An Ultracold Neutron Source for TRIUMF

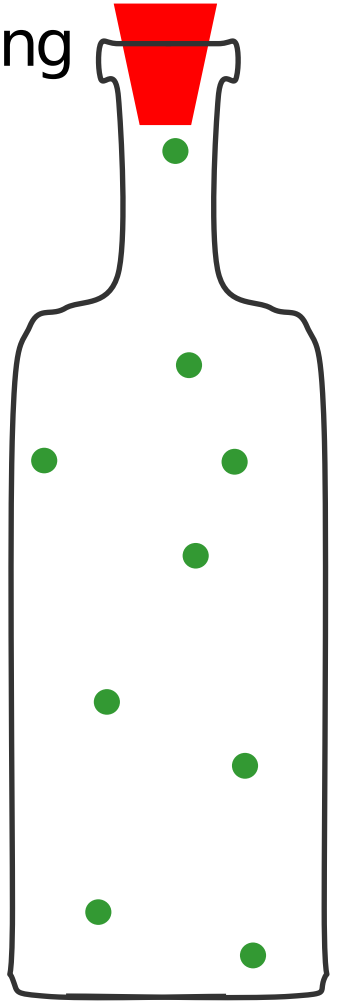
Jeff Martin (U. Winnipeg)

for Chuck Davis (TRIUMF), Akira Konaka (TRIUMF), Yasuhiro Masuda (KEK), and the rest of the UCN working group

1. UCN interactions
2. UCN physics experiments
3. Source work at RCNP and TRIUMF
4. CFI, relationship, collaboration, KEK

Ultracold Neutrons

- UCN are neutrons that are moving so slowly that they are totally reflected from a variety of materials.
- So, they can be confined in material bottles for long periods of time.
- Typical parameters:
  - velocity < 8 m/s
  - temperature < 4 mK
  - kinetic energy < 300 neV
- Interactions:
  - gravity: $V=mgh$ ($h < 3$ m)
  - weak interaction (allows UCN to decay)
  - magnetic fields: $V=-\mu \bullet B$ (100% polarization)
  - strong interaction



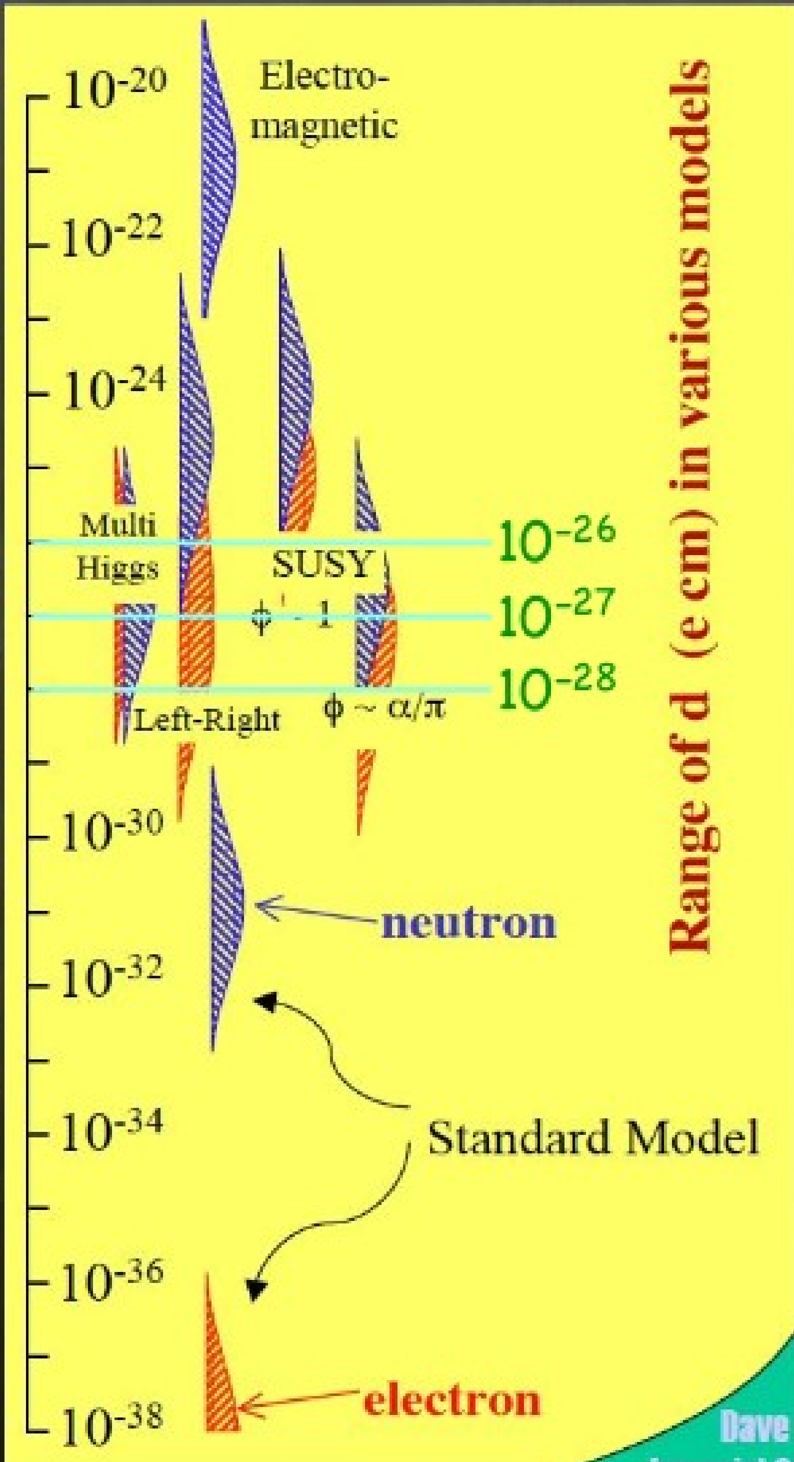
World comparison

	Source type	E_c and τ_s	UCN density ρ_{UCN}(UCN/cm^3)
TRIUMF 5 kW$_{av}$ proton	0.8K He-II	E_c = 210 neV τ_s = 150 s	1.8 x 10^4 at experimental port
Grenoble 60MW reactor	0.5K He-II	E_c = 250 neV τ_s = 150 s	1000 in He-II
SNS cold neutron beam	0.3K He-II	E_c = 134 neV τ_s = 500 s	430 in He-II
Munich 20MW reactor	SD_2	E_c = 250 neV	10^4 in source
North Carolina 1 MW reactor	SD_2	E_c = 335 neV	1300 in source
PSI 12 kW$_{av}$ proton	SD_2	E_c = 250 neV τ_s = 888 s	2000 in source
Los Alamos 2.4 kW$_{av}$ proton	SD_2	E_c = 250 neV τ_s = 2.6 s	120 in source

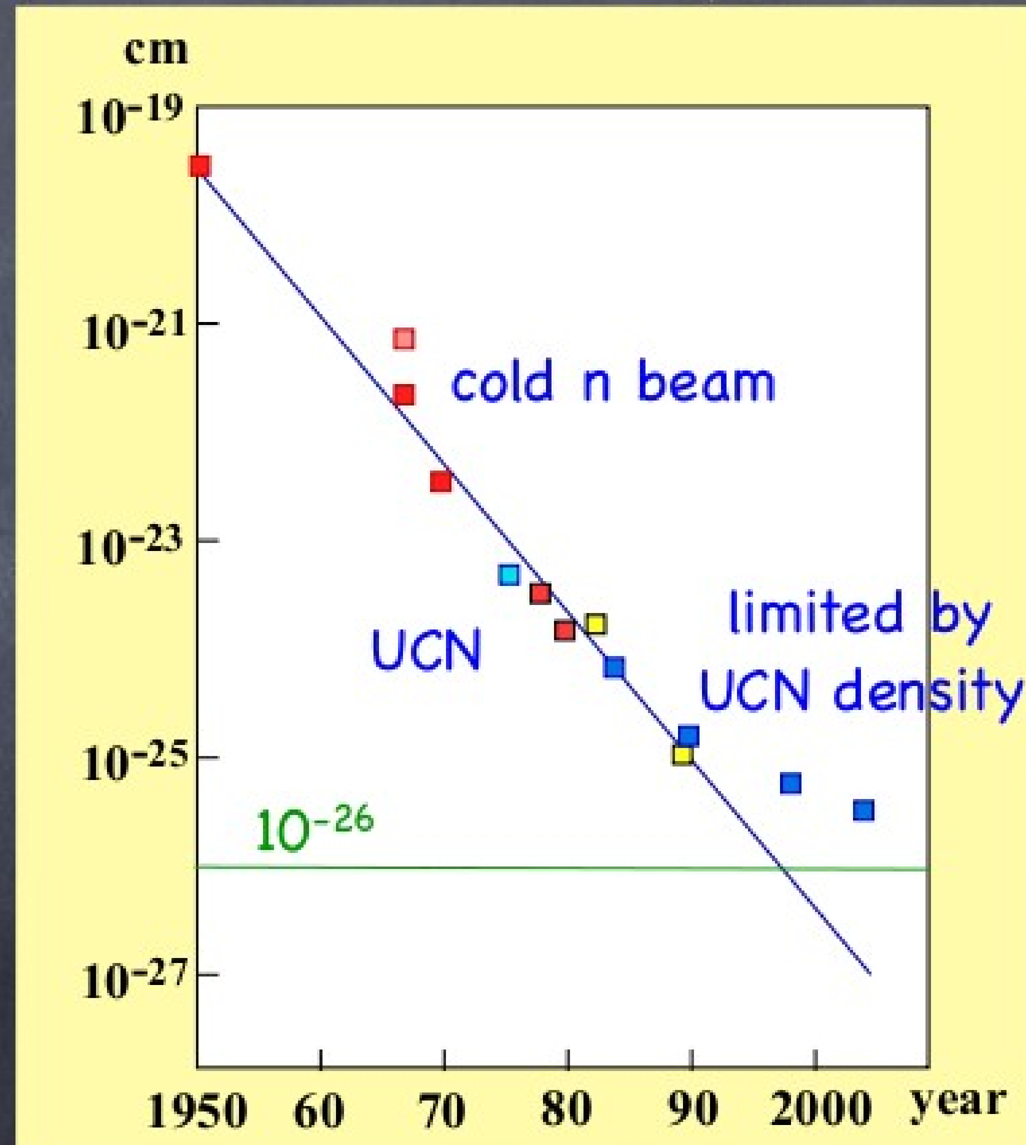
UCN Physics

- fundamental interactions of UCN
  - EDM
  - gravity
  - beta-decay
  - nnbar
- astrophysics
  - BBN
  - r-process
- surface physics
- development towards JPARC 2nd target station

Theory EDM history

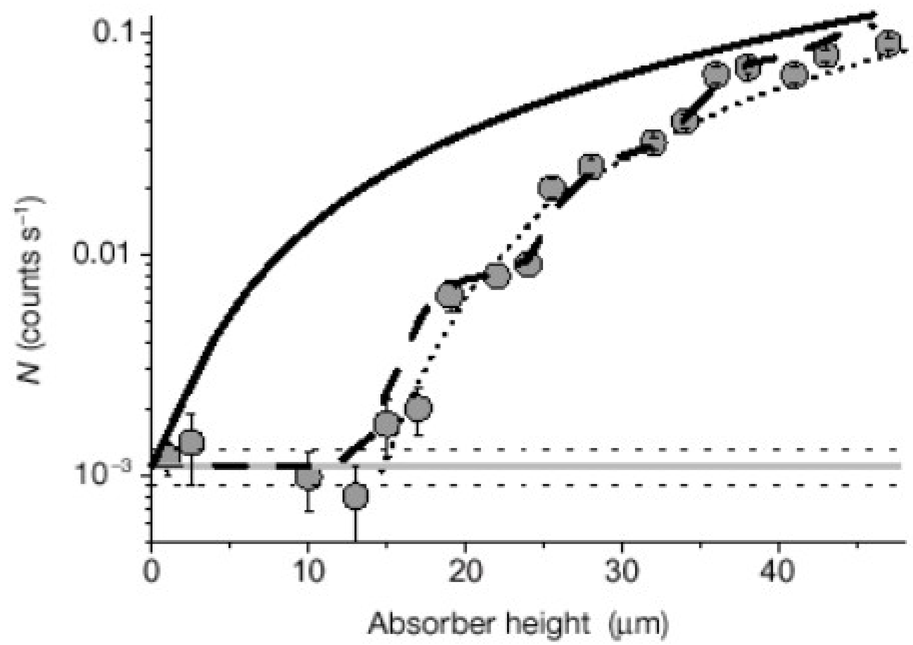


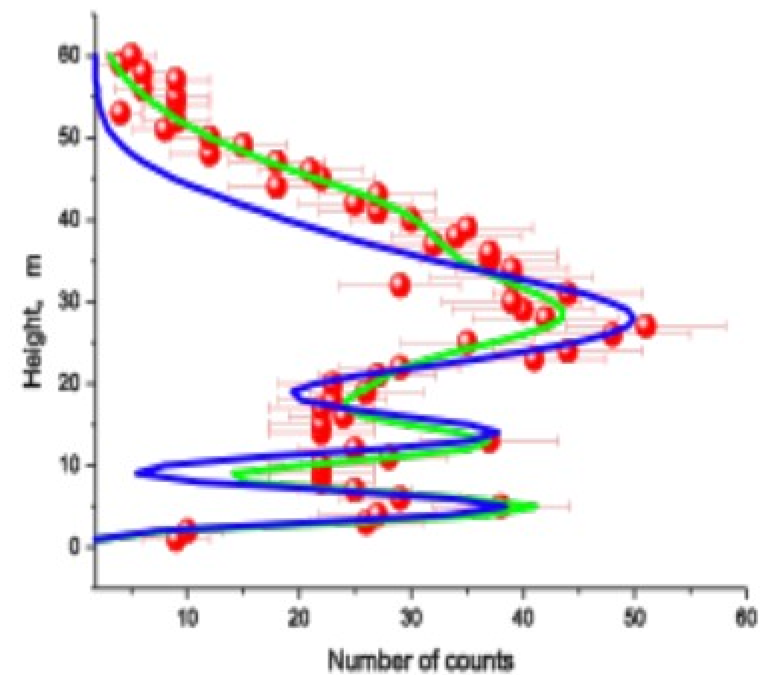
Experiment

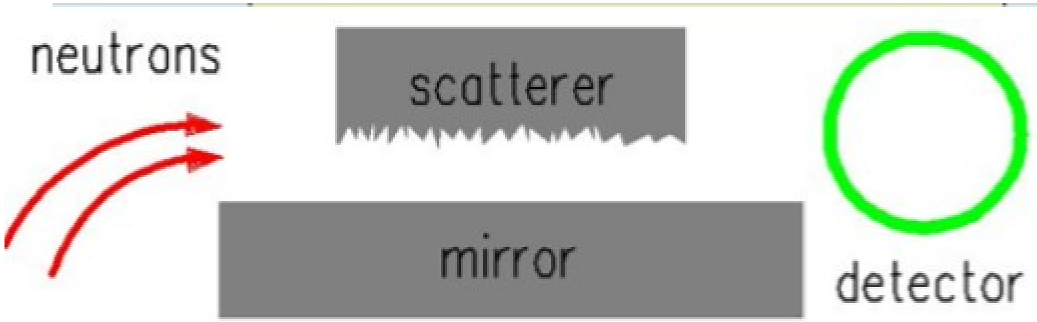


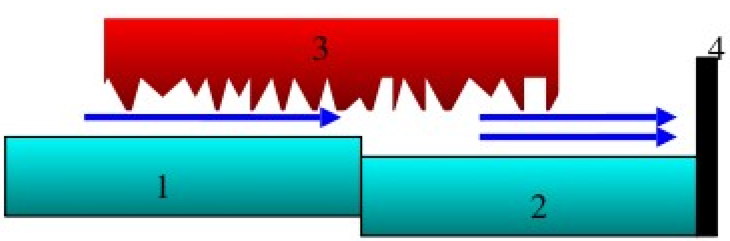
UCN quantum states in gravity

- test of gravity at 10 um scale









Surface Physics

- Many ideas to use UCN to study 10 nm thin surface films
  - (n,gamma)
  - UCN loss measurements
  - n scattering
  - reflectometry
- shown to be sensitive to low-frequency excitations (interesting for surface physics)
- In all cases, lack of UCN worldwide is the problem

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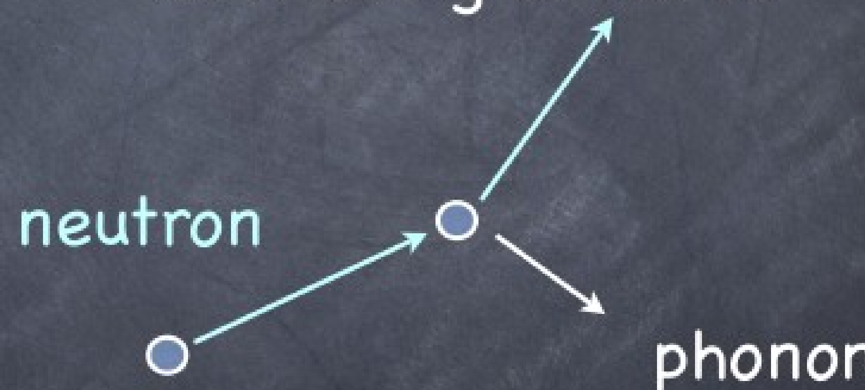
Superthermal UCN production in He-II

M.R. Gibbs et al. (1999)

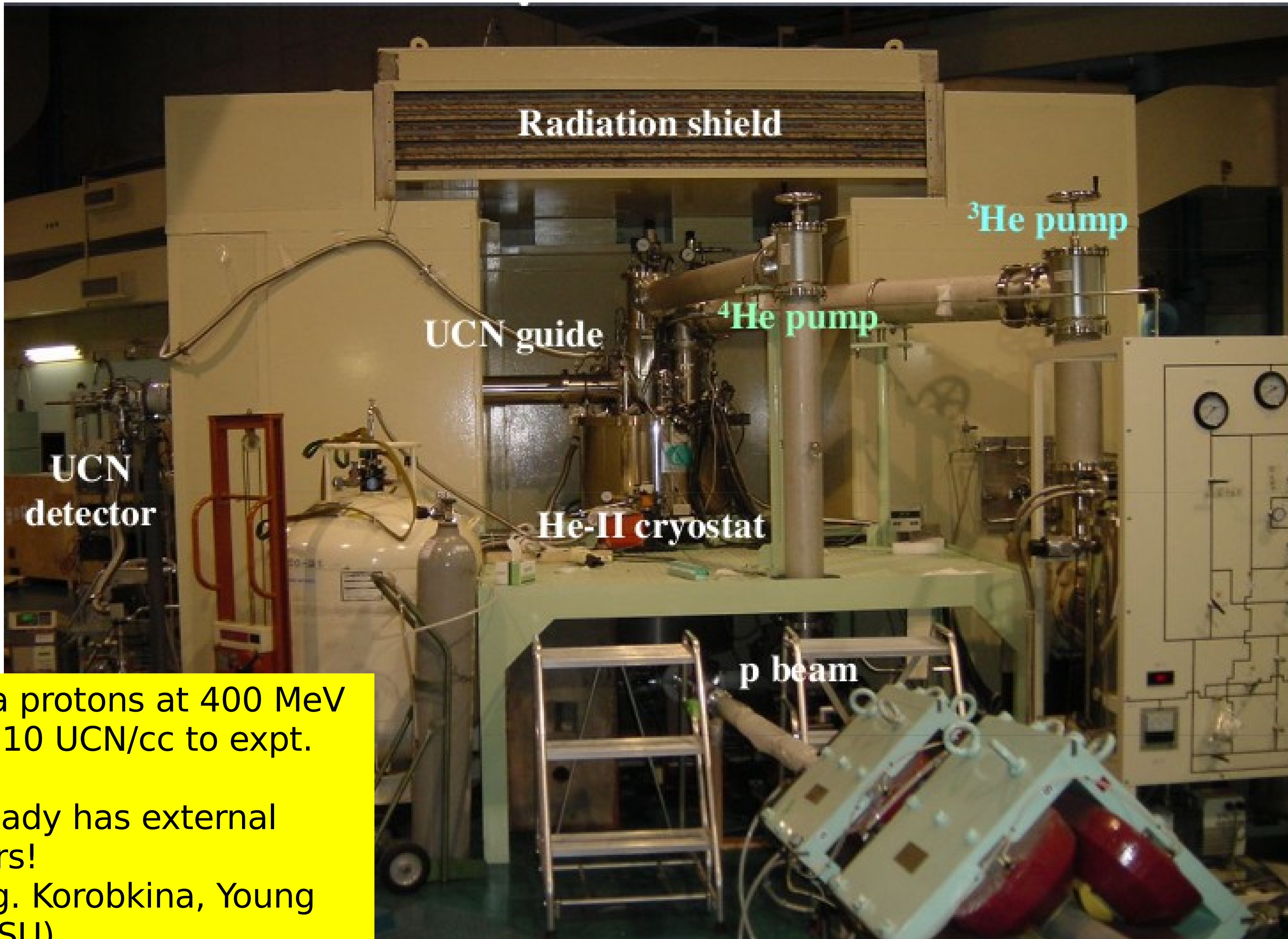
Coherent inelastic neutron scattering in He-II



Born approximation

$$d^2\sigma/dQd\omega$$
$$= k_f/k_i\, a^2\, S(Q,\omega)$$
$$= \sigma_{coh}/4\pi \cdot k_f/k_i \cdot S(Q,\omega)$$

RCNP UCN Source (Masuda, et al)



1 ua protons at 400 MeV
=> 10 UCN/cc to expt.

Already has external users!
- e.g. Korobkina, Young (NCSU)

New cryostat

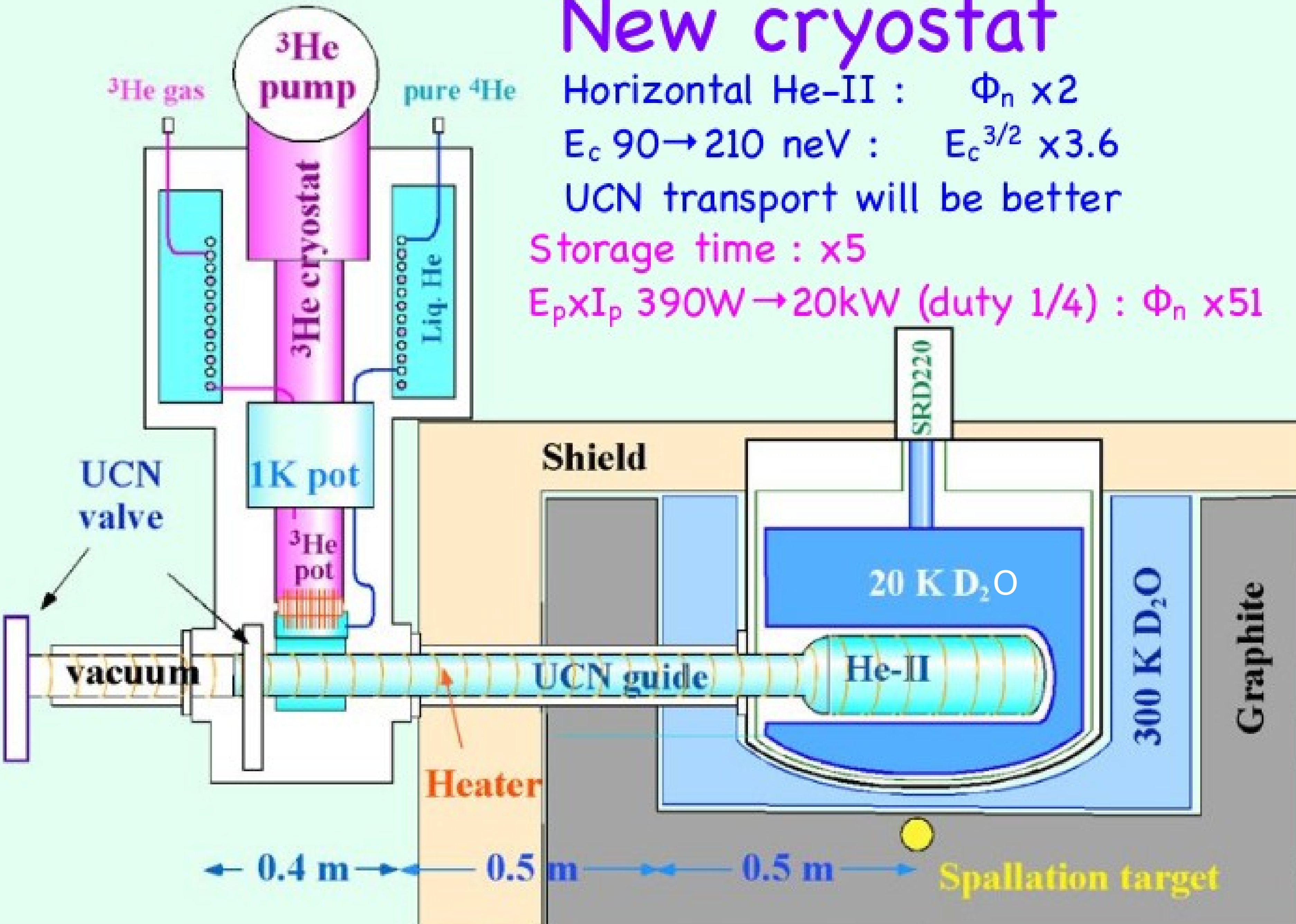
Horizontal He-II : Φ_n x2

E_c 90→210 neV : $E_c^{3/2}$ x3.6

UCN transport will be better

Storage time : x5

$E_p x I_p$ 390W→20kW (duty 1/4) : Φ_n x51



Collaboration

- led by Winnipeg, Manitoba groups
- strong KEK group who have already created a world-class facility (Masuda et al)
- well-attended working group at this townhall meeting
- UCN workshop at TRIUMF Sept. 13-14, 2007
  - world experts in attendance
- Interest in submitting a CFI proposal in 2008 from these groups

Shameless advertising

International Workshop: UCN Sources and Experiments

September 13-14, 2007
TRIUMF, Vancouver, Canada
http://www.triumf.info/hosted/UCN

Registration is free, but please do register

~25 speakers from all over the world
ILL, FRM-II, NCSU, LANL, PSI, KEK, Mainz, ...

Supported by TRIUMF and TUNL

Some key statements for the white paper

- e-linac in same general area (space)
- BL4 used to feed ISAC (time)
- UCN would be planned to minimize conflict with either program
- UCN source at TRIUMF would be a world-class facility
- A flagship experiment at this UCN source would impact knowledge of fundamental interactions of neutrons

Summary

- An opportunity exists to create the world's highest density UCN source at TRIUMF
- A flagship physics experiment done this facility would be world's best
- We would like to pursue this unique and timely opportunity

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Speakers at TRIUMF UCN Workshop Sept. 13-14, 2007

H. Abele*, Heidelberg

S. Baessler, Mainz/UVa

L. Buchmann, TRIUMF

M. Daum, PSI

S. Gardner*, U. Kentucky

P. Geltenbort*, ILL

E. Gutsmiedl, Munich FRM-II

R. Golub, NCSU

B. Filippone, Caltech

P. Huffman, NCSU

T. Ito, LANL

E. Korobkina, NCSU

C.-Y. Liu, Indiana U.

M. Makela, LANL

J.W. Martin, U. Winnipeg

Y. Masuda, KEK

C. Morris, LANL

P. Mumm, NIST

J. Nico*, NIST

J. Ng, TRIUMF

S. Paul*, T.U. Muenchen

M. Pospelov*, U. Victoria/Perimeter Inst.

J.-M. Poutissou, TRIUMF

W.M. Snow*, Indiana U.

F. Wietfeldt, Tulane U.

A. Young, NCSU

O. Zimmer*, ILL

Agenda

Aug. 1

morning - plenary session, charge, and introduction of working groups

12:00 lunch

13:00 Welcome + Charge (Martin) (10+5)
13:15 UCN Sources Worldwide and for TRIUMF (Masuda) (45+10)
14:10 Photofission, (gamma,n) Sources and UCN (Behr) (10+10)
14:30 coffee (30)
15:00 SCRF joint session: Electron Linac Design (Koscielniak) (20+10)
15:30 UCN Infrastructure and Proton Hall Floorplan (Davis) (10+10)
15:50 Proton Hall Radiation Limits (Trudel) (10)
16:00 Discussion (Chair: Davis) (30)
16:30 tour of proton hall? (if desired) (Davis) (30)

Aug. 2

09:00 Continued infrastructure Discussion (60)
10:00 UCN Physics Intro (Martin) (10+5)
10:15 UCN Beta Decay (Melconian) (20+10)
10:45 coffee (30)
11:15 n-EDM (Masuda and/or Hayden?) (20+10)
11:45 radioactive beams (Buchmann) (10+10)

12:05 lunch

13:15 gravity levels (Konaka) (5+10)
13:30 other physics (Martin) (15+10)
13:55 discussion of physics priorities and strategy (chair: Martin) (35)
14:30 begin writing
    more joint sessions
    draft Aug. 3 morning presentation

Aug. 3

morning - presentations of results from the working groups.

Back-ups

Options considered

- for duty cycle
  - fast kicker + local beam dump in hall
- for BL4 sharing with ISAC
  - two stripper foils on same extraction probe + septum
    - difficult, more appropriate for BL1
  - other lines: BL1, BL5
  - (gamma,n) or photofission source of neutrons (Behr)
    - requires further study
- for space
  - locate UCN source in ISAC 2^{nd} target
- for LHe
  - modest consumption 200 L/day

Outline of White Paper

- Physics
  - prioritized and realistic, as much as possible
- UCN Source
  - proposed intensity at TRIUMF
  - world context and relevance
- Required Infrastructure
  - floorspace, shielding
  - duty cycle
  - He liquefier
- Required funding
  - CFI and collaboration, and international

Measuring (n,ɣ) cross sections of the r-process (Buchmann)

132Sn stored in ring interacts
with free neutron (UCN) target.

132Sn current 5e17 /s
UCN density 2e4 /cc
meter-long target
sigma ~ 100 mb
=> 50 interactions per hour

recoil separator