Canada's national laboratory
for particle and nuclear physics
and accelerator-based science

Status of the UCN guide development for the TRIUMF UCN source and TRIUMF neutron EDM experiment.

Edgard PIERRE
for the TUCAN collaboration

October 17, 2017, nEDM2017 workshop, Harrison Hot Springs

Outline

- Interaction of UCN with materials
- Developments at RCNP
- Guides for the prototype source at TRIUMF
- Future plans for the nEDM experiment and the next generation source
- Conclusion

Interaction of UCN with materials

- UCN see a potential V

$$R = 1 - T = \left(\frac{1 - \sqrt{1 - V/E_\perp}}{1 + \sqrt{1 - V/E_\perp}} \right)^2$$

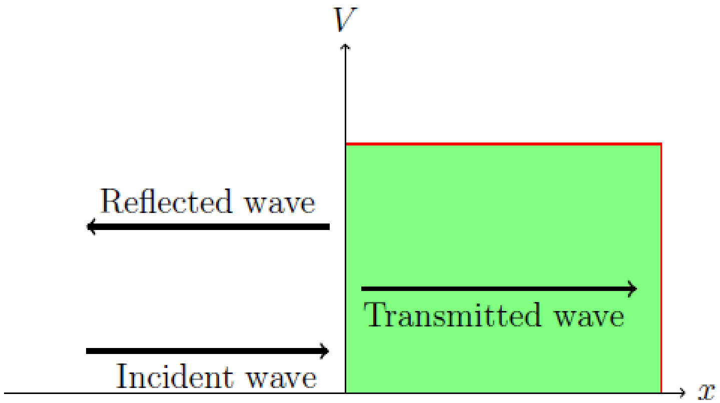
- Fermi potential:

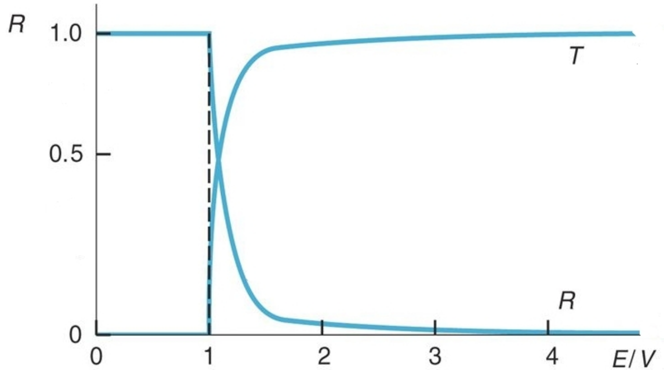
$$V_F = V - iW = N\hbar \left(\frac{2\pi\hbar}{m_n} b - \frac{i}{2} v \sigma_{loss} \right)$$

$$\eta = \frac{W}{V}$$

- Wall loss probability:

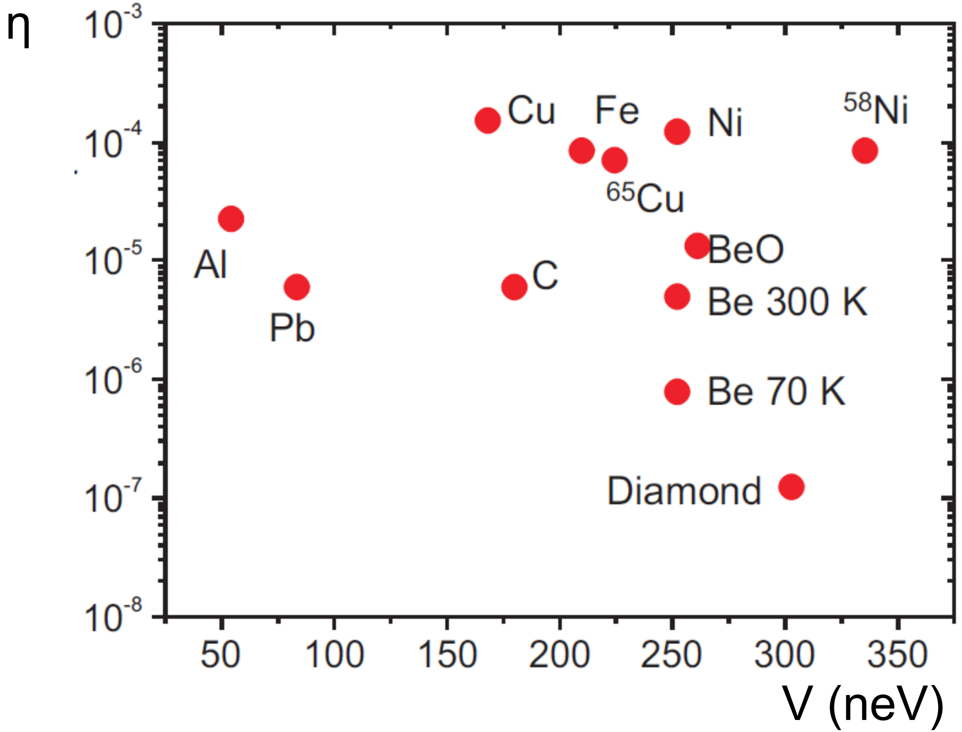
$$\mu(E) = 2\eta \left[\frac{V}{E} \arcsin\left(\frac{E}{V}\right)^{1/2} - \left(\frac{V}{E} - 1\right)^{1/2} \right]$$





Interaction of UCN with materials

- High V_F low η are suitable for guide material
- UCN have a spin and can be polarized
- Like μ, one can define a depolarization probability per bounce β (depending on material)



Plot from PR C **96**, 035205 (2017)

Interaction of UCN with materials

- nEDM statistical sensitivity

$$\sigma_{d_n} = \frac{\hbar}{2\alpha T E \sqrt{N_0}}$$

Interaction of UCN with materials

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- UCN count
- Electric field
- Precession time
- Visibility (polarization)

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Interaction of UCN with materials

- nEDM statistical sensitivity

$$\sigma_{d_n} = \frac{\hbar}{2\alpha T E \sqrt{N_0}}$$

f(β) f(η)

- UCN count
- Electric field
- Precession time
- Visibility (polarization)

- Minimizing η and β is required in order to minimize σ_{dn}

Developments at RCNP

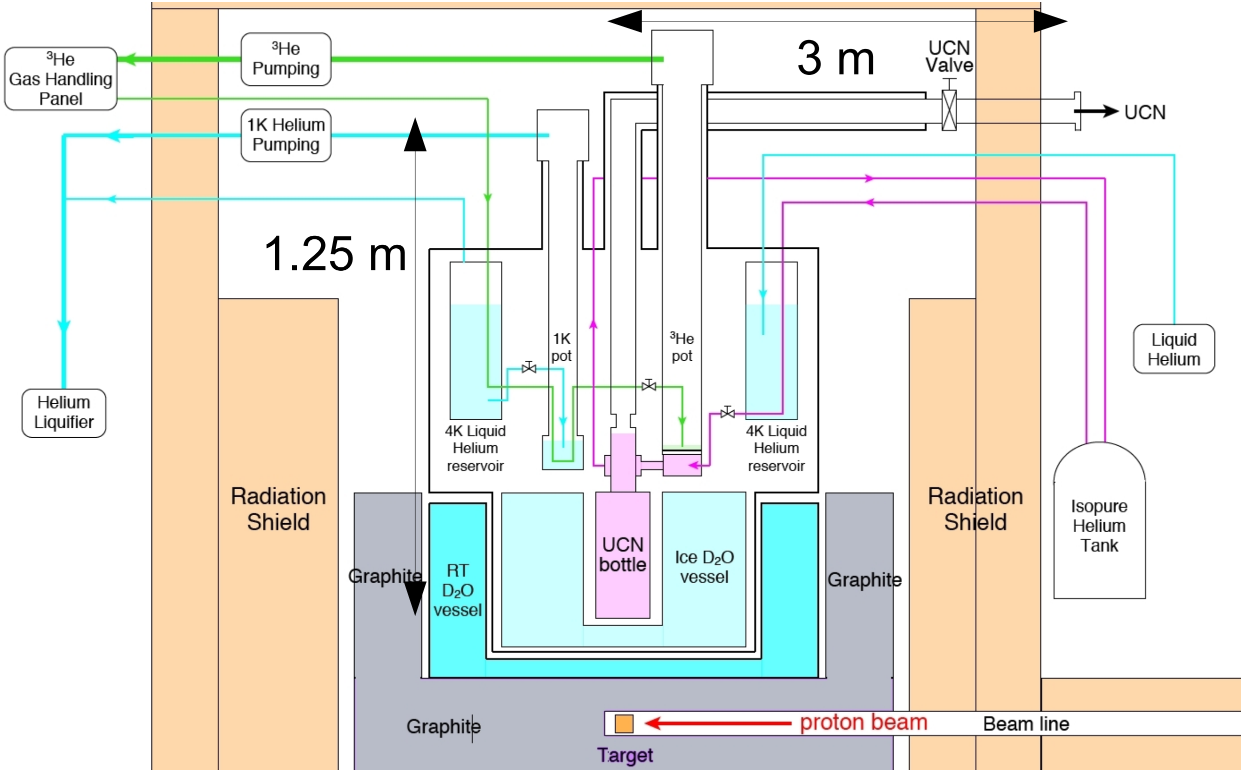
- Prototype source developed from 2002 to 2012

Bottle: Al with NiP coating

Guides: SUS with NiP coating

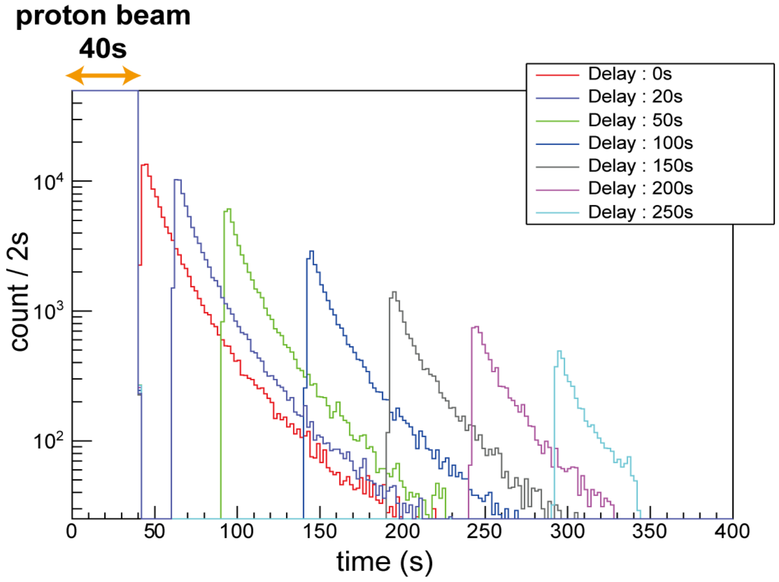
$V_{theo,\ NiP}$ ~ 214 neV

Mean flight length: ~ 5.5 m



Developments at RCNP

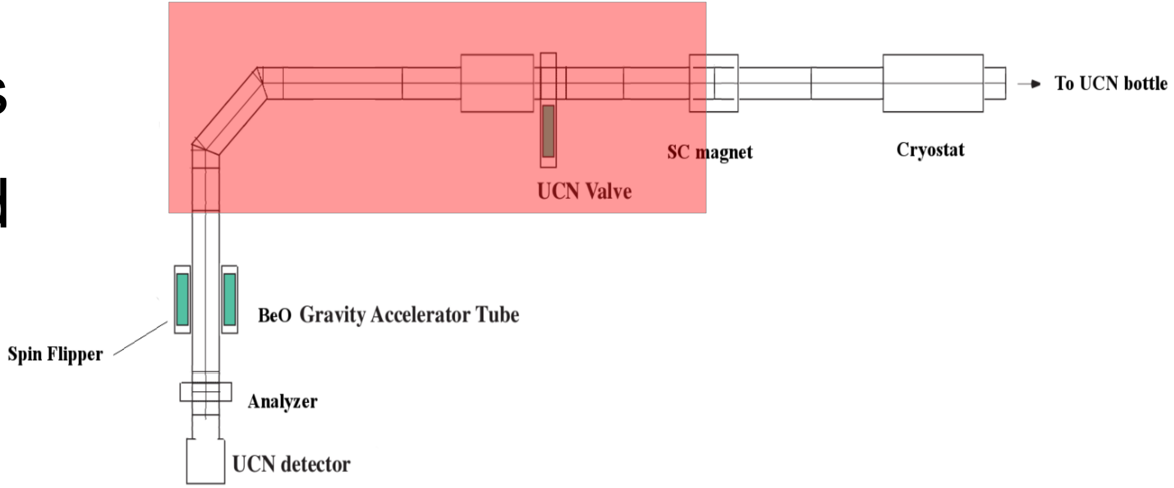
- Prototype source developed from 2002 to 2012
- Improvement of the storage lifetime mainly due to μ reduction



Year	τ_s	T_{HeII}	Improvement
2002	14 s	1.2K	
Jun 2006	29 s	0.9K	Use ^3He cryostat
Nov 2006	34 s	0.8K	Reduce HeII film perimeter (8.5 cm → 5 cm)
Jul 2007	39 s	0.8K	Remove ^3He contamination
Apr 2008	47 s	0.8K	Fomblin coating
Dec 2009	61s	0.8K	Alkali cleaning
Feb 2011	81s	0.8K	High temperature baking (140°C)

Developments at RCNP

- Polarization of the UCN beam measured with SUS coated with non magnetic nickel alloy (NiMo)
- 3 settings:
  - 1: SUS guides
  - 2: Cu 90° bend
  - 3: 10G field



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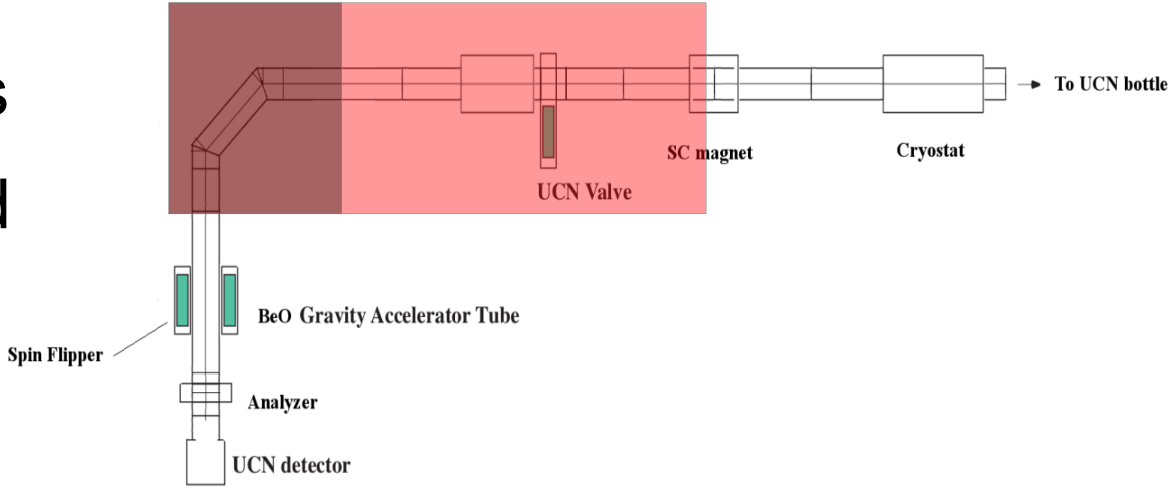

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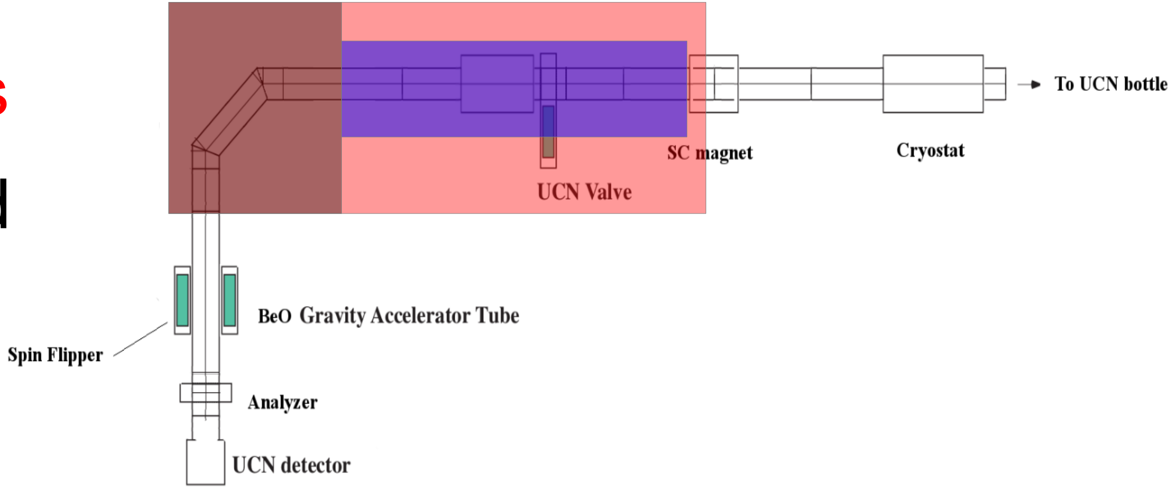
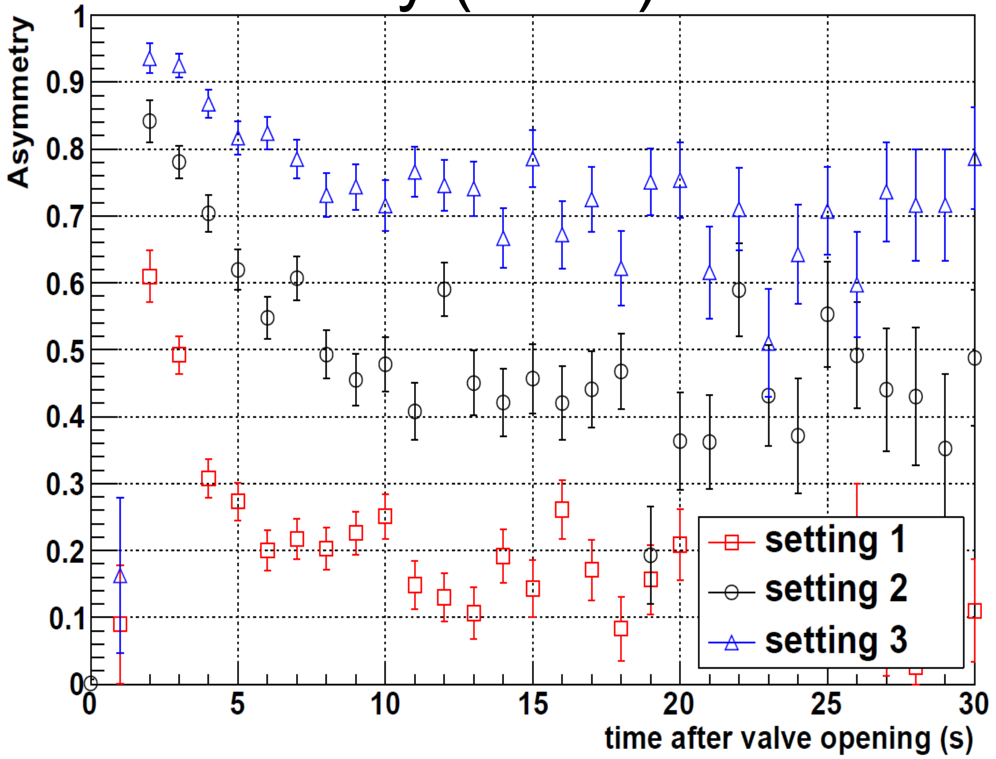


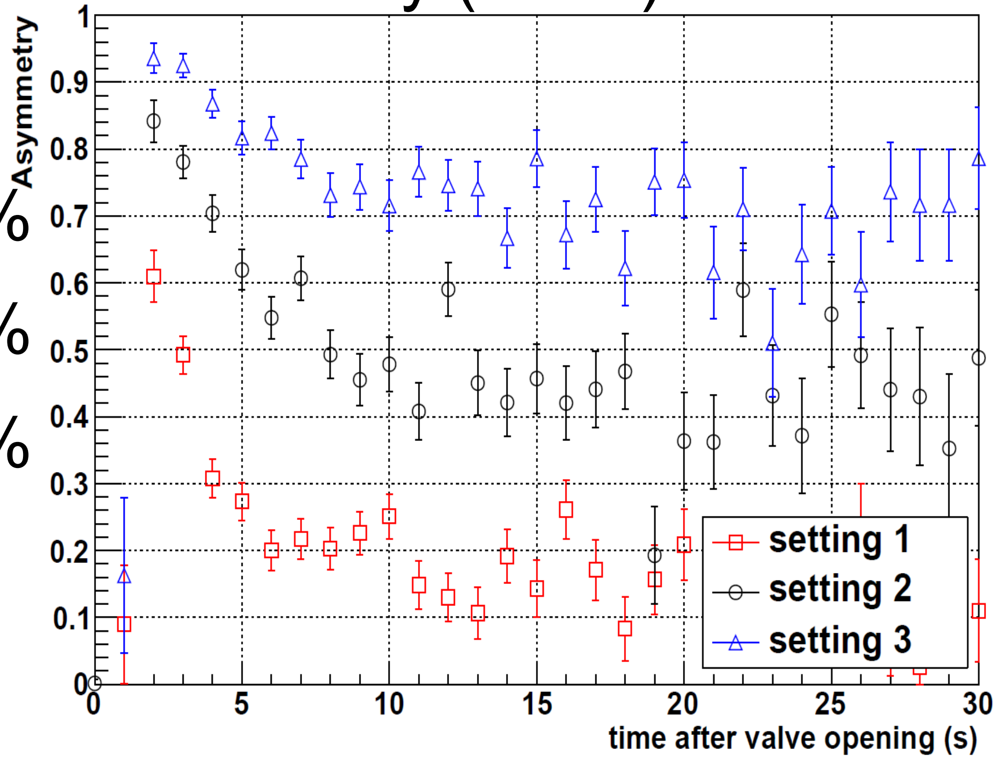
Developments at RCNP

- Polarization of the UCN beam measured with SUS coated with non magnetic nickel alloy (NiMo)
- 3 settings:
  - 1: SUS guides
  - 2: Cu 90° bend
  - 3: 10G holding field

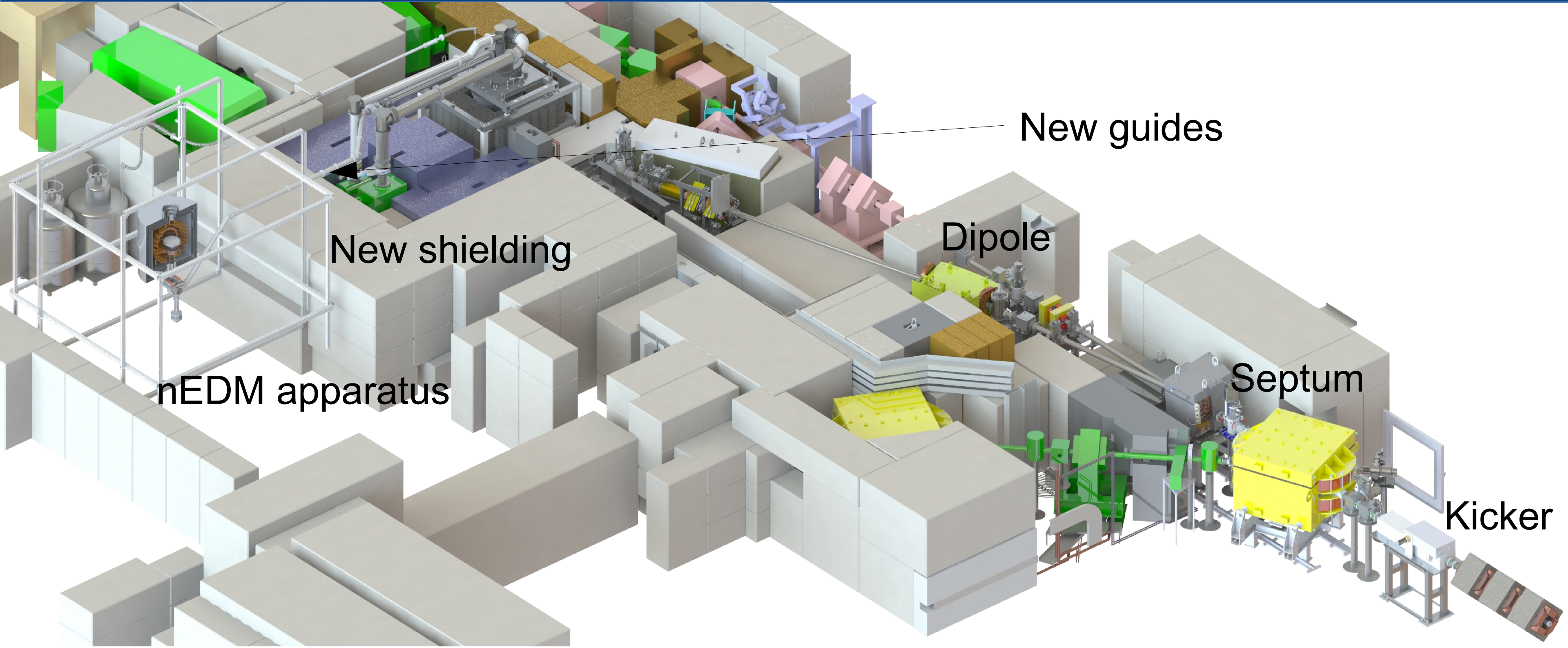


Developments at RCNP

- Polarization of the UCN beam measured with SUS coated with non magnetic nickel alloy (NiMo)
- 3 settings:
  - 1: P(10s)=21.5±0.5%
  - 2: P(10s)=52.1±0.7%
  - 3: P(10s)=74.8±0.9%
- Huge substrate effect



Source installation at TRIUMF



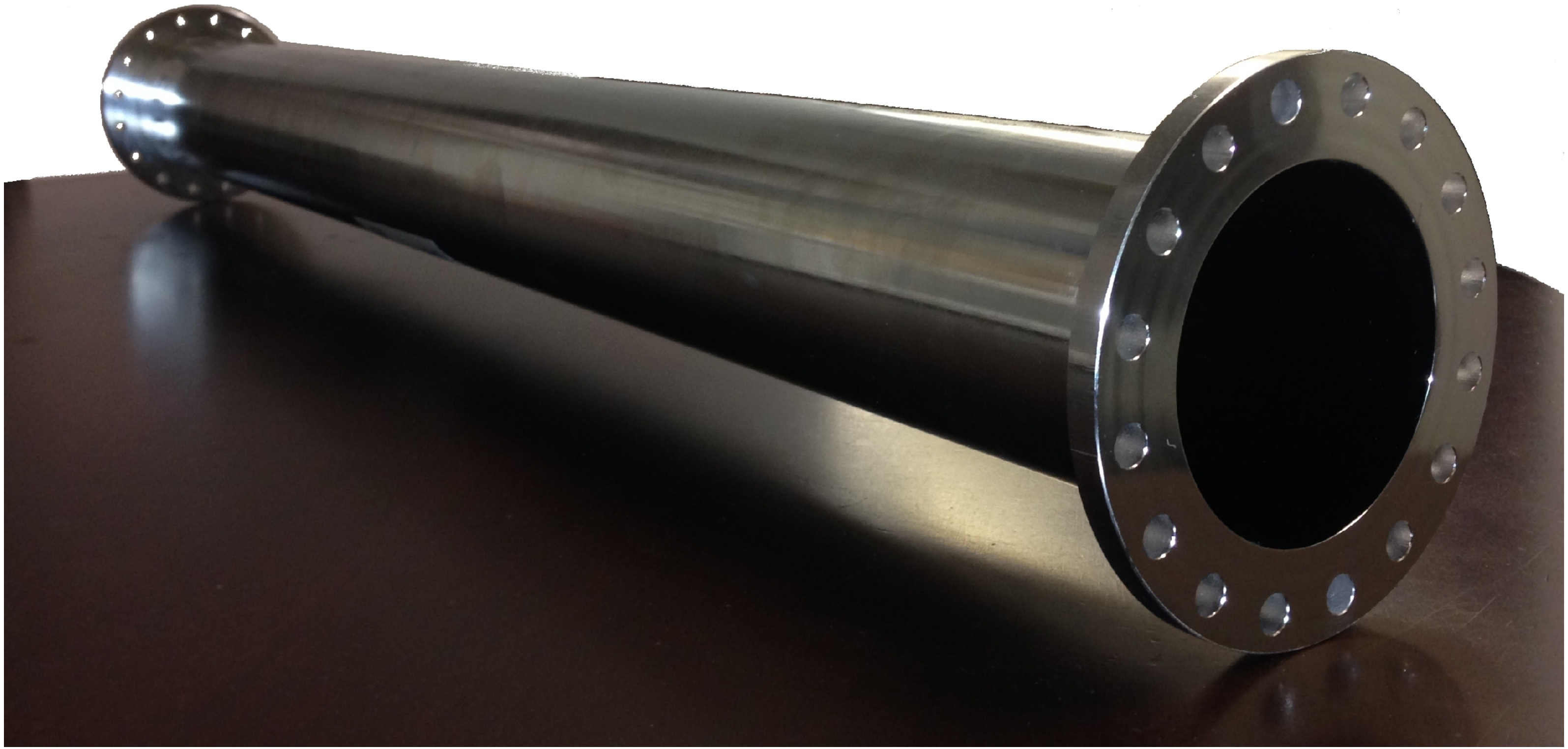
- New shielding increased the UCN flight length by ~ 3.5 m
- New guides are necessary

Guide preparation at TRIUMF

- New guides were chosen to be SUS (V~188 neV) without coating. Cut and welded at TRIUMF

Guide preparation at TRIUMF

- Electro polished in order to reach Ra<3μin (60 nm)



Guide preparation at TRIUMF

- Cleaned using RCNP procedure in a clean room

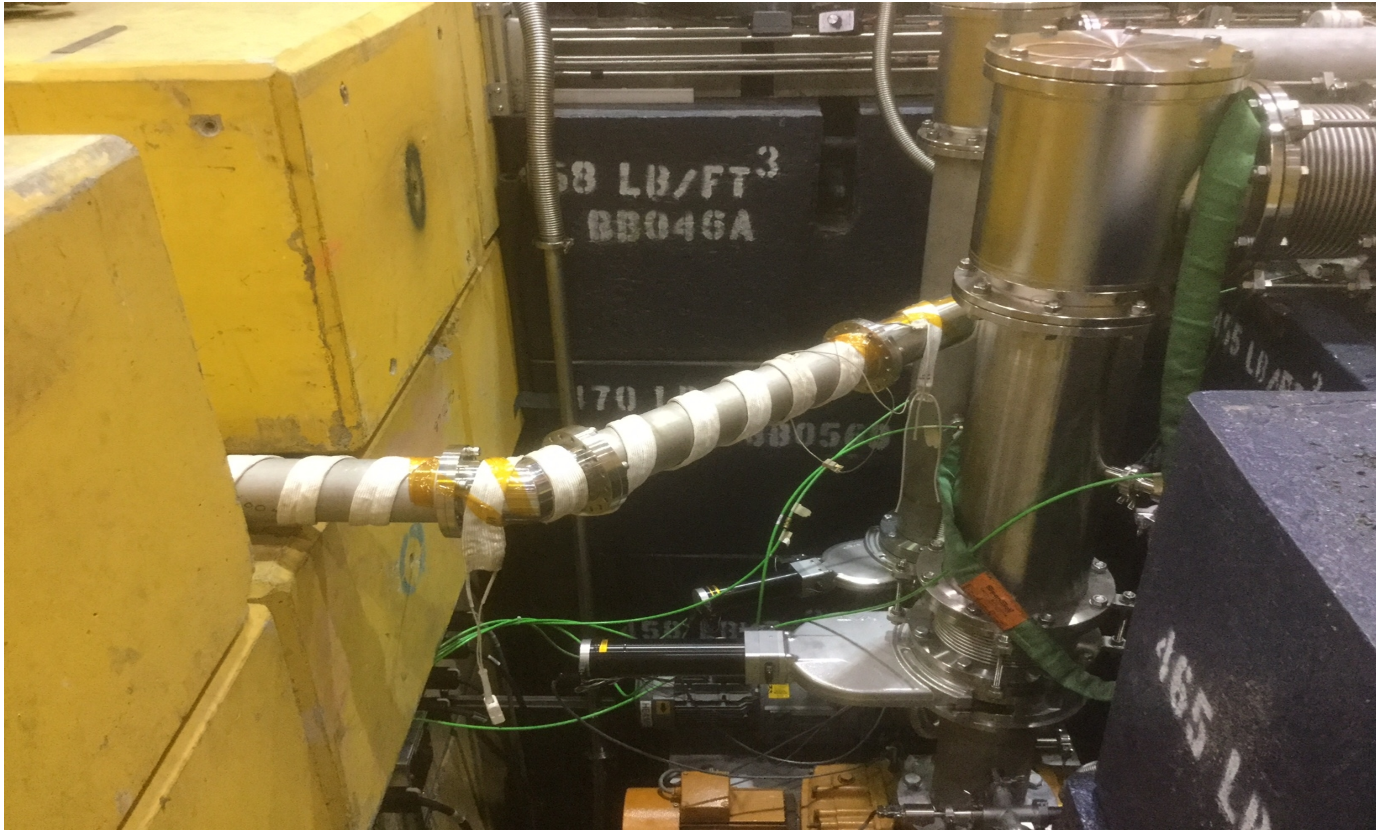
X2 {
- NaOH (5%) degreasing ("soap")
- Water rinsing

X2 {
- HNO3 (5%) neutralization
- Water rinsing

- Ethanol drying
- N2 gas drying

Guide preparation at TRIUMF

- Baked (400 K, 12 hours) and installed on the source

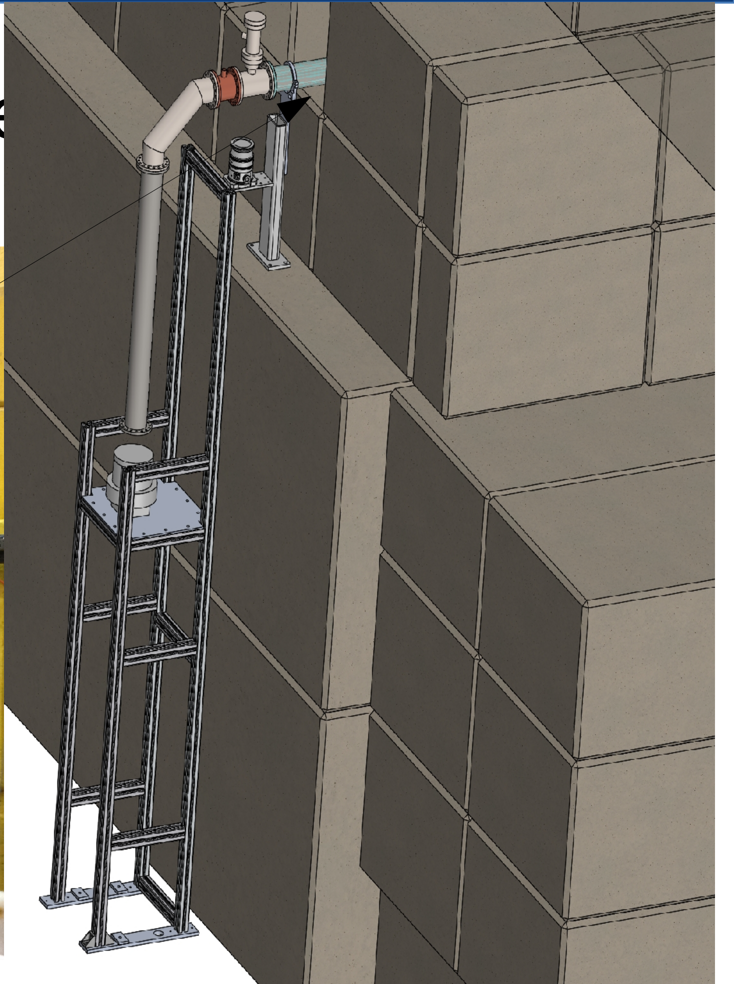


Guide preparation at TRIUMF

- Status October 17: UCN guides ready to be mounted!

Guide preparation at TRIUMF

- Status October 17: UCN guide mounted!

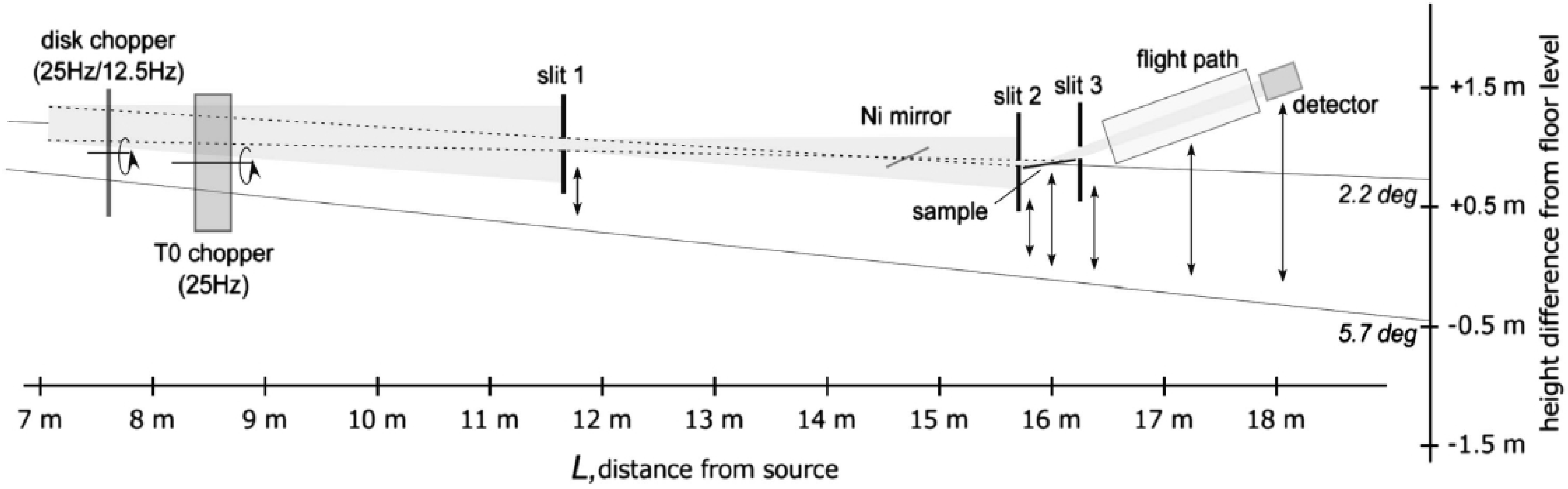


Future plans for nEDM

- We plan to expend the beamline with substrate guides coated with NiP. NiP must be characterized, in term of V, β, η and transmission
- Other candidates such as DLC are also considered
- V_{NiP} was measured using CN reflectometry
- β_{NiP} will be cross-checked at PSI
- η_{NiP} and transmission will be measured at TRIUMF

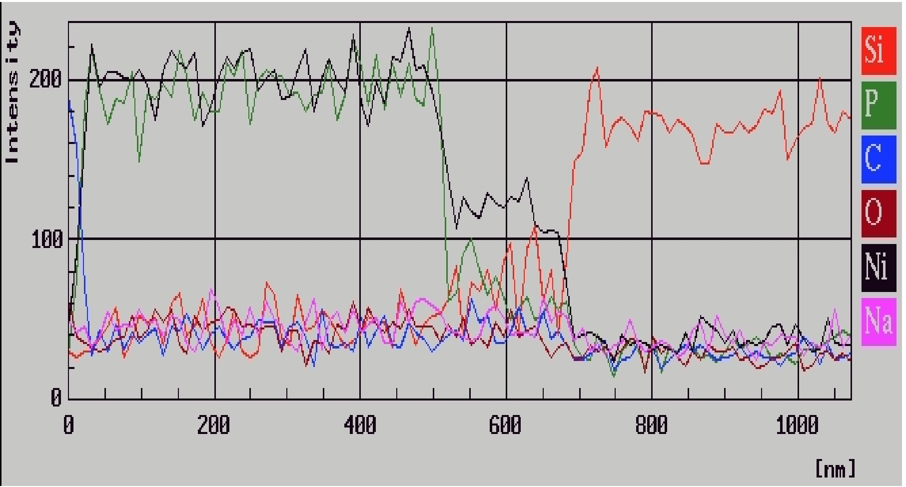
CN reflectometry at MLF (J-PARC)

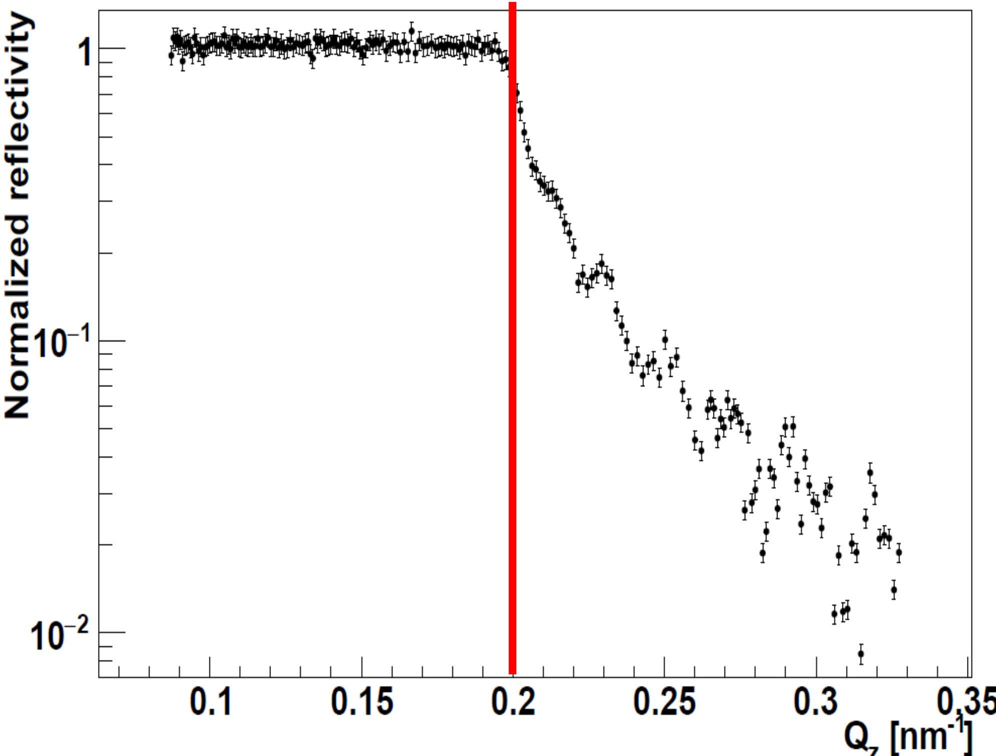
- NiP potential was measured using CN reflectometry



CN reflectometry at MLF (J-PARC)

- $V_{NiP(10\%)}$=207±5 neV
- Slightly lower than theoretical value (214 neV) because of sample impurities





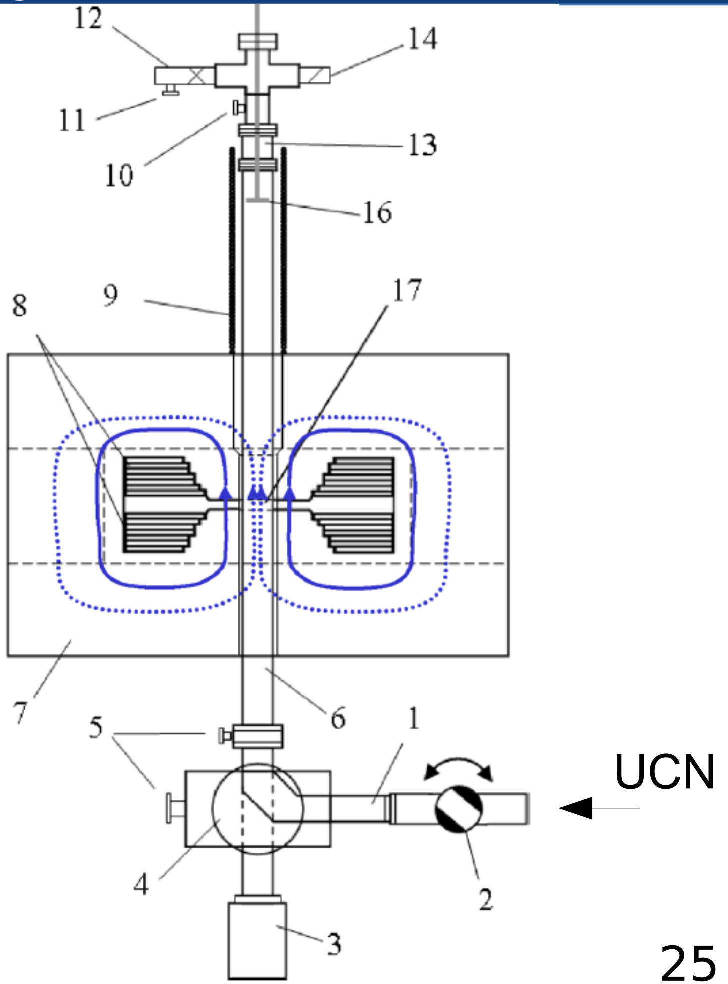
Depolarization in a magnetic trap

- β_{NiP} was measured at LANL (for thick coating)

  $\beta_{NiP}<6.2\times10^{-6}$ (NIMA **827**, 32 (2016))

- New measurement planned this year at PSI for thin coating using the apparatus described in

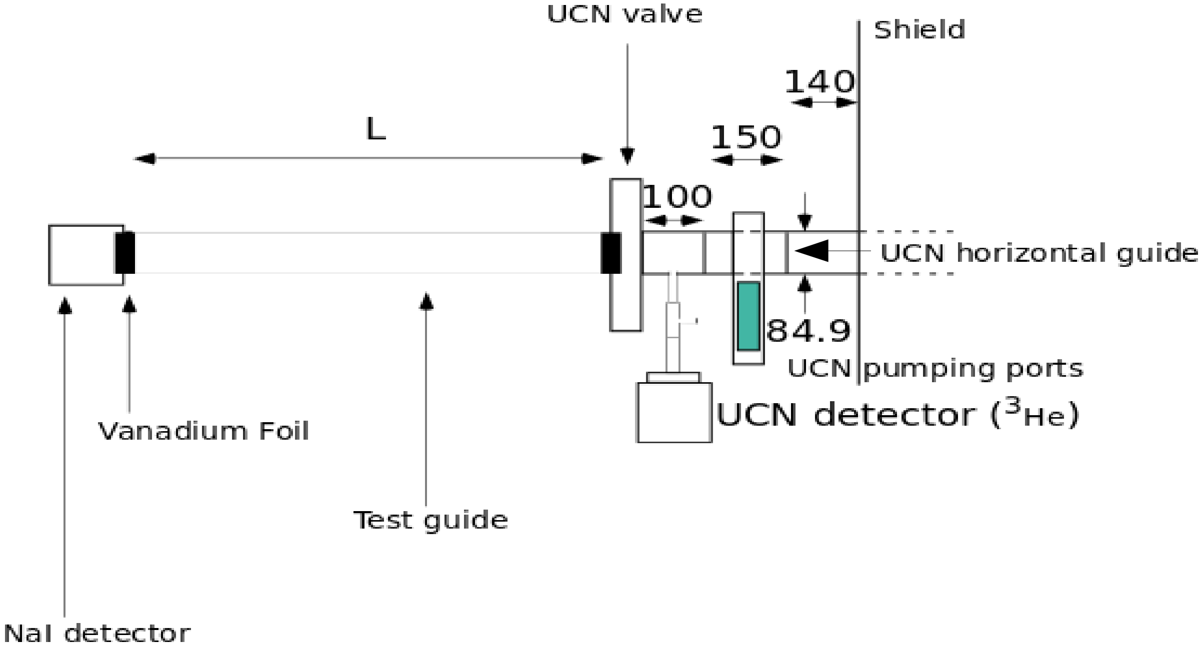
  PR C **96**, 035205 (2017).



UCN guide transmission

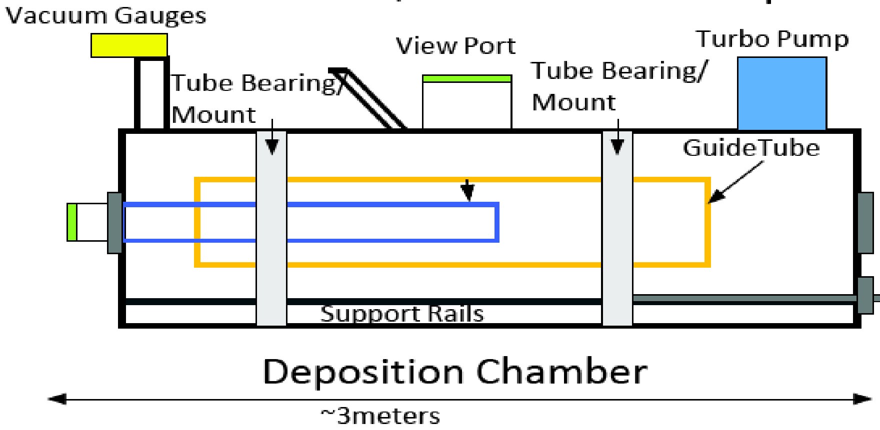
- guide transmission is would be measured with the new UCN source at TRIUMF, using method developed in

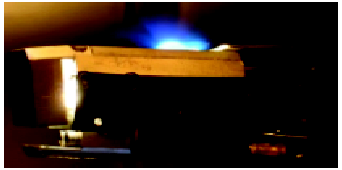
  NIMA **612**, 2 (2010). (proposal)



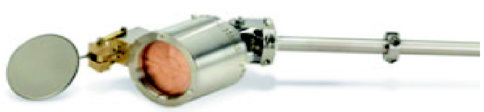
Coating facility at the University of Winnipeg

- Nominally designed for pulsed laser deposition. Can accept magnetron sputtering, electron beam, and thermal evaporation sources.

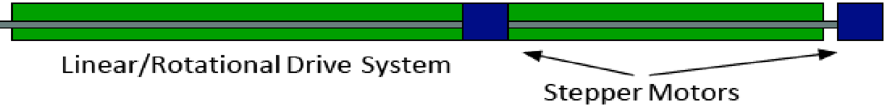


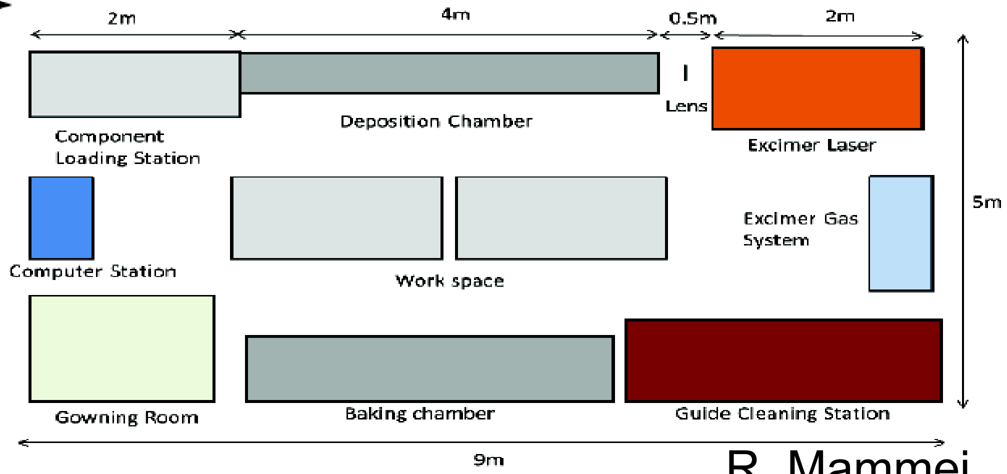


Ebeam evaporation



Magnetron Sputtering





Measure Fermi potential using low angle neutron scattering in Japan to evaluate various deposition technologies

CFI approved

R. Mammei

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Outlook

- First UCN beamline (made of EP SUS) is ready and will be tested during the first UCN production at TRIUMF in 3 weeks
- NiP alloy is our current candidate for our next generation guides. Its Fermi potential has been measured with CN, and other characteristics will be measured in the coming month
- A coating facility will be built at the University of Winnipeg, allowing us to make our own guides
- Our UCN facility will be used to test next generation UCN guides

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Merci!

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