TRIUMF
CANADA'S NATIONAL LABORATORY FOR PARTICLE AND NUCLEAR PHYSICS

Owned and operated as a joint venture by a consortium of Canadian universities via a contribution through the National Research Council Canada

Canadian Spallation Ultracold Neutron Source

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(Winnipeg, Manitoba, ORNL, TRIUMF, NCSU, Caltech, RCNP, SFU, LANL, KEK, Tokyo, UNBC, Osaka, Kentucky)

LABORATOIRE NATIONAL CANADIEN POUR LA RECHERCHE EN PHYSIQUE NUCLÉAIRE ET EN PHYSIQUE DES PARTICULES

Propriété d'un consortium d'universités canadiennes, géré en co-entreprise à partir d'une contribution administrée par le Conseil national de recherches Canada

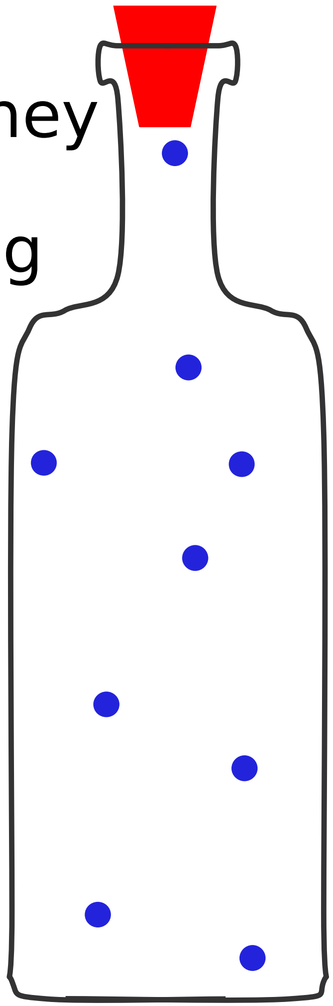
Summary

- We are proposing to construct the world's highest-density source of ultracold neutrons, at TRIUMF.
- The source will be used carry out fundamental physics research in the years beyond 2012.
- Experiments we're looking into:
  - n-lifetime
  - gravity levels
  - n-EDM

near term (n-lifetime, gravity levels)

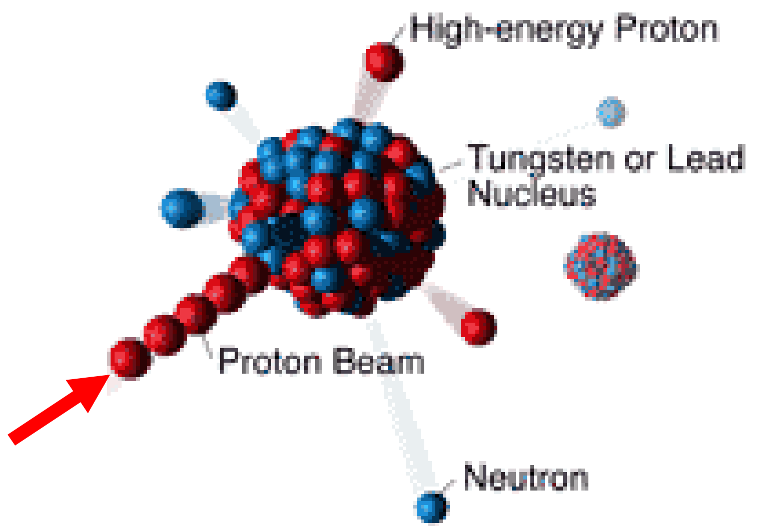
longer term (n-EDM)

Ultracold Neutrons

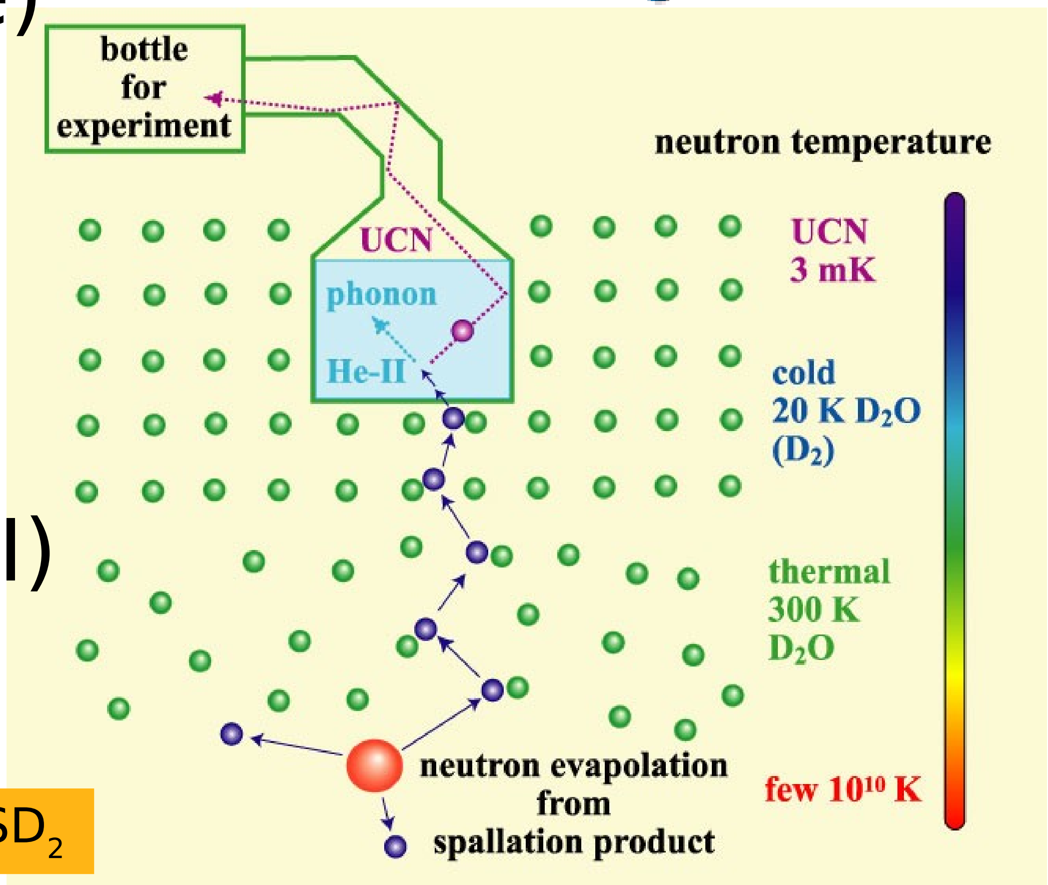


- UCN are neutrons that are moving so slowly that they are totally reflected from surfaces of materials.
- So, they can be confined in material bottles for long periods of time.
- Typical parameters:
  - velocity < 8 m/s
  - temperature < 4 mK
  - kinetic energy < 300 neV
- Interactions:
  - gravity: V=mgh (h < 3 m)
  - weak interaction (allows UCN to decay)
  - magnetic fields: $V=-\mu \bullet B$ (magnetic trap)
  - strong interaction (material trap)
- Experiments at UCN sources are chronically limited by UCN density. TRIUMF can provide the world's largest density.

How to make UCN



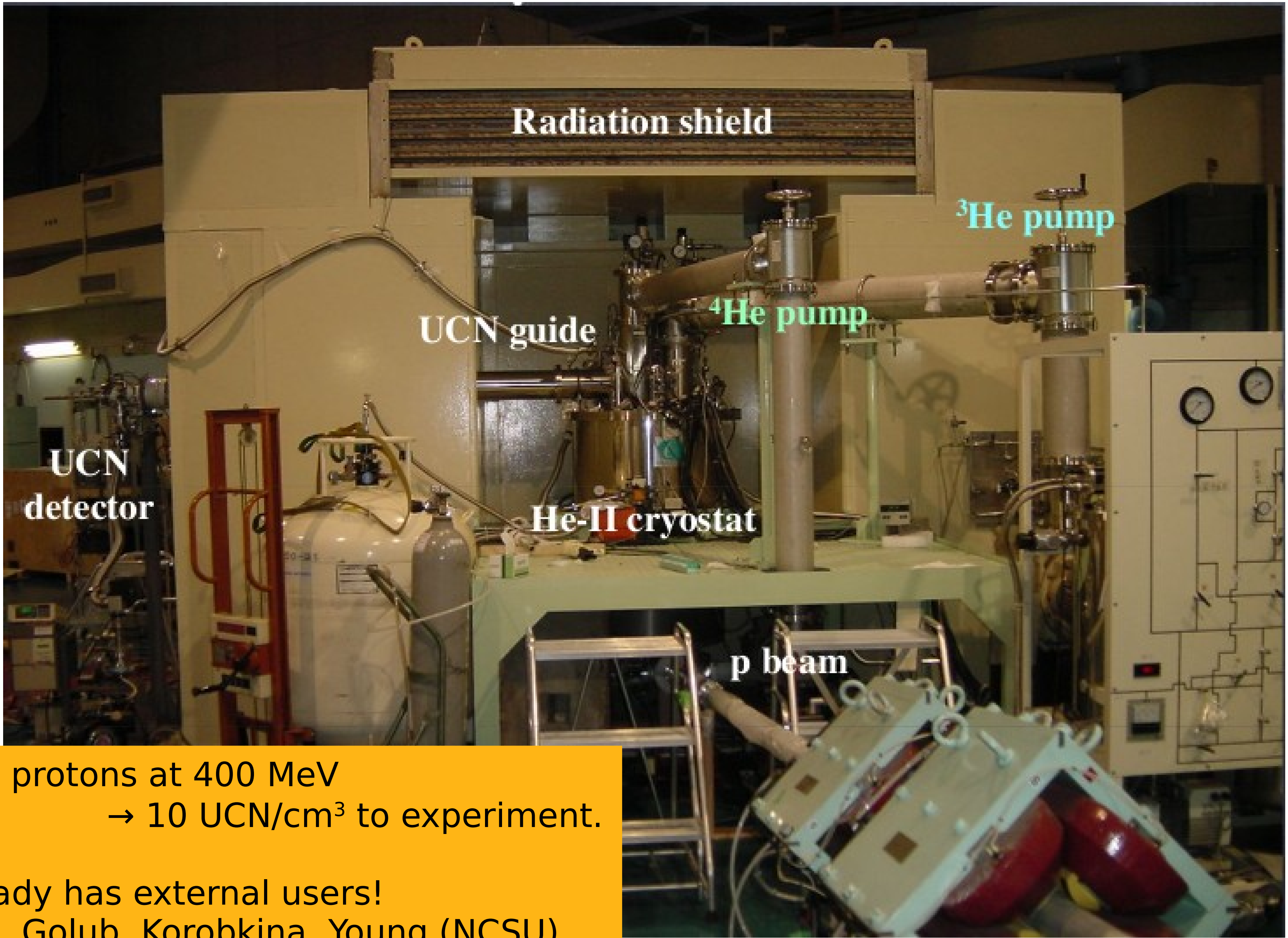
1. Liberate neutrons by proton-induced spallation.
2. Moderate (thermalize) in cold (20 K) D_2O.
3. Cold neutrons "downscatter" to near zero energy (4 mK) in superfluid helium (He-II) via phonon production.



Unique to TRIUMF! Other proposals use SD_2

Prototype UCN Source

(Y. Masuda, et al, RCNP, Osaka)



1 μA protons at 400 MeV
→ 10 UCN/cm^3 to experiment.

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

Gain Factors for TRIUMF

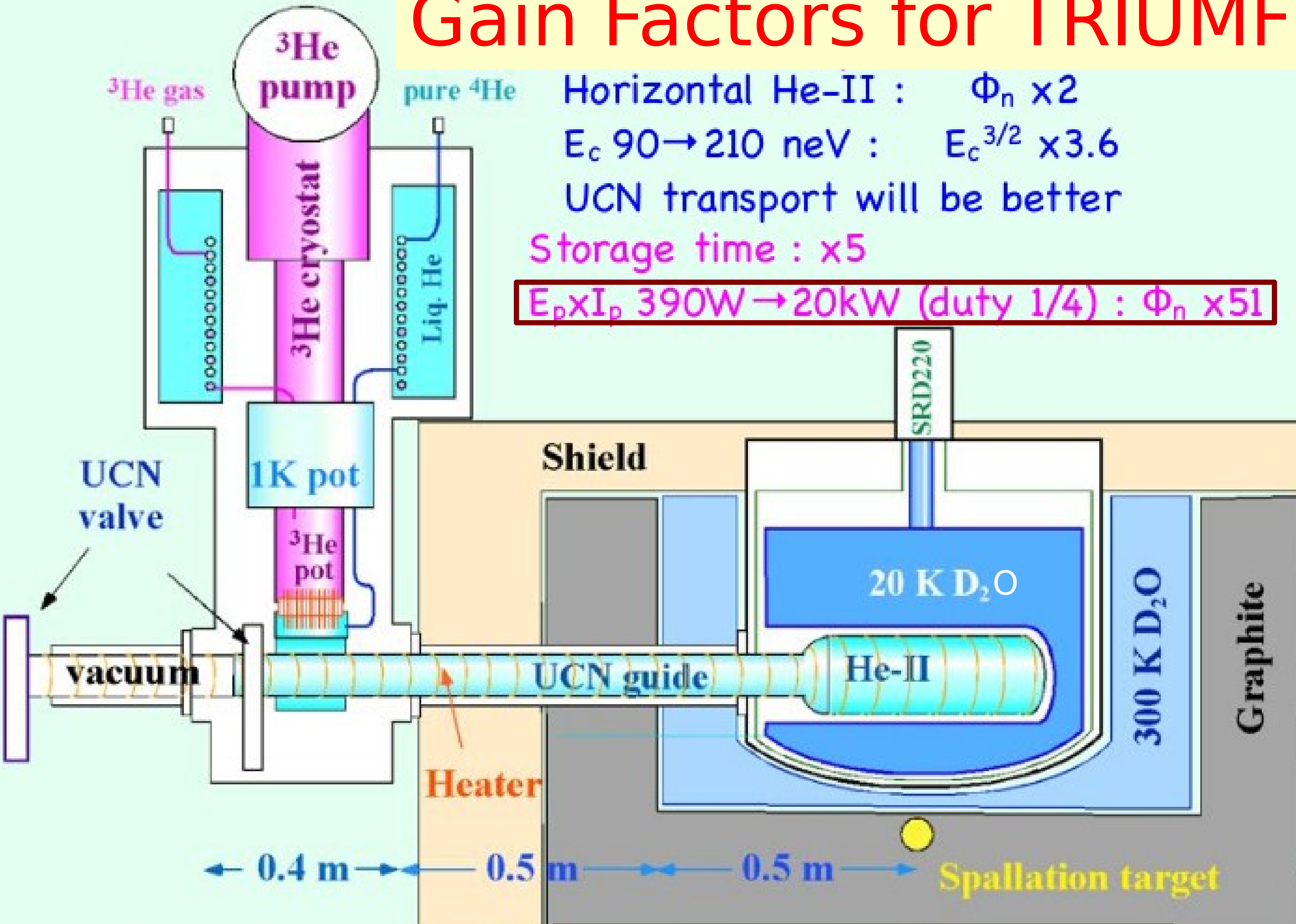
Horizontal He-II : Φ_n x2

E_c 90→210 neV : $E_c^{3/2}$ x3.6

UCN transport will be better

Storage time : x5

E_pxI_p 390W→20kW (duty 1/4) : Φ_n x51



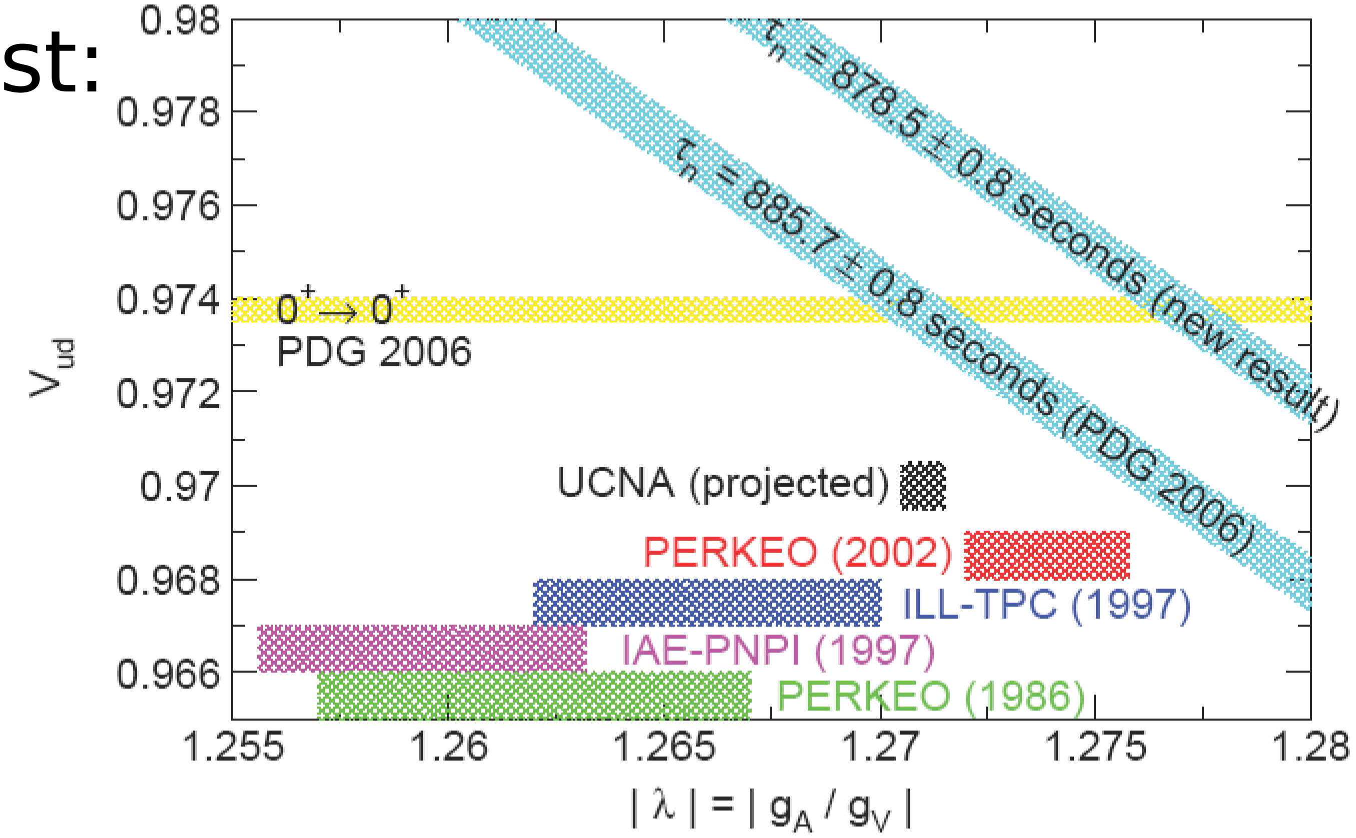
Future Upgrade: D_2O ice → LD_2 : x5

World's UCN projects

	source type	E_c neV	P_{UCN} /cm^3/s	T_s s	ε_{ext}	ρ_{UCN} /cm^3 source/exp.
TRIUMF	spallation He-II	210	0.4×10^4 (10L)	150	~1	3×10^5 (20L) 1-5 x 10^4
ILL	n beam He-II	250	10	150	~1	**/1000
SNS	n beam He-II	134	0.3 (7L)	500	1	**/150
LANL *	spallation SD2	250	4.4×10^4 (240cm^3)	1.6	1.3×10^3/ 4.4×10^4	**/120
PSI	spallation SD2	250	2.9×10^5 (27L*)	6	0.1	2000 (2m^3) /1000
NCSU	reactor SD2	335	2.7×10^4 (1L)	**	**	1300/**
Munich	reactor SD2	250	**	**	**	1×10^4/**

Neutron Lifetime

- Physics interest:
  - BBN
  - V_{ud}

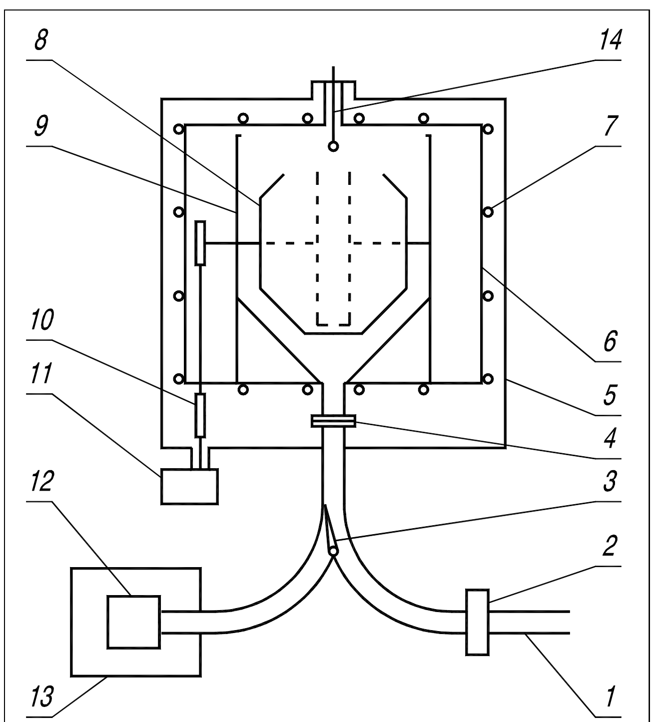


- Currently a 6.5 sigma discrepancy between n-lifetime experiments

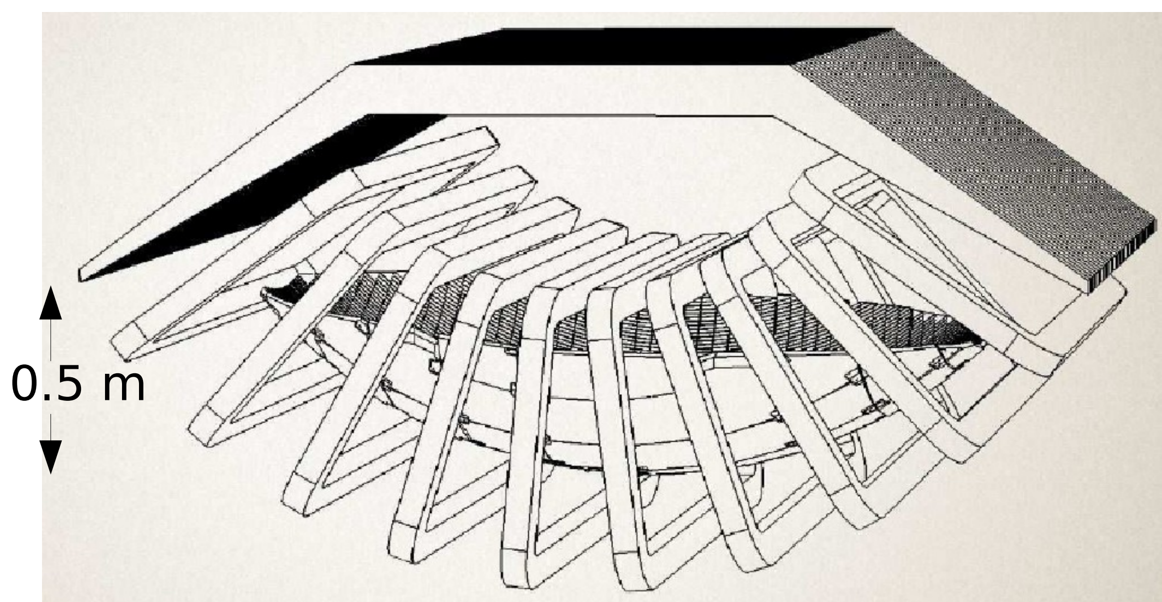
Neutron Lifetime

- Basic experiment: trap UCN for varying amounts of time
- All previous precise experiments used material traps
- Wall effects give dominant systematic effects

- Newer efforts: magnetic trap to remove wall effects
- However, need more UCN!
- TRIUMF concept deals with marginally trapped neutrons using chaotic orbits



Gravitrap (ILL)

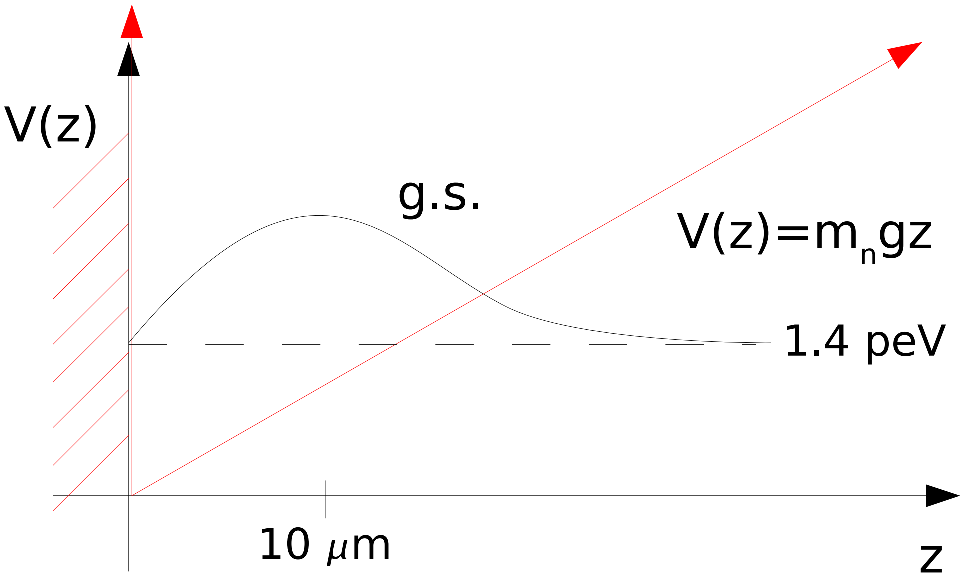


TRIUMF concept (Bowman et al)

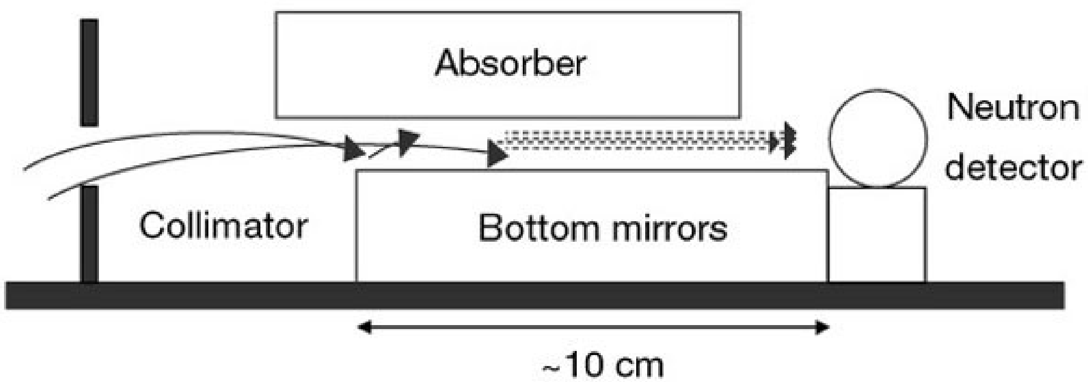
Neutron Lifetime Plans for TRIUMF

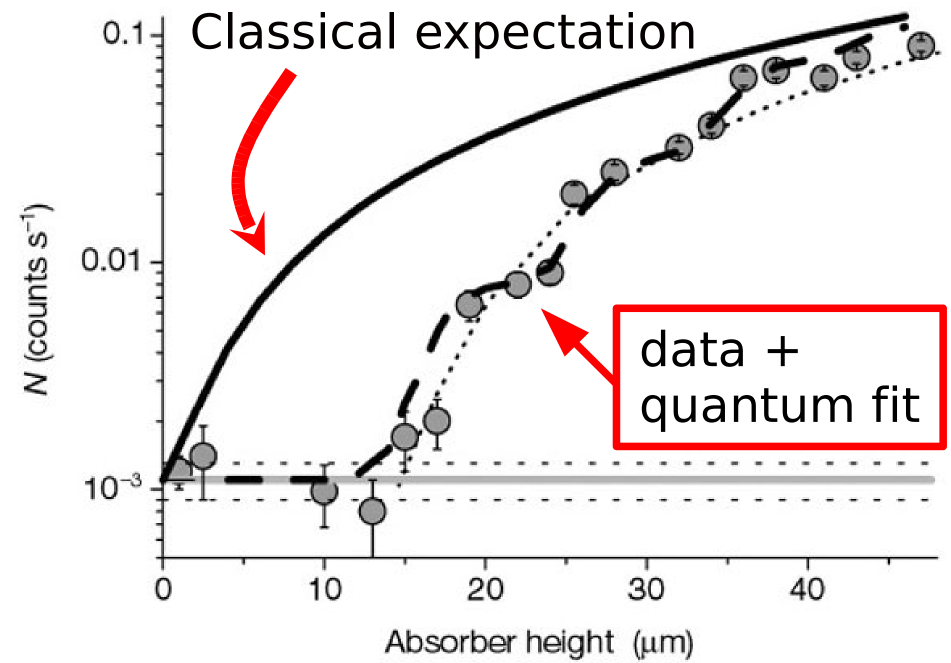
- TRIUMF experiment would build on preliminary work done at LANL (Bowman, et al)
- Candidate for a first physics experiment using the TRIUMF UCN source

UCN Quantum States in Gravity



- Confine UCN in 1D by gravity
- Experimental results have been used to place limits on
  - 10 um scale modifications to gravity
  - extra dimensions
  - axions

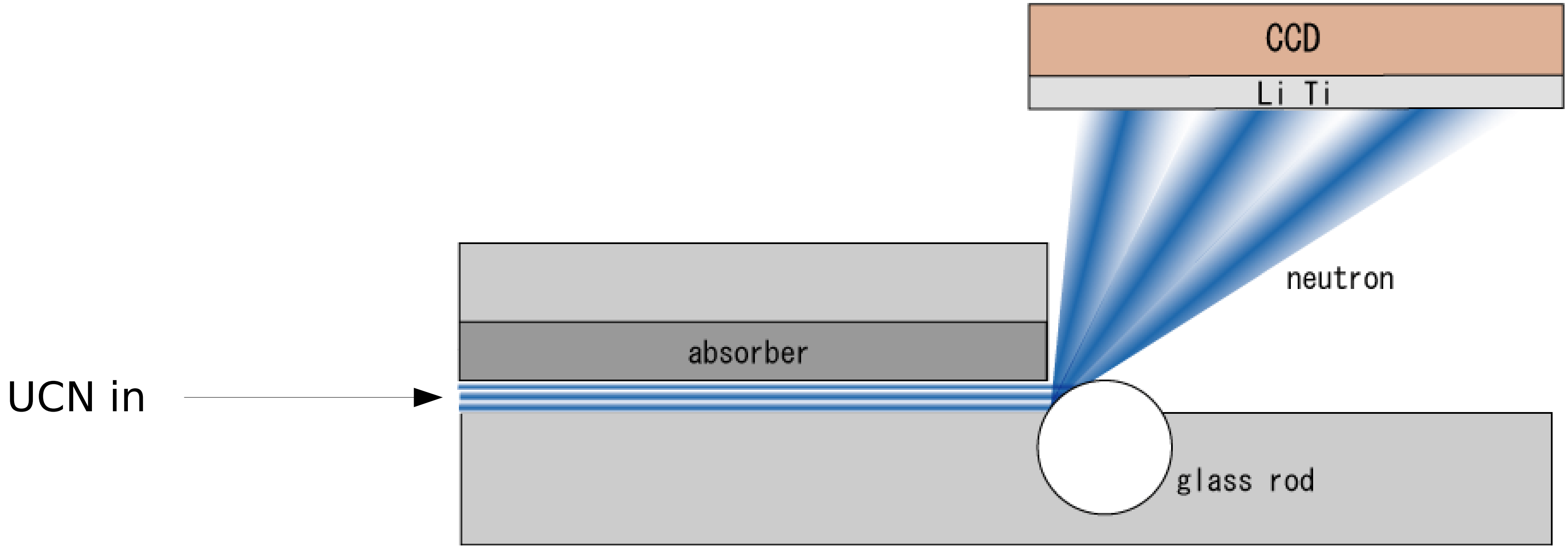




Further experiments:

- Bottle the UCN to increase time the UCN is contact with the mirror.
- Excite resonant transitions between quantum states.
- Increase purity of states by preselection.
- Goal: improve precision on energy of state and hence increase sensitivity to modifications to gravity.

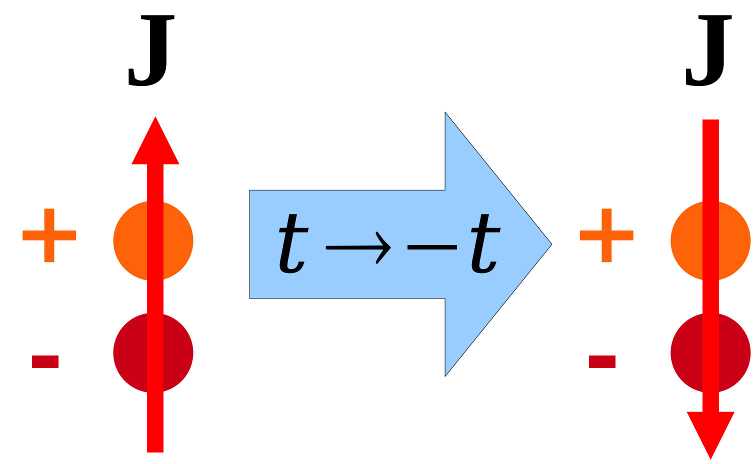
Concept for TRIUMF Experiment

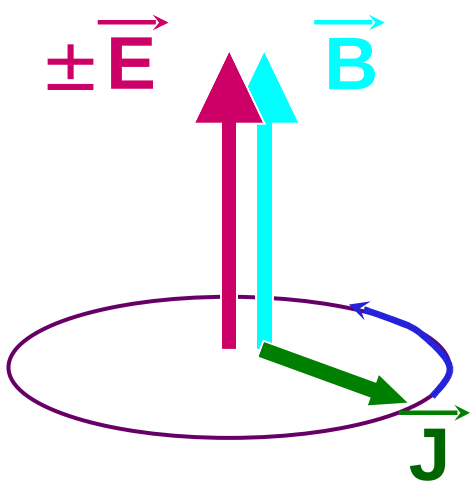


- Features:
  - glass rod "magnifier"
  - Li-coated CCD readout
- Initiated by Japanese groups (S. Komamiya, et al).
- Good candidate first experiment.

Neutron Electric Dipole Moment (n-EDM)

- Existence of EDM implies violation of Time Reversal Invariance
- CPT Theorem then implies violation of CP conservation





$$h\nu = 2\mu_n B \pm 2\mathrm{d}_e E$$

- Present Exp. Limit < $3\mathrm{x}10^{-26}$ e-cm
- Standard Model value: 10^{-31} e-cm
- Supersymmetry or Multi-Higgs models can give 10^{5}xSM
- Significant discovery potential with new high sensitivity *n*-EDM experiment

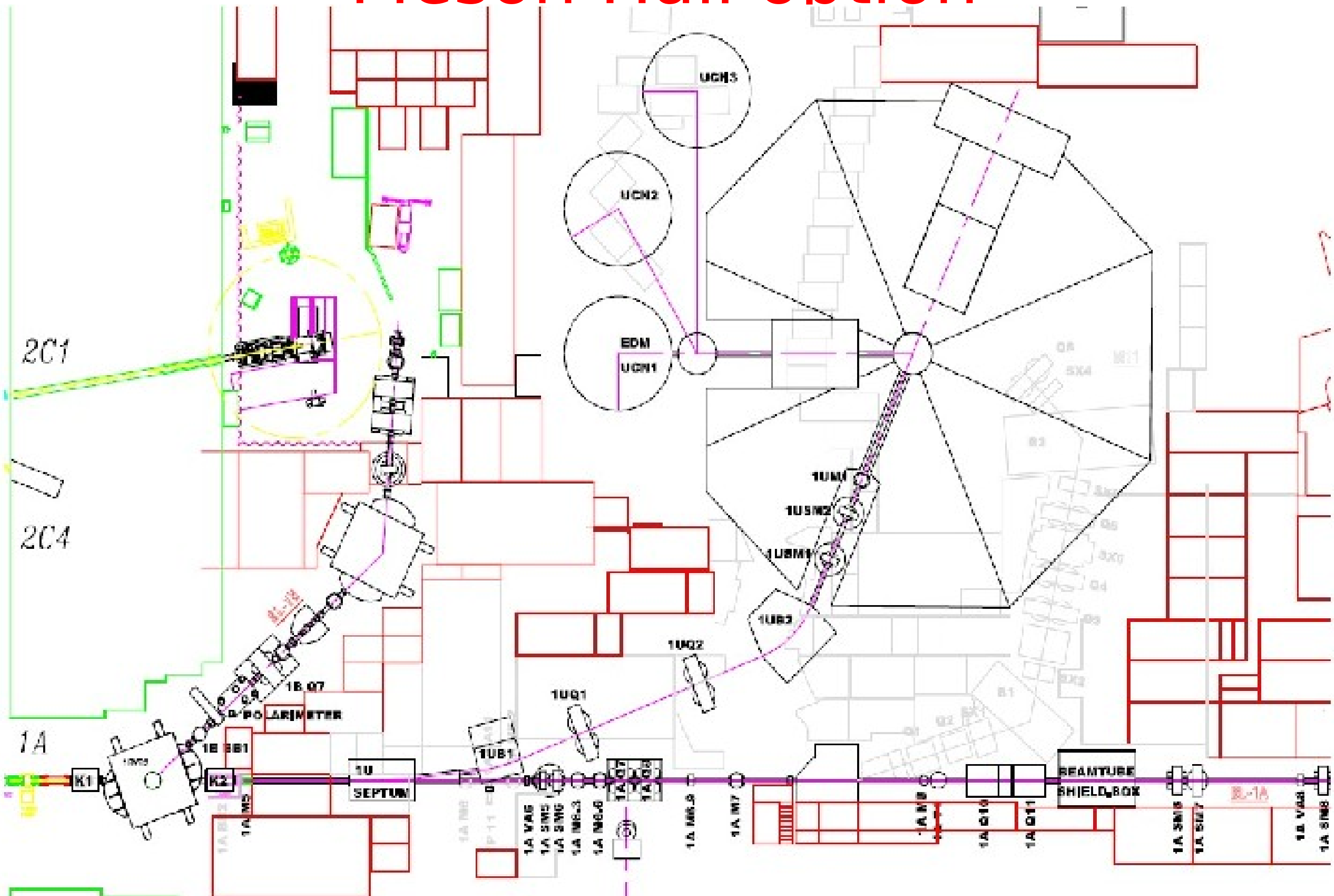
Plans for TRIUMF

- Begin with modified ILL, SNS, or PSI setup
  - higher UCN density allows smaller cell size
    - Smaller "geometric phase" effect
  - development of magnetometers, Ramsey-resonance technique (Masuda)
- proposal ~ 2011
- expect number of EDM-experienced collaborators to grow if UCN source is approved:
  - B. Filippone, R. Golub, M. Hayden, T. Ito, E. Korobkina, Y. Masuda, B. Plaster

UCN Source Overall timeline

- 2008: CFI NIF proposal in preparation
  - In-kind contributions from Japan, TRIUMF
- 2009-12 – develop UCN source in Japan, preparations and design in Canada
- 2012-13 – Install, commission at TRIUMF
- First experiments (n-lifetime, gravity) 2012-15
- longer term: n-EDM, 2014 and beyond

Implementation at TRIUMF
Meson Hall option



- Beamline design (J. Doornbos, G. Clark)
- Kicker feasibility, design (M. Barnes)
- Shielding estimates (A. Trudel)
- Layout (above) (S. Austen, C. Davis)

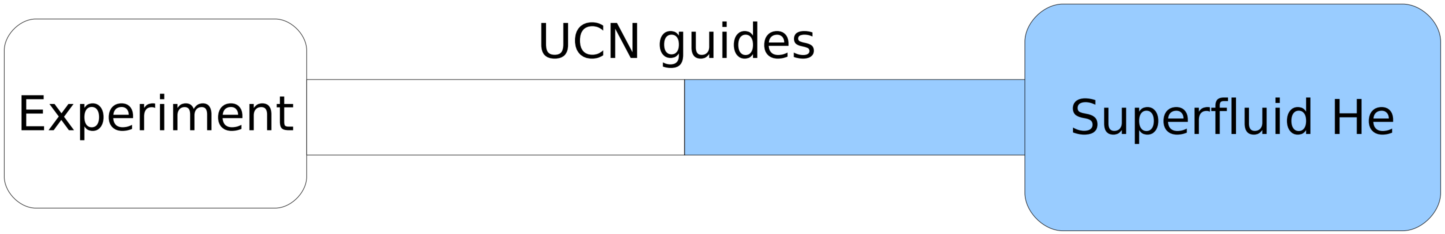
- Cost/Sched/Manpower (V. Verma, W.D. Ramsay, C. Davis)
- ...and many useful discussions with E. Blackmore, R. Baartman, ...

Conclusion

- Canada has an opportunity to construct a world-leading UCN facility at TRIUMF.
- Proposal to CFI NIF in preparation through U. Winnipeg with several Canadian universities involved. Matching supplied by Japan and TRIUMF.

We are looking for collaborators!!!
UCN source or UCN experiments

Why UCN *density* is the most important factor

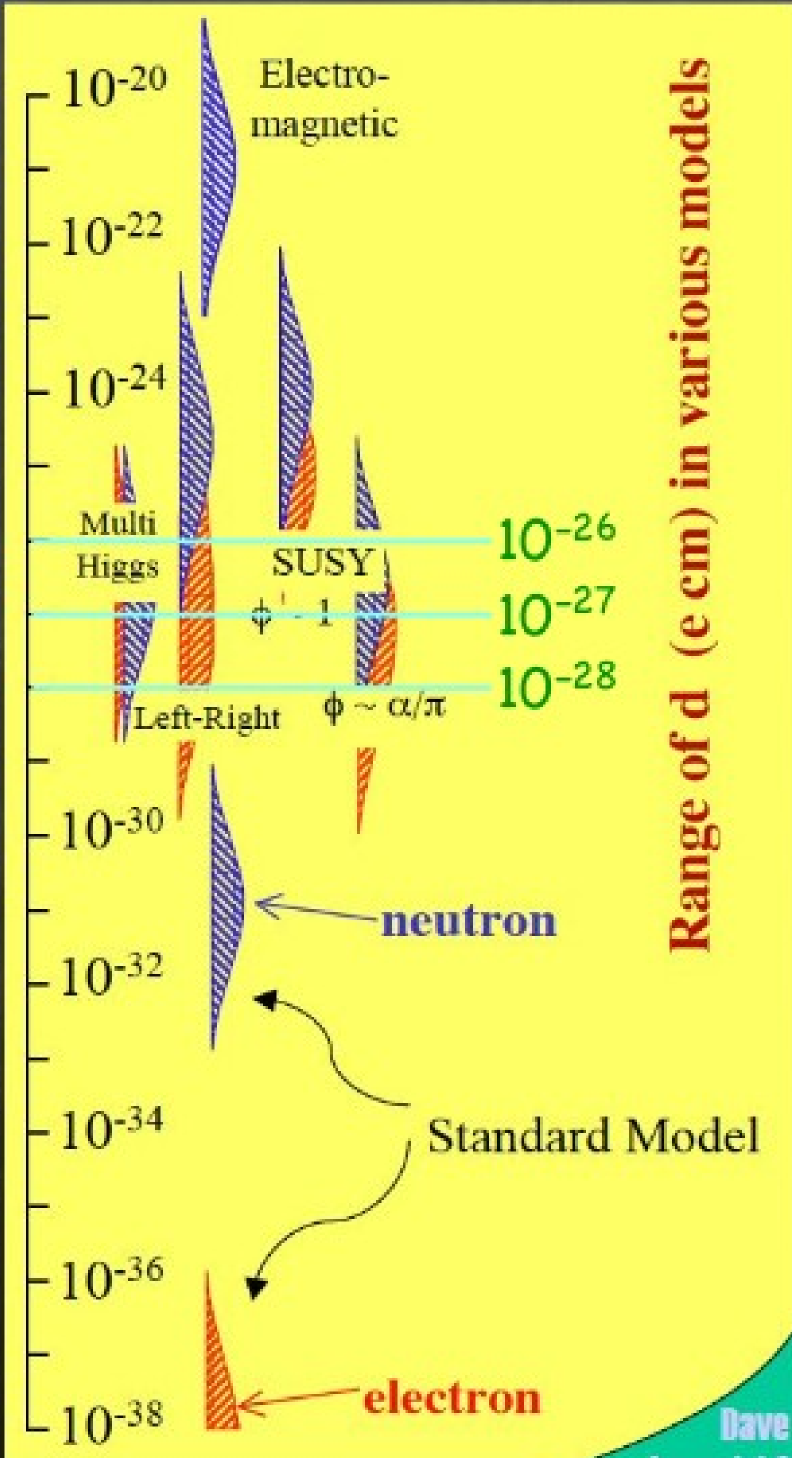


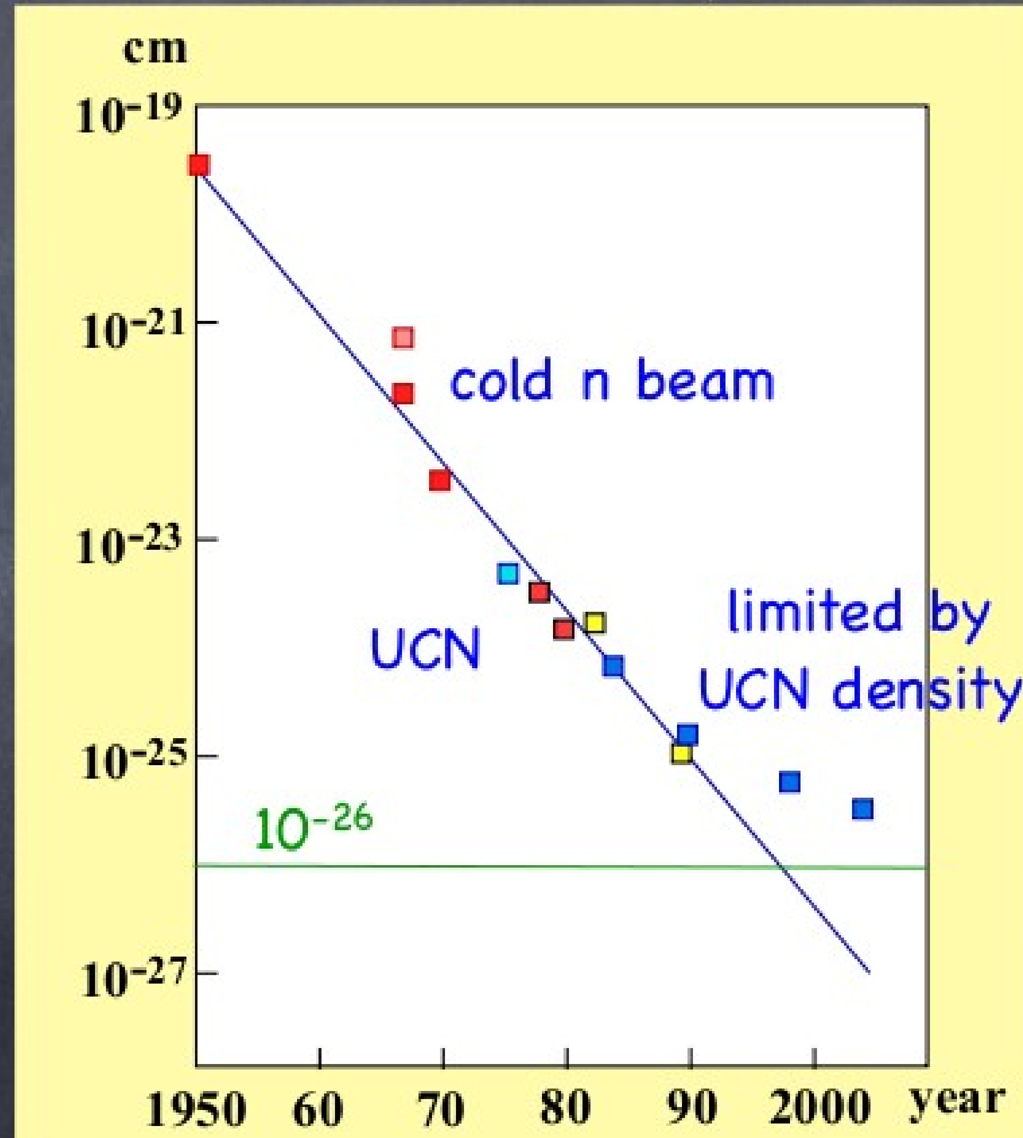
- UCN behave like an ideal gas
- As long as the experiment volume is much less than the total volume, UCN density is the most important factor.
- This is the case for every experiment we are pursuing for TRIUMF.

UCN Source Design and How We Would Achieve the World's Highest UCN Density

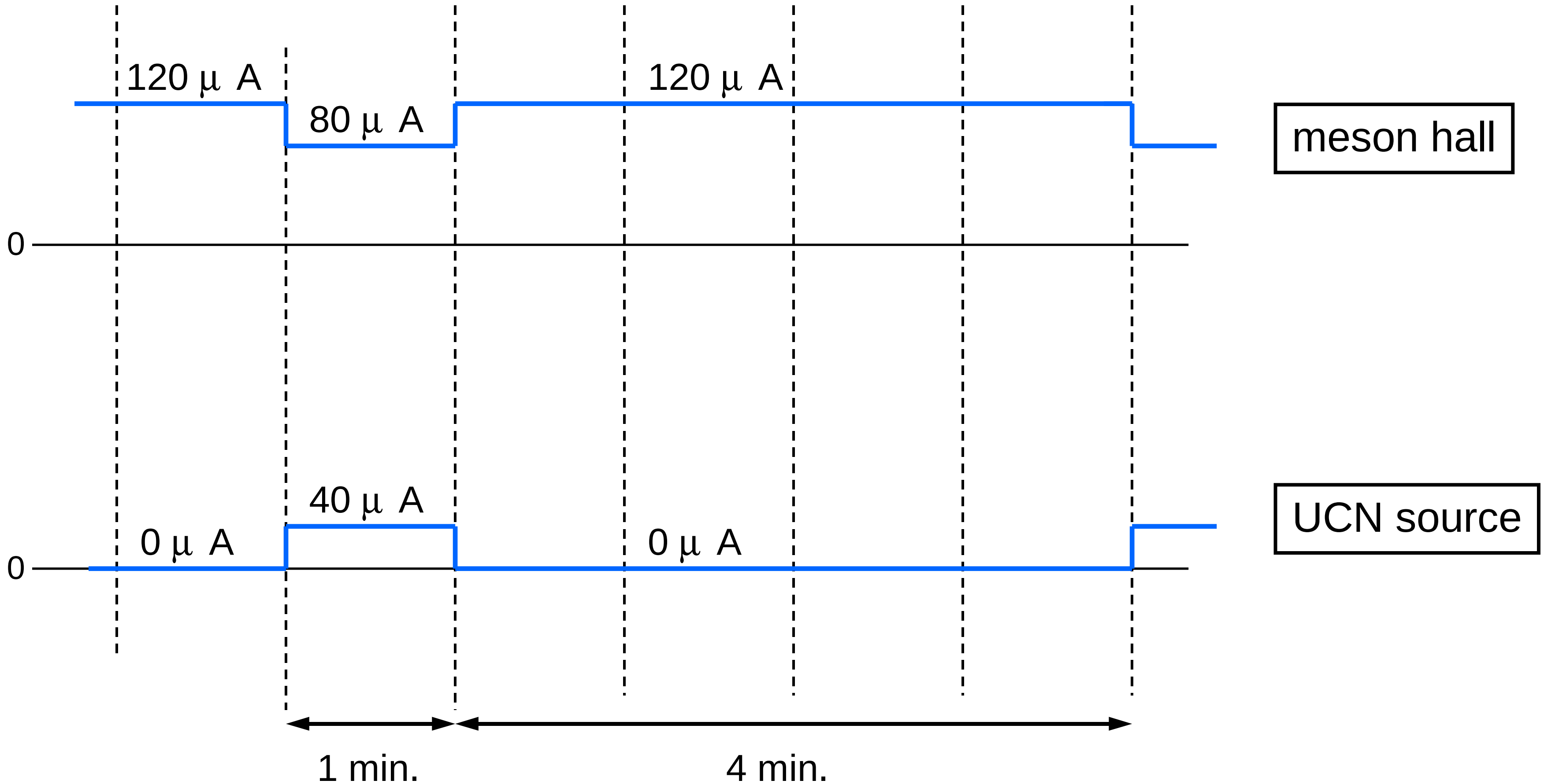
- Most other proposed sources use solid deuterium (ortho) at ~4K
  - ice quality
  - Fermi potential
  - para fraction, H-contamination
- We would use superfluid He-II (Masuda et al PRL)
  - lower specific production
  - NO loss mechanisms.

Theory EDM history Experiment





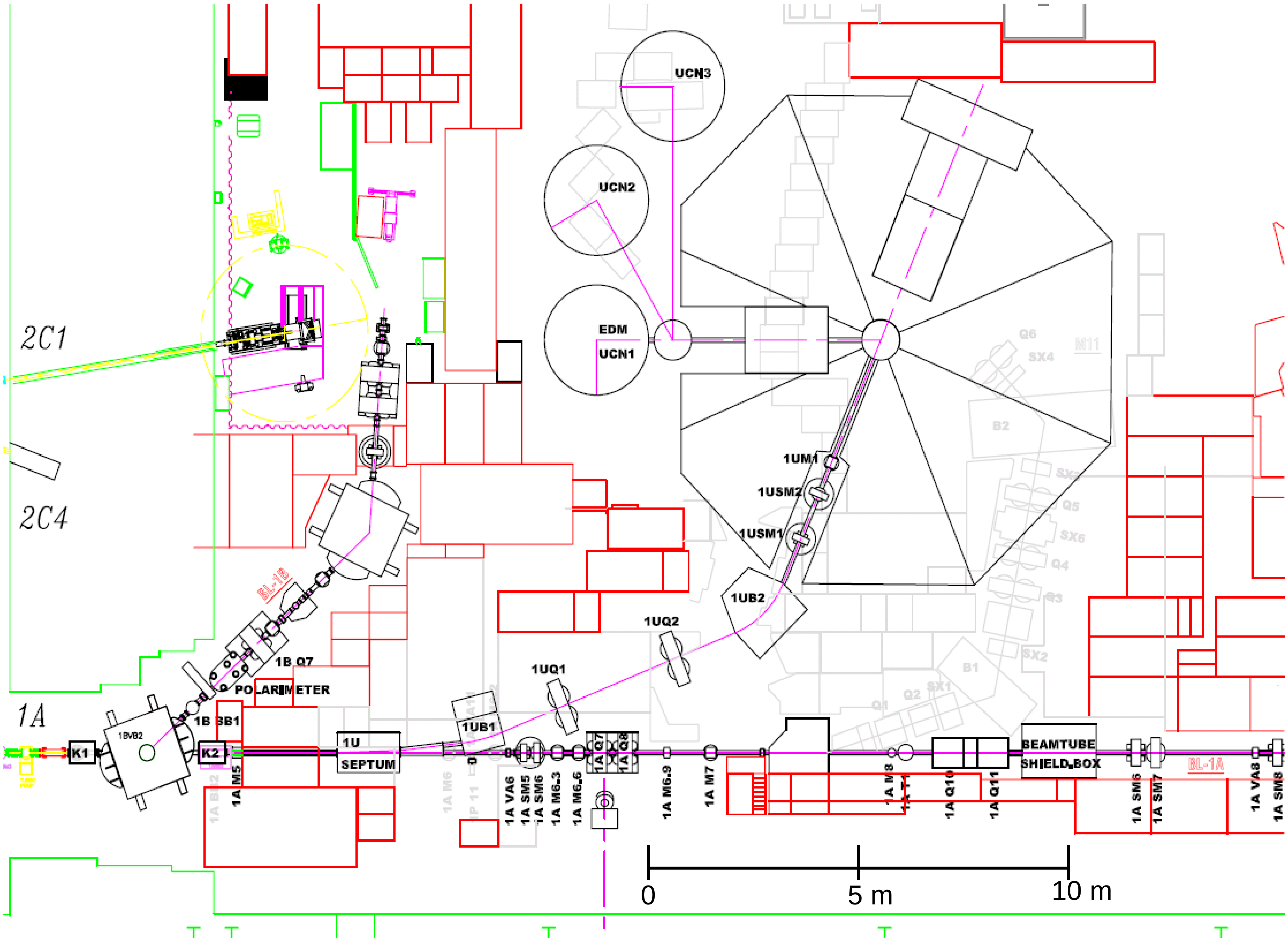
Example of Proton Beam Sharing



Constraints on beam sharing schemes

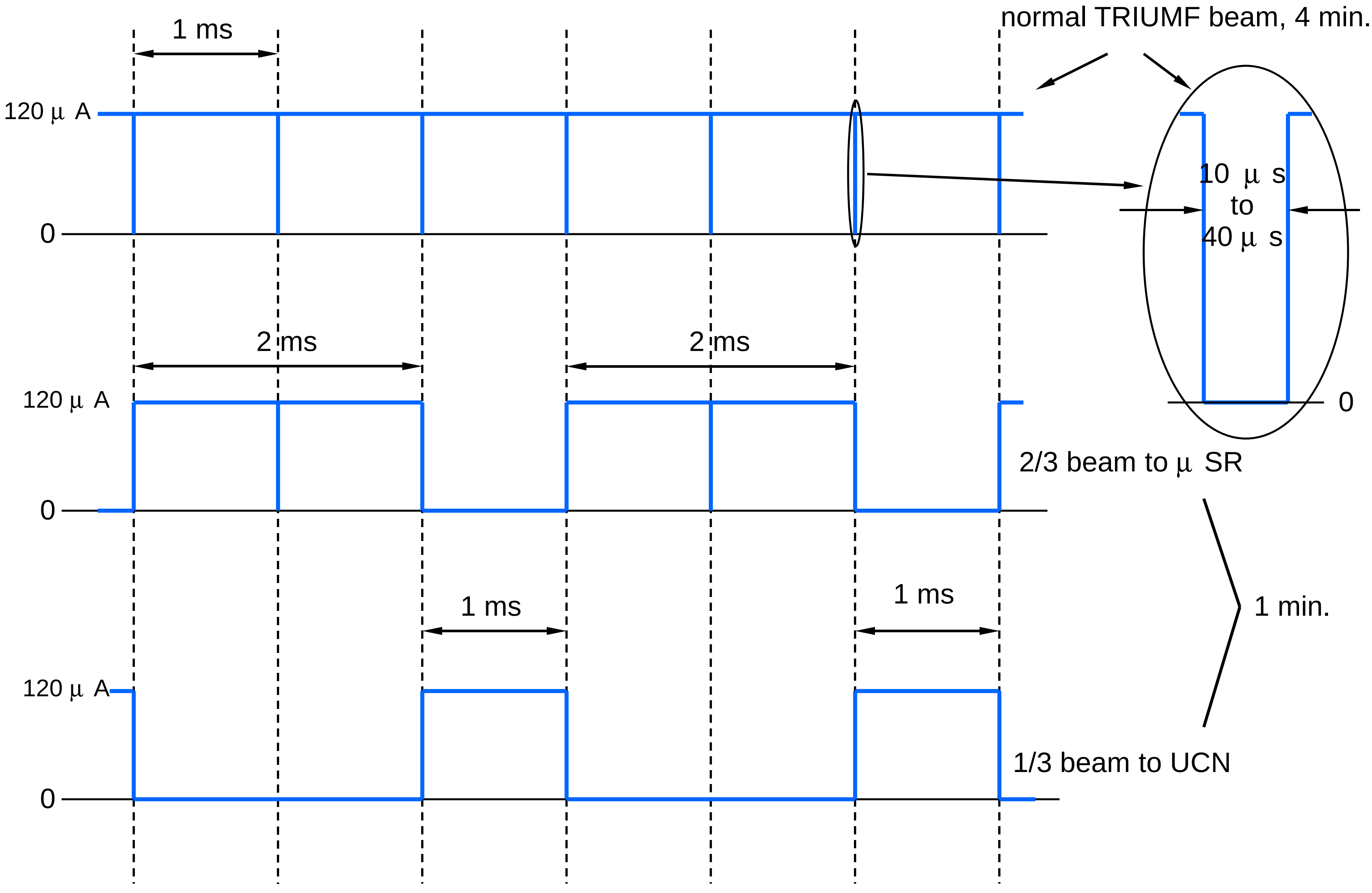
- The cyclotron beam can't be interrupted for more than ~1ms (ISAC target)
- The instantaneous meson hall beam should be stable.

UCN Facility in Meson Hall



Chuck Davis / Stu Austen

Proposed time division of beam



Features of the Proposed Beam Sharing Scheme

- The beam tune of beamline 1A is untouched.
- The instantaneous beam current does not change.
- A gate could be delivered to experimenters during beam-blanking.
- Downstream users only lose 7% of their averaged beam.

Meson Hall: Other Options