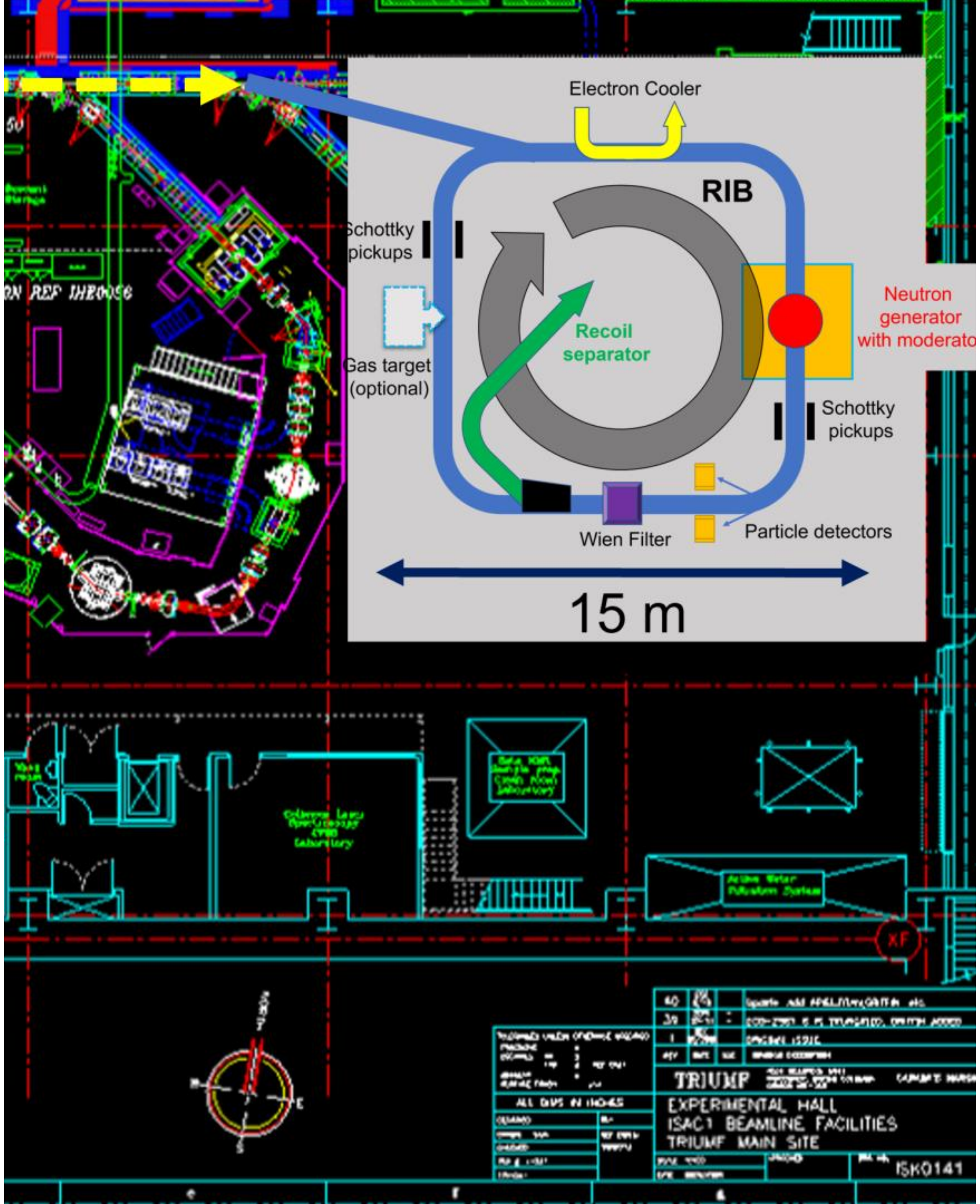
TRIUMF

TRISR:

The TRIUMF

Storage Ring Project

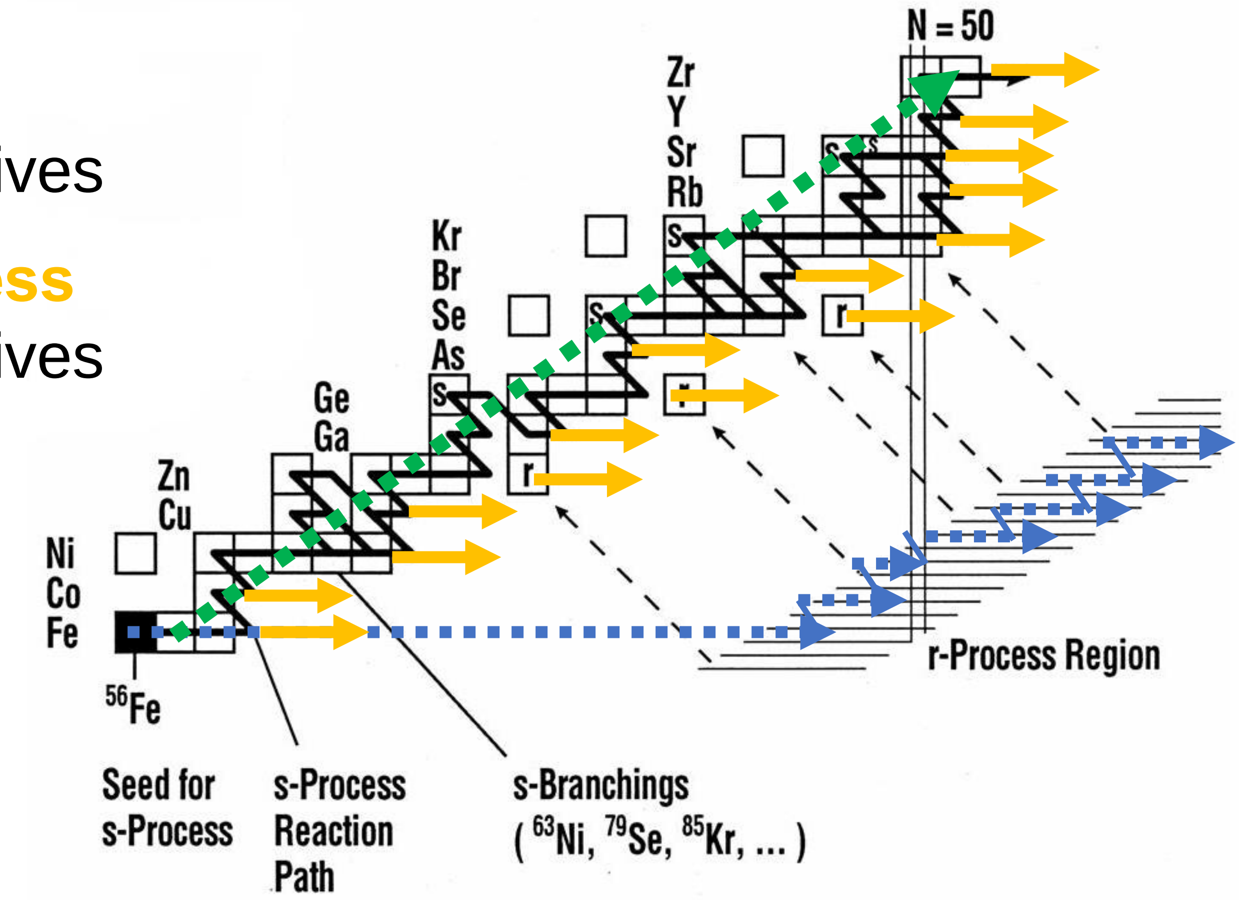


Iris Dillmann
Research Scientist (TRIUMF)
Adjunct Professor (University of Victoria)

Discovery, accelerated

Nuclear Physics Input for Astrophysical Neutron Capture Processes

- “slow” neutron capture process
  neutron capture cross sections, half-lives
- “intermediate” neutron capture process
  neutron capture cross sections, half-lives
- “rapid” neutron capture process
  neutron capture cross sections, half-lives, masses, neutron-branching ratios, fission probabilities (A>240),



Creation of elements heavier than iron DRIVEN by neutron captures!

Discove accelera

How well are (n,γ) cross sections for radioactive nuclei known?

- Statistical model (NON-SMOKER): **factor ~2 around stability** (except for N_{magic})

→ More than factor 100 for more n-rich nuclei

Variations in (n,γ) predictions within same model

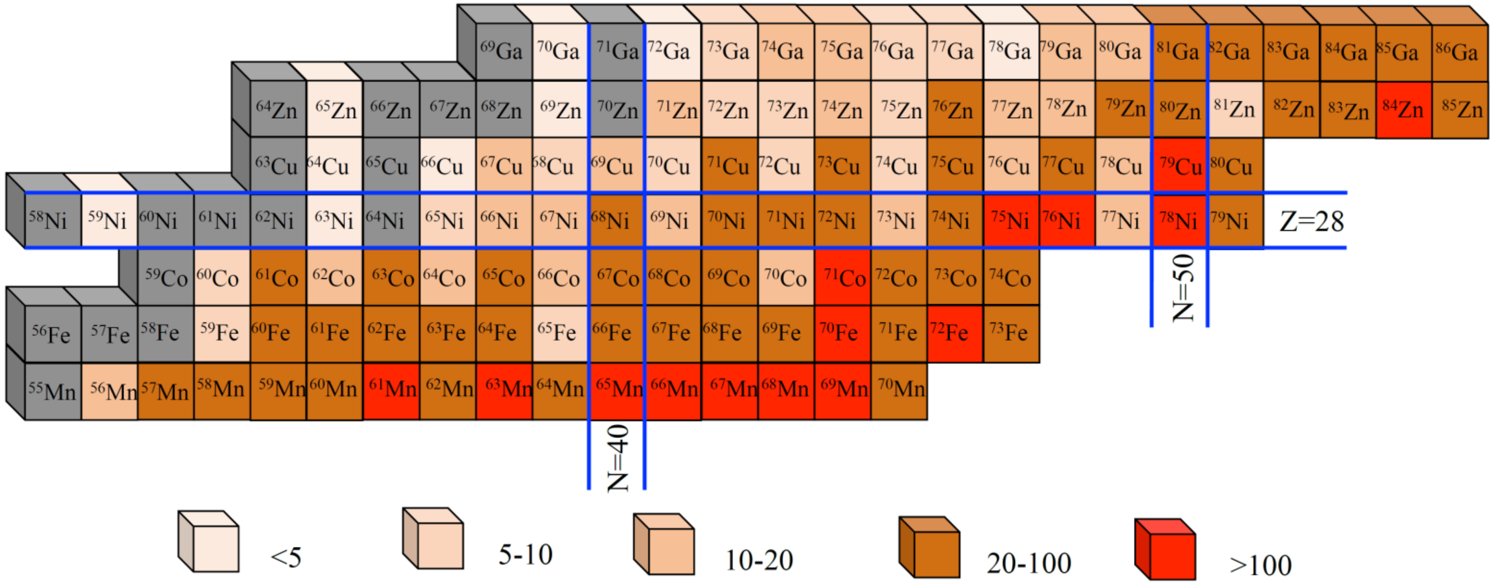


Figure 2: Variation in the theoretical prediction of neutron-capture reaction rates around mass 70. The (n,γ) rates were calculated with the reaction code TALYS [73, 74] varying the level density and γ-strength function as listed in Tab. I of Liddick *et al.* [76].

Ratio of calculated (n,γ) cross sections at 1.5 GK

Model: TALYS, varying level density and γ-strength functions

Liddick and Spyrou, PRL (2016)
Larsen, Spyrou, Liddick, Guttormsen (2019)

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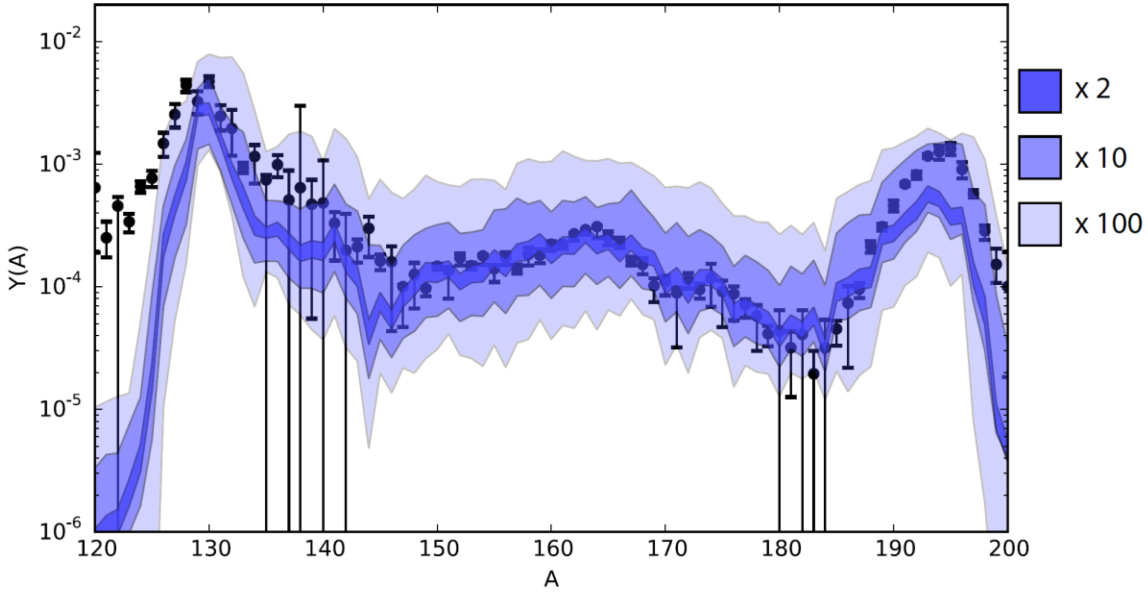
Impact for r-process abundances

- At the moment: **largest nuclear contribution to uncertainty in r-process predictions comes from (n,γ) cross sections!**



Ambitious goal

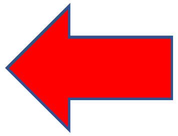


FIG. 1: Monte Carlo study of the effect of reaction rate uncertainties to calculations of nucleosynthesis yields in an r-process example. The blue shaded area

Nikas, Peridikakis et al, arXiv:2010.01698v1

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How to measure direct neutron cross sections?

Beam

Target

Neutrons → **Stable/ long-lived nuclei** ➡ **Measure decay or reaction products**

For astrophysical neutron capture measurements (100 mb cross sections):

Φ_{tot}	*	N_i	➡	N_{act}
10^{14} n/cm^2		* 10^{15} atoms	➡	~10^4 activated

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How to measure direct neutron cross sections?

Beam

Target

Neutrons → **Stable/ long-lived nuclei** ➡ **Measure decay or reaction products**

Neutrons → ~~**Short-lived nuclei**~~

"inverse kinematics"

Short-lived nuclei → ~~**Neutrons**~~ ~~$t_{1/2}$=10 min~~

Indirect measurements

Deuterium *(d,p) reactions* ➡ **Measure reaction products**

Storage Ring

Short-lived nuclei → **Neutrons** ➡ **Measure reaction product**

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Storage Ring + “Neutron target”

PHYSICAL REVIEW SPECIAL TOPICS - ACCELERATORS AND BEAMS **17,** 014701 (2014

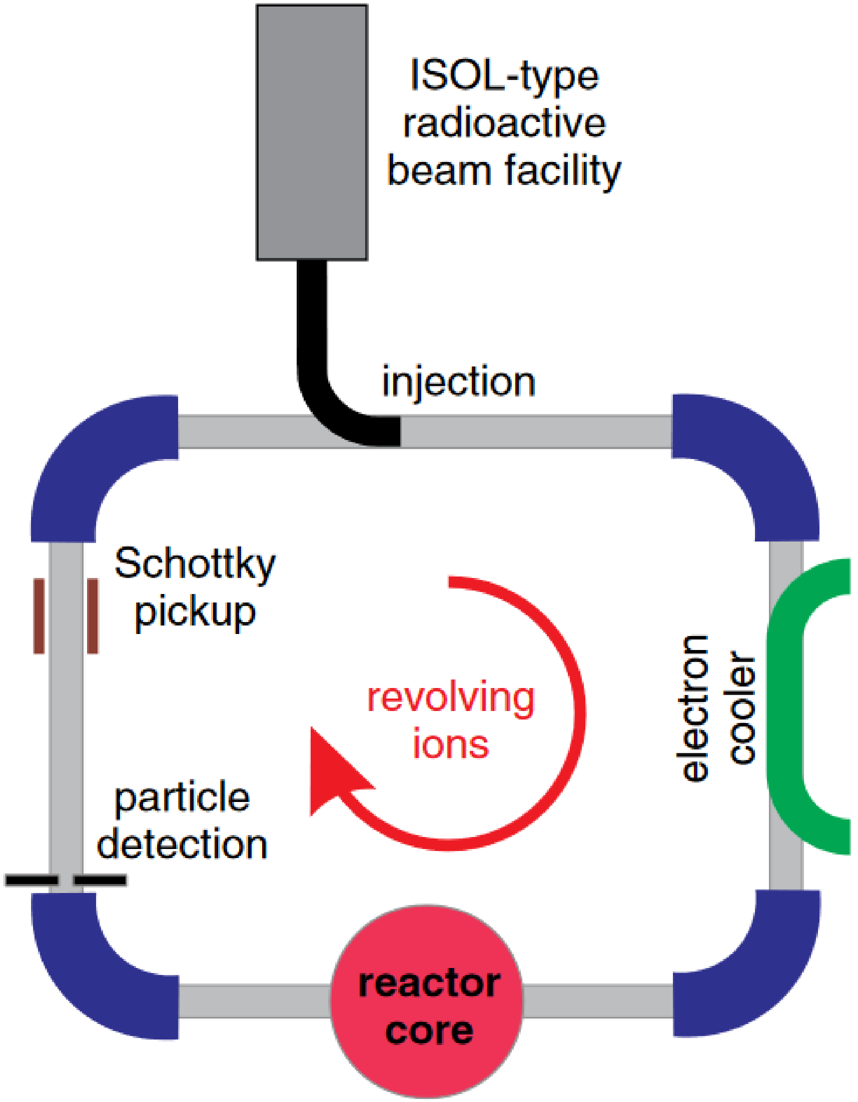
Measurements of neutron-induced reactions in inverse kinematics

René Reifarth[1] and Yuri A. Litvinov[2,3]

[1]*Goethe-Universität Frankfurt am Main, Max-von-Laue-Str.1, 60438 Frankfurt am Main, Germany*
[2]*GSI Helmholtzzentrum für Schwerionenforschung, 64291 Darmstadt, Germany*
[3]*Max-Planck-Institut für Kernphysik, 69117 Heidelberg, Germany*
(Received 17 September 2013; published 10 January 2014)

Neutron capture cross sections of unstable isotopes are important for neutron induced nucleosynthesis as well as for technological applications. A combination of a radioactive beam facility, an ion storage ring and a high flux reactor would allow a direct measurement of neutron induced reactions over a wide energy range on isotopes with half lives down to minutes.

DOI: 10.1103/PhysRevSTAB.17.014701 PACS numbers: 25.40.Lw, 29.38.-c, 28.41.-i



Storage Ring + Spallation Neutron Target

PHYSICAL REVIEW ACCELERATORS AND BEAMS **20,** 044701 (2017)

Spallation-based neutron target for direct studies of neutron-induced reactions in inverse kinematics

René Reifarth,[*] Kathrin Göbel, Tanja Heftrich, and Mario Weigand
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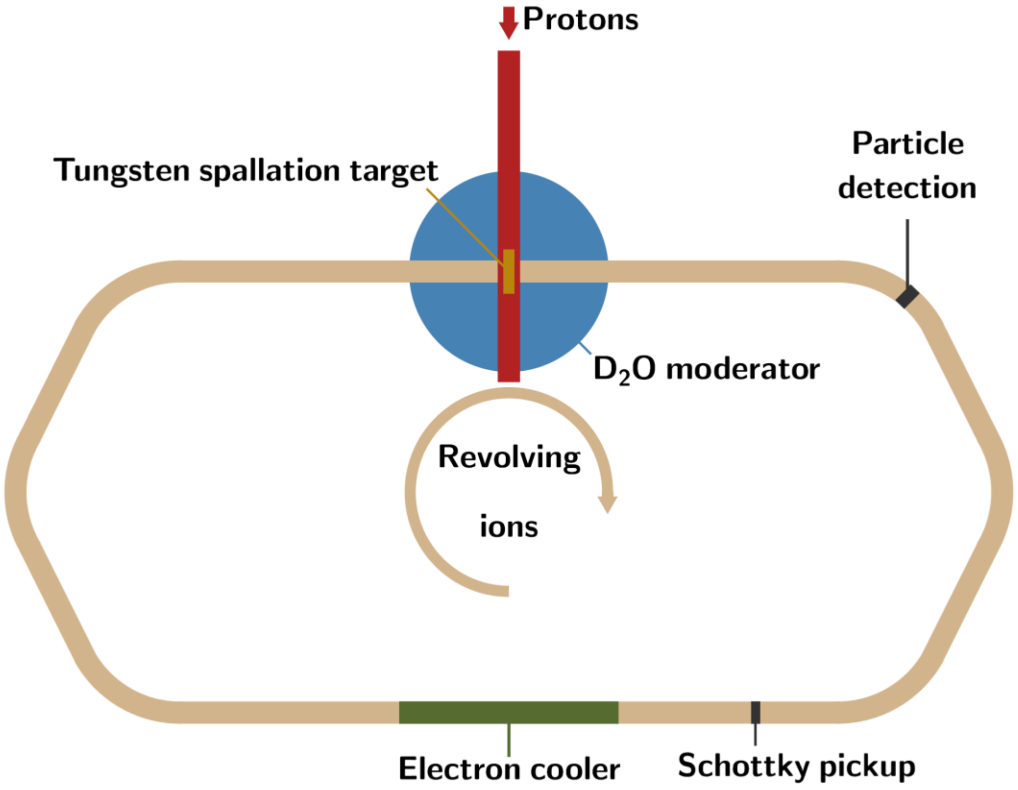
(Received 29 November 2016; published 6 April 2017)

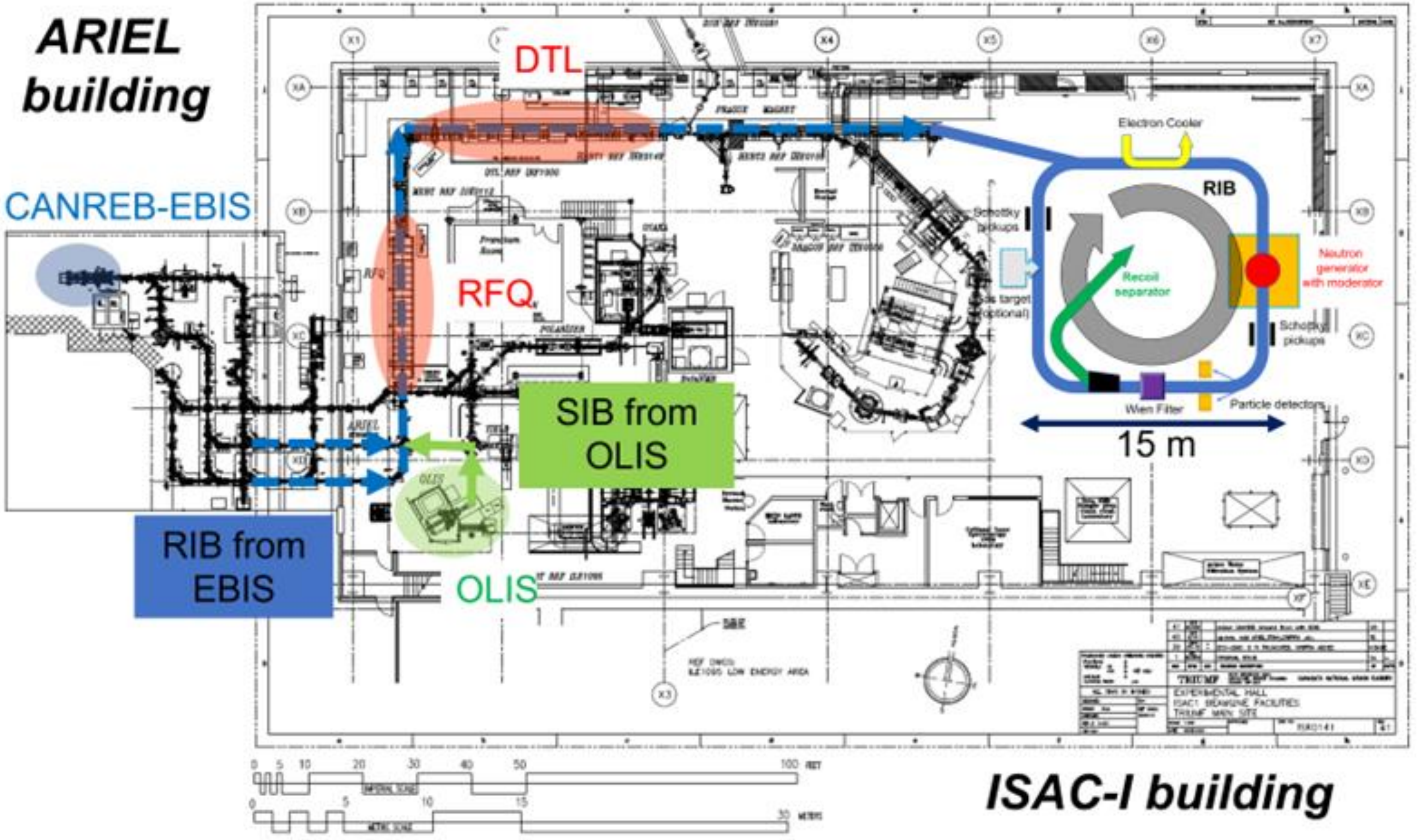


→ *see Los Alamos Project (S. Mosby, A. Couture, R. Reifarth):*
Los Alamos Report LA-UR-21-30261 (Oct. 2021)

Discover accelerated

TRIUMF Storage Ring: TRISR@ISAC-I

- Low-energy ring (0.1 – 2 A MeV)
- 40-50 m circumference
- Bρ(max)= 2 Tm
- A/q ≤ 7 (ISAC DTL)
- Injection from 0.15 A MeV up to 1.8 A MeV
- Radioactive beams and stable beams (OLIS)
- Charge-breeding via new CANREB EBIS



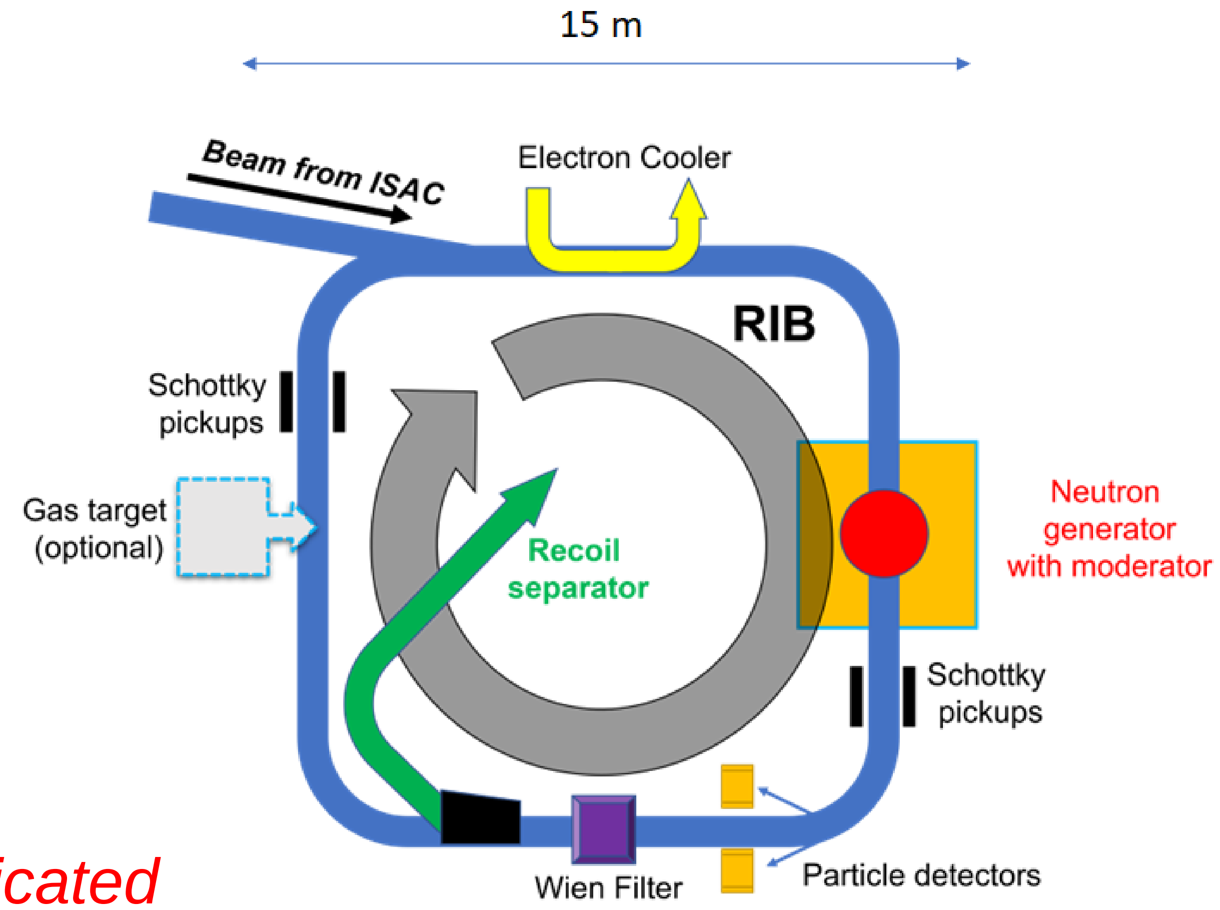
Focus on neutron capture cross sections for heavy nuclei with A>50 (r- and i-process) at astrophysical energies (100-2000 keV)

TRIUMF Storage Ring: TRISR@ISAC-I

Includes
- Electron cooler
- Particle detection via Schottky pickups and particle detectors

Unique features:

- Compact **high-flux neutron generator**
- Sensitive reaction product detection via **recoil separator**



Neutron generator needs dedicated feasibility study since no one has ever tried to combine it with a storage ring!

Potential Compact Neutron Generator

PHOENIX

- Alectryon 300T from Phoenix LLC: **highest-output gaseous target DT neutron generator on the market**
- Neutron flux **up to $5*10^{13}$ n/s**
- **Compact size:** 2.1m (W) x 2.7m (H), length 6 m

First step: **Feasibility study** which moderated neutron fluxes can be reached at target area – **need >10^8 n/cm^2/s**

https://phoenixwi.com/neutron-generators/d-t-neutron-generator-deuterium-tritium/

Can we measure neutron cross sections in a ring?

Short-lived nuclei → Storage Ring → **Neutrons** → **Measure reaction product**

For astrophysical neutron capture measurements (100 mb cross section):

φ	*	f * t_{meas} *	N_{RIB}	→	N_{act}	
10^8 n/cm²/s	*	135 kHz * 10s *	10^8 pps	→	~1 events/ day	

Needs high neutron flux

for E= 150 A keV

Need long beam lifetime (UHV)

Need sensitive detection system

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TRIUMF Storage Ring Project: Other applications

- Neutron activation measurements of environmental samples
- Production of radioisotopes for research (e.g. ^{177}Lu, ^{161}Tb for LS)
- Implantation of radioisotopes in μm depth
- …

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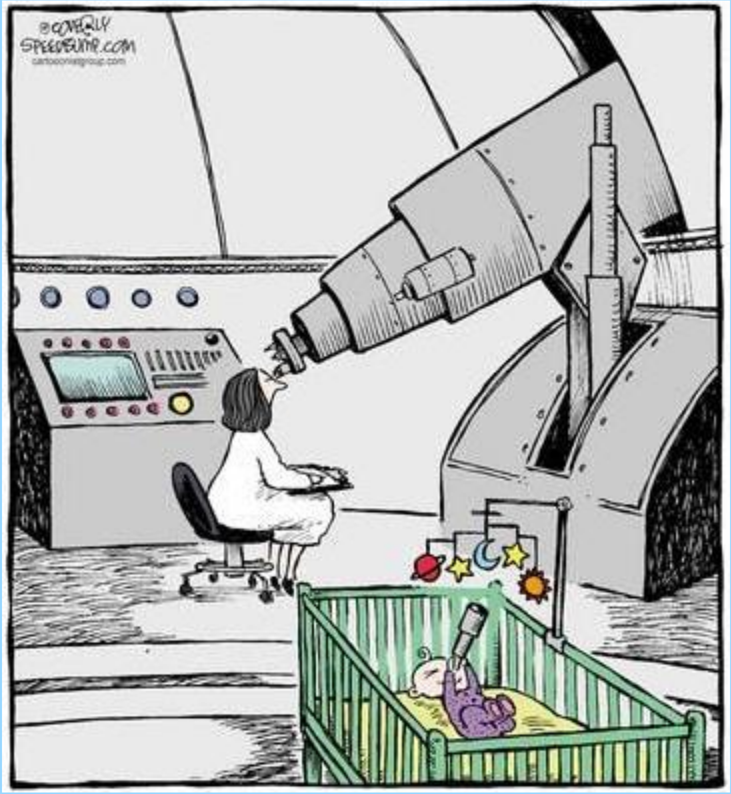
Outlook:
Funding & Timeline



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New NSERC Project Grant (2022)

TRISR Feasibility Studies:

WP 1: Storage Ring Matrix (Rick Baartman, Dobrin Kaltchev, Tobias Junginger, Oliver Kester)

WP 2: In-Ring Detection (Iris Dillmann)

WP 3: Neutron Generator and Moderator (Iris Dillmann, Oliver Kester) **not NSERC fundable ☹**

WP 4: Recoil-Separation Technique (Alan Chen, Annika Lennarz, Chris Ruiz, Barry Davids)

WP 5: Astrophysical Calculations & Theory (Nicole Vassh)

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Alternative Funding Sources?

Feasibility study for neutron generator is crucial! Needs to be the first step.

Alternative funding sources:

- **Next TRIUMF 5YP**
- **ERC Synergy Grant (tbd- next deadline Nov. 8, 2022)**
- ~~NSERC Alliance Grant~~
- ~~Find rich donor (unlikely)~~

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ERC Synergy Grant


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Home » Funding » Synergy Grants

SYNERGY GRANTS

Are you a researcher that wants to address a research problem so ambitious, that can not be dealt with you and your team alone? The Synergy Grants could be for you!

Who can apply?

A group of **two to maximum four Principal Investigators (PIs)** – of which one will be designated as the corresponding PI (cPI) – working together and bringing different skills and resources to tackle ambitious research problems. **No specific eligibility criteria regarding the academic training** are foreseen for ERC Synergy Grants. PIs must present an **early achievement track-record** or a **ten-year track-record**, whichever is most appropriate.

Proposals will be evaluated on the **sole criterion of scientific excellence** which, in the case the ERC Synergy Grants, takes on the additional meaning of **outstanding intrinsic synergetic effect**.

OPEN CALL

- Synergy Grants ERC-2023-SYG
  - Information for Applicants
  - Timeframe Synergy Grant 2023

  Deadline: 8 Nov 2022

ON-GOING EVALUATIONS

- Timeframe Synergy Grant 2022
- Timeframe Synergy Grant 2023

USEFUL DOCUMENTS

- ERC Work Programme 2023

- 2-4 PIs:
  Yuri Litvinov (GSI Darmstadt),
  Iris Dillmann (TRIUMF),
  NN (tbc)
- Up to 10 MEuro for 6 years
- Deadline: November 8, 2022

Can pay the feasibility study for the neutron generator!

TRIUMF Storage Ring: Anticipated timeline

- **2022** — Submit funding for CDR of neutron generator
- **2024** — Submit NSERC project grant storage ring concept
- **2024–2025 or 2025-2026** — (If funded) Conceptual Design Report of neutron generator
- **2025** — Define physics program in User Workshop (Gate 1)
- **2026** — Physics Book
  Project feasible or not?

Continue mission

Abort mission

TRIUMF Storage Ring: If feasibility study positive

2026–2027

Technical Design Report
(Gate 2A)

Submit CFI funding proposal (C$30-40M)

2029

Start construction

~ 2032

First commissioning experiments

~ 2033

Day-0 experiments

TRIUMF

Summary: Neutron Generator + Storage Ring

- **Worldwide unique facility!**
- Fits in existing TRIUMF-ISAC infrastructure (no new building needed)
- Will highly benefit from **new ARIEL infrastructure**: CANREB-EBIS, higher beam intensities, cleaner neutron-rich beams
- **Unique access to direct neutron capture cross sections of RIB** but will be likely **limited to high-intensity beams and by beam lifetime (~s)**
- Diverse research program **complementary to existing ISAC program**
- **Logical future extension of existing TRIUMF-ISAC program with potential to attract new users**

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Thank you!

Merci!

www.triumf.ca

Follow us **@TRIUMFLab**