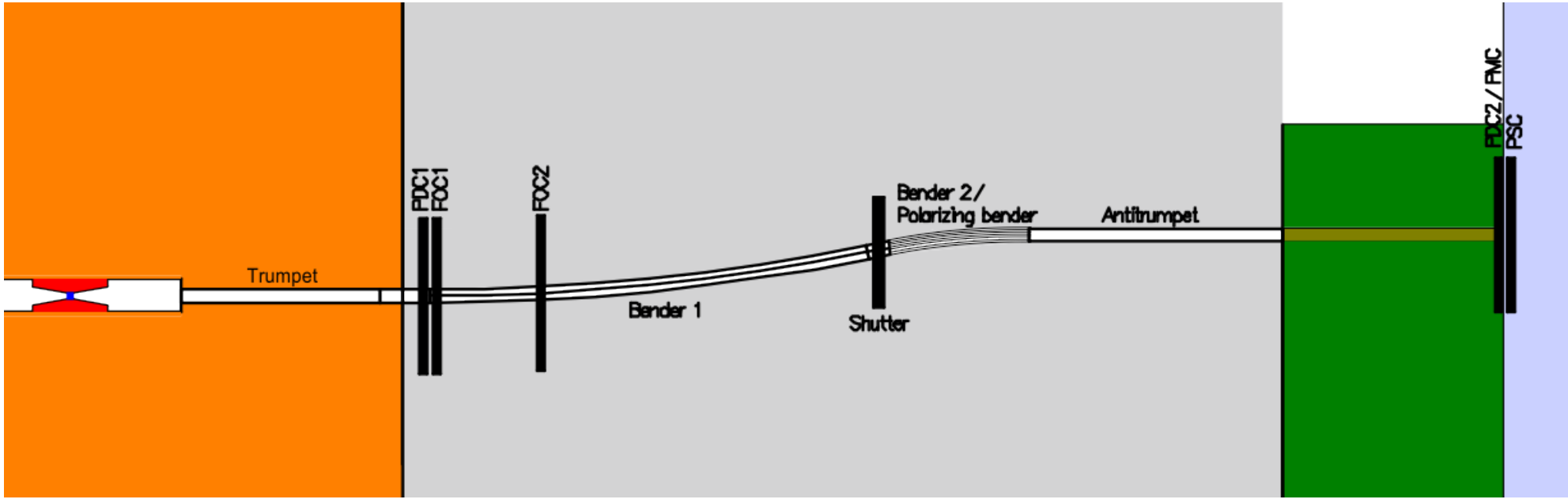
Opportunity for HPV experiments? MAYBE



5MW long-pulsed spallation neutron source
Rotating W spallation target
~3 msec pulses, 2 GeV proton linac, 14 Hz rep rate

ANNI concept for ESS

Maximum statistics at minimum systematics for versatile user instrumentation

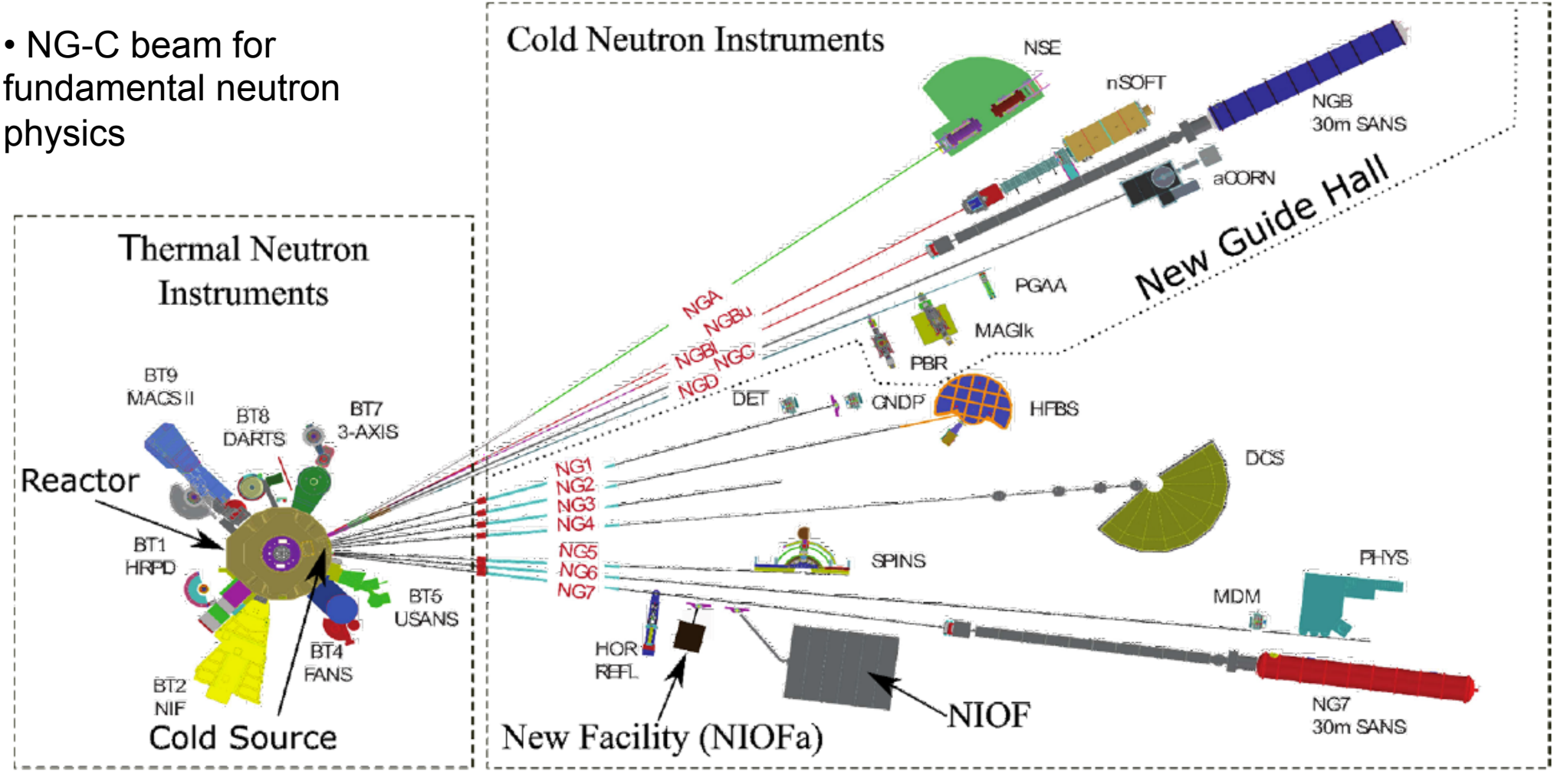


Next proposal call in 2019
ESS wants to have a fundamental neutron physics component
ESS user facility start set for 2023

Opportunity for HPV experiments? YES

NIST Guide Hall Layout

- NG-C beam for fundamental neutron physics



Fundamental Neutron Physics Beamline NG-C at Center for Neutron Research, NIST

Experiments completed: aCORN neutron beta decay

In progress: BL2 beam neutron lifetime measurement

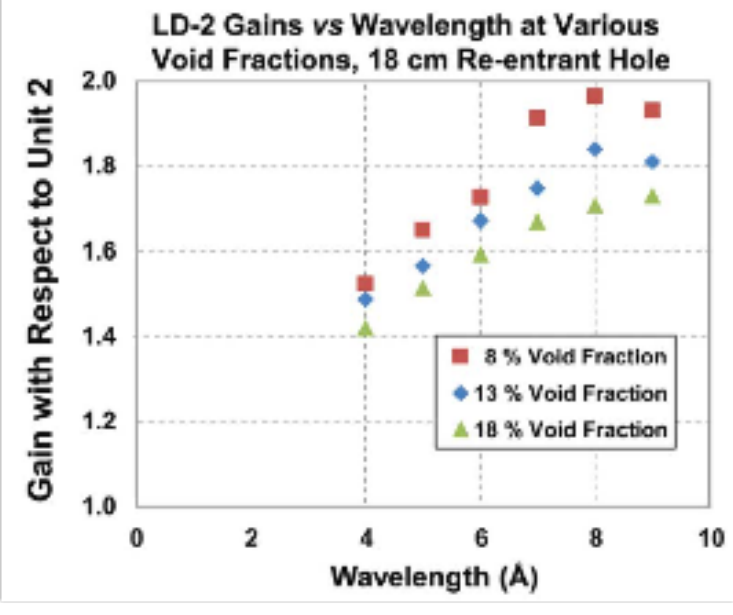
Expressions of interest: n-4He spin rotation, aCORN B

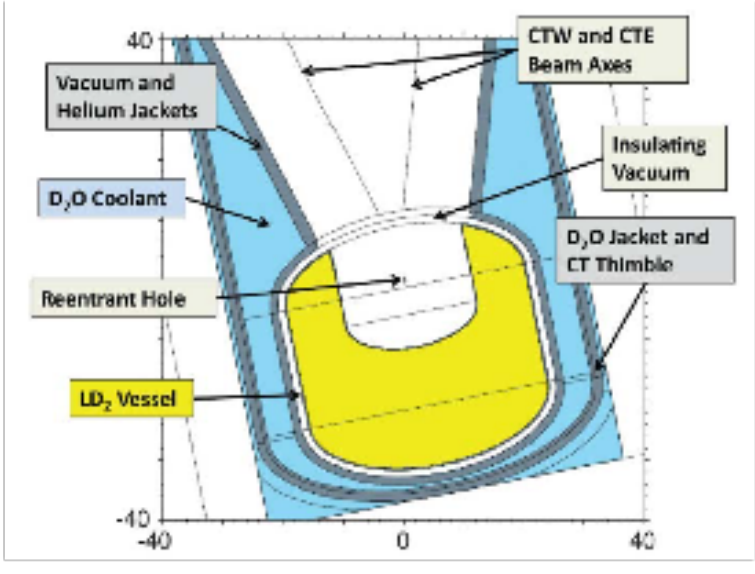
Opportunity for HPV experiments? YES

FACILITY DEVELOPMENTS

Improving reactor reliability and availability
Continuing reactor system upgrades
Updating operating and maintenance procedures

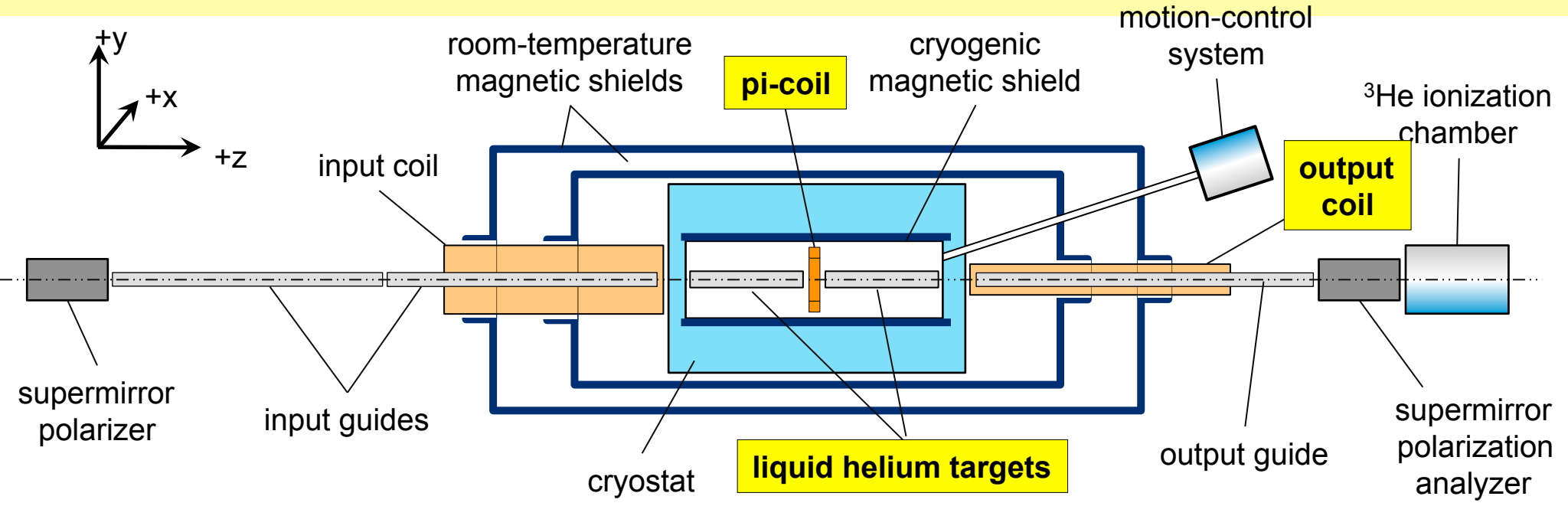
Liquid D_2 cold source design underway
Major procurements on-going





Preliminary installation timeframe: Spring 2016 → 2021 (slide from R. Dimeo 3/2013)

4He spin rotation apparatus: all done but cryogenics



No modern theoretical calculation yet, but doable. p-4He parity violation already measured

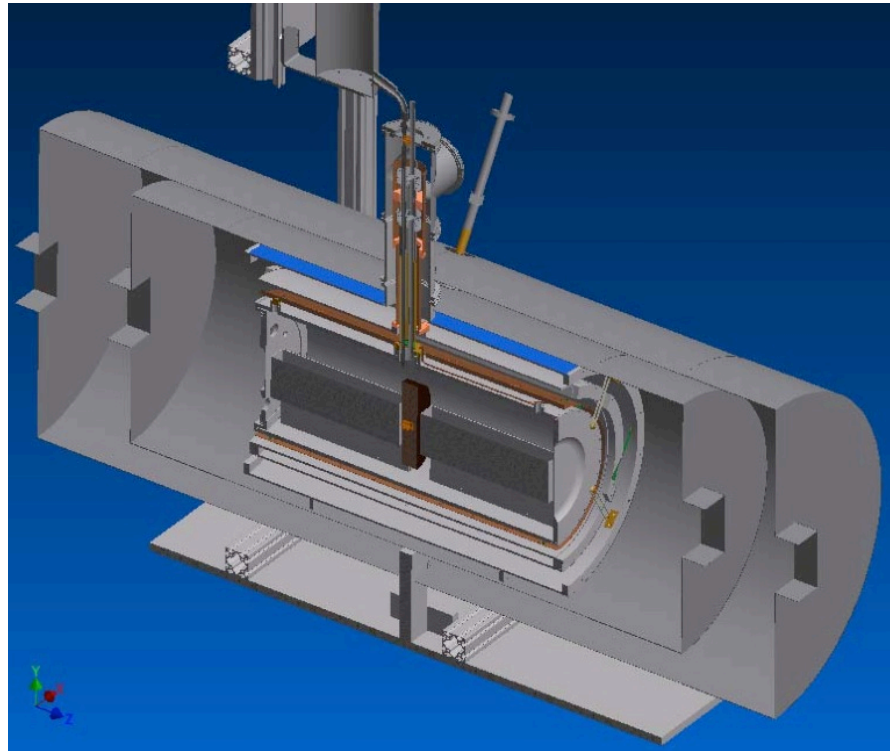
PV spin rotation angle estimated to be “large” (~7 E-7 rad/m)

Can use same components as for the helium spin rotation apparatus except for the cryogenic target

With NIST cold source upgrade and longer running time: 1E-7 rad/m statistical error is possible, systematics very encouraging

NSR-III Cryogenics

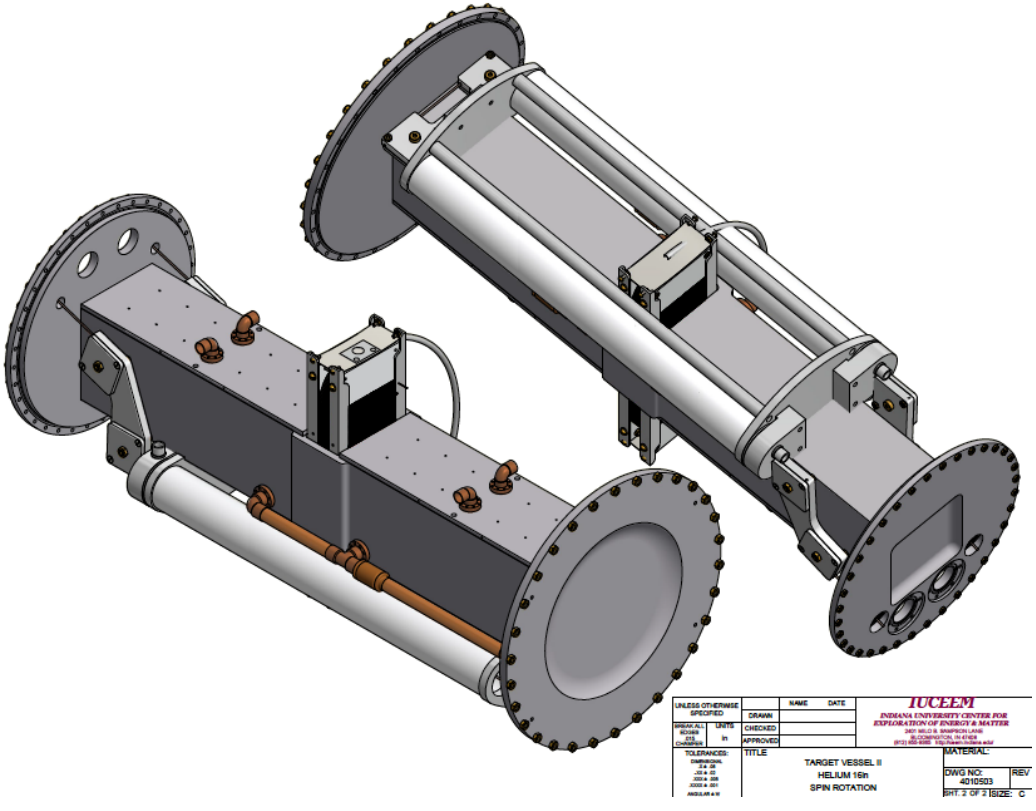
- Improved cryogenic design for reduced heat load, simpler assembly/disassembly, and more robust operation
- He re-liquefier removes necessity of LHe fills
- R&D on new LHe pump to reduce target change time

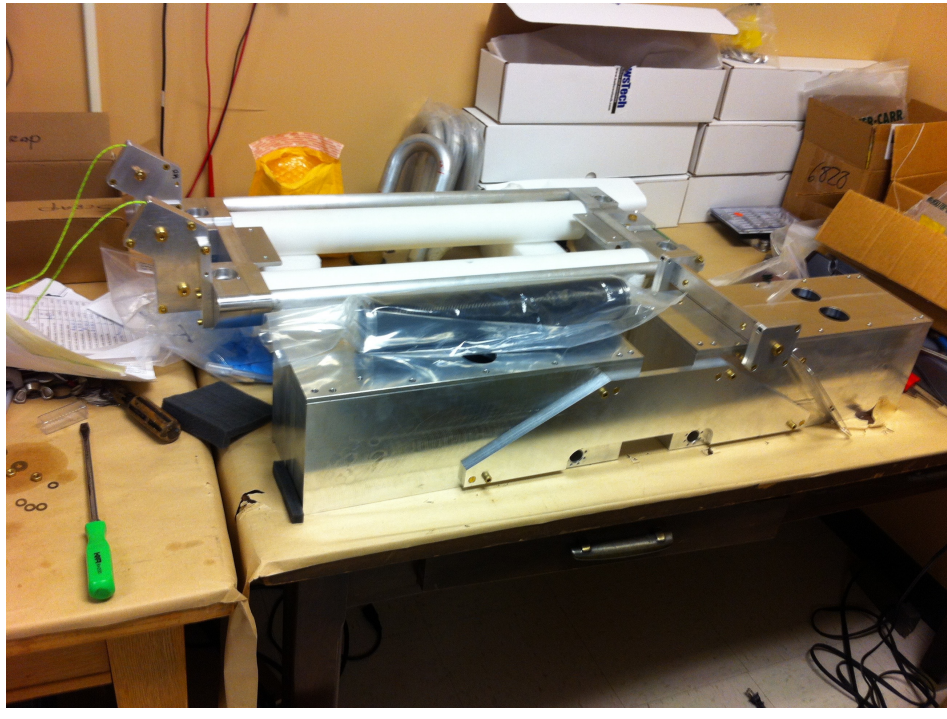


Liquid Helium Pump/Target Design

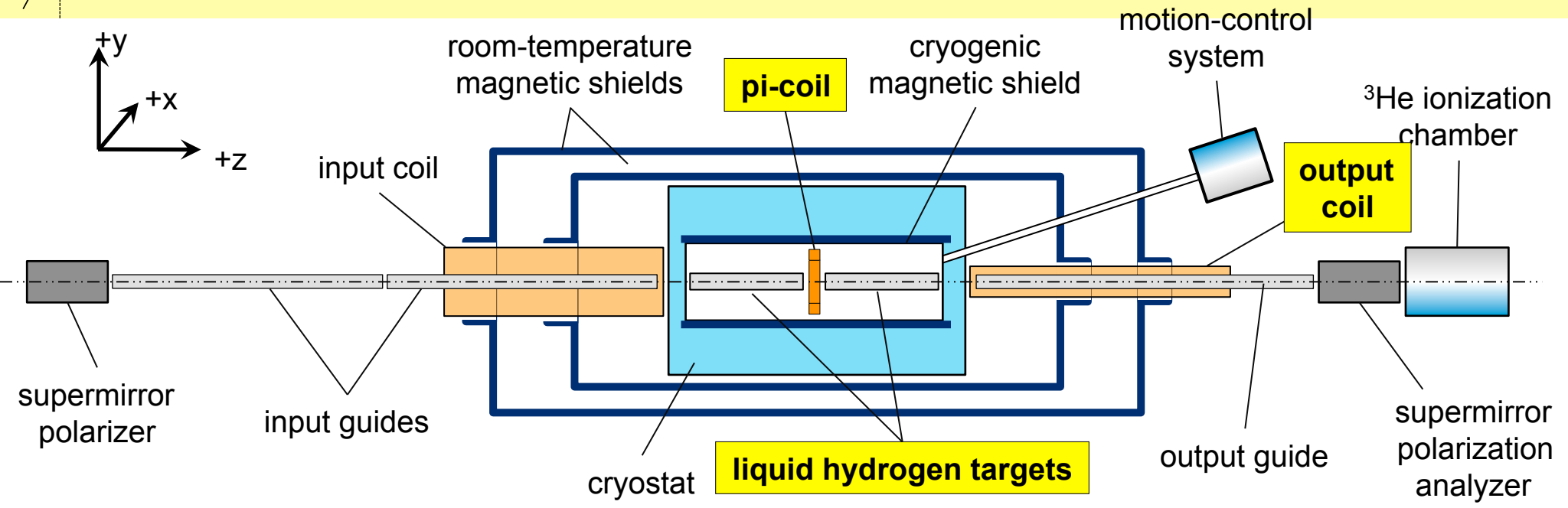
Titanium bellows pump design: tested for ~600,000 cycles in liquid nitrogen

Helium pump under construction at IU





What about Liquid Hydrogen Spin Rotation?



2-body system: very nice from pionless EFT point of view, some sensitivity to isotensor amplitude

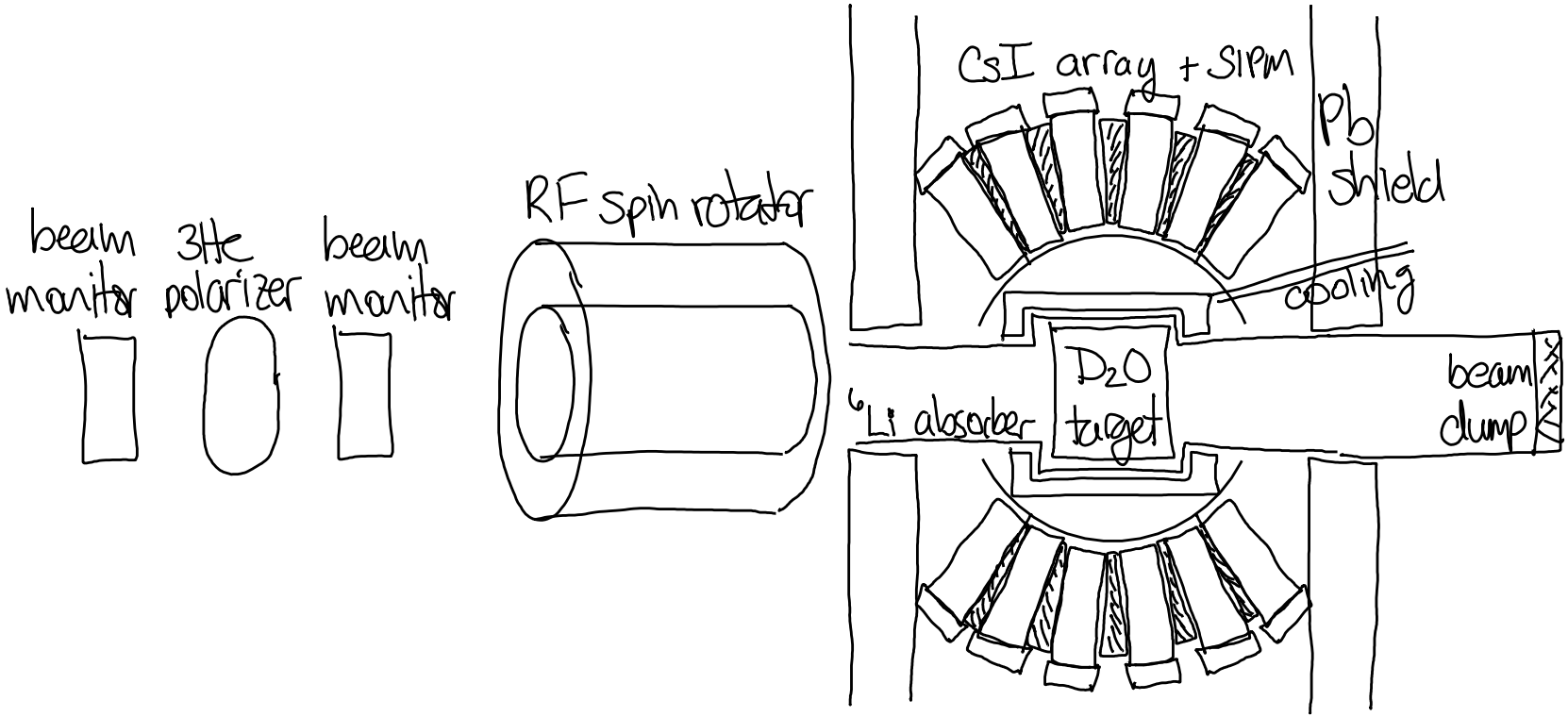
PV spin rotation angle estimated to be “large” (1 E-6 rad/m)

Can use same components as for the helium spin rotation apparatus except for the cryogenic target

Target length is shorter than for 4K helium by ~factor of 2, more small angle scattering systematics

With NIST cold source upgrade and longer running time: 1E-7 rad/m statistical error is possible

NDTG possibility at NIST NG-C



3-body system: calculation looks doable in pionless EFT, need it to judge the physics impact (new calculations by Gudkov et al and others exist)

PV asymmetry should be “large” (~10E-6)

~1E-7 statistical error on asymmetry looks possible at NIST NG-C (needs checking)

Some work done on preservation of n polarization on D capture in D2O

Many of the hardware components are in-hand/inexpensive

Would need a large double-cell 3He neutron spin filter: possible (see Jlab cells)

Conclusions

There are enough neutrons to do more HPNC experiments

Best beam for this in the short-term is NIST NG-C

Three experiments appear within reach statistically at NG-C:

(1) n-4He spin rotation (under construction)

(2) NDTGamma (proposed at this workshop)

(3) n-p spin rotation (active parahydrogen target is a challenge)

If/when ESS beam is constructed, can get ~X5 more polarized cold neutrons for this physics