Nuclear Magnetic Resonance

- Nuclei with non-zero spin have a magnetic moment
- Provides a subatomic probe of the magnetic field
- In materials, the local field at a nucleus depends on the surrounding electrons
- A local (real space) probe of solids
- Extensive use in chemistry, condensed matter physics, medicine (MRI), …
- First observed in 1940s,

  see Bloch and Purcell Nobel (1952)

TSW, Aug. 3, 2023

βNMR in the Age of ARIEL

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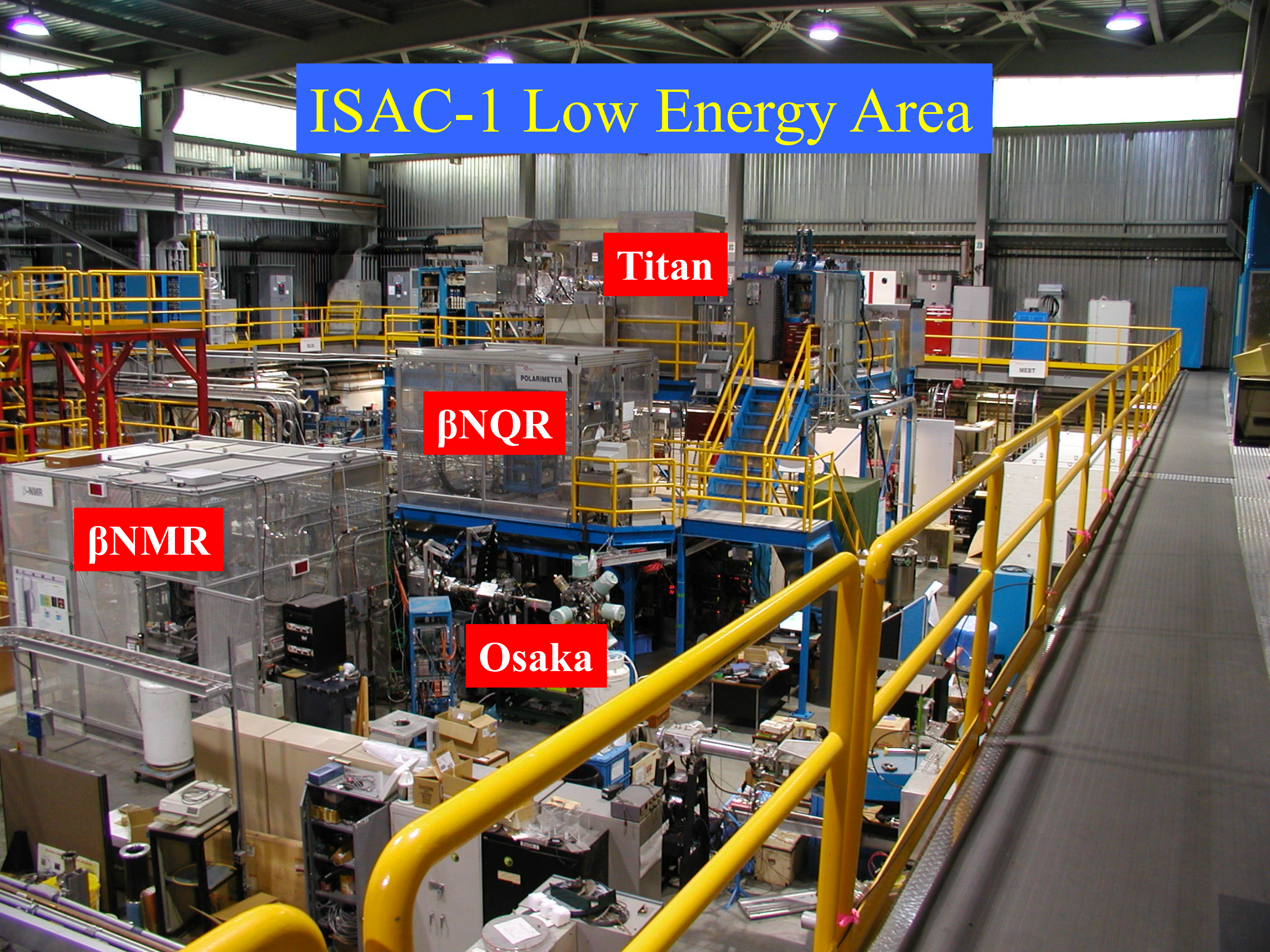
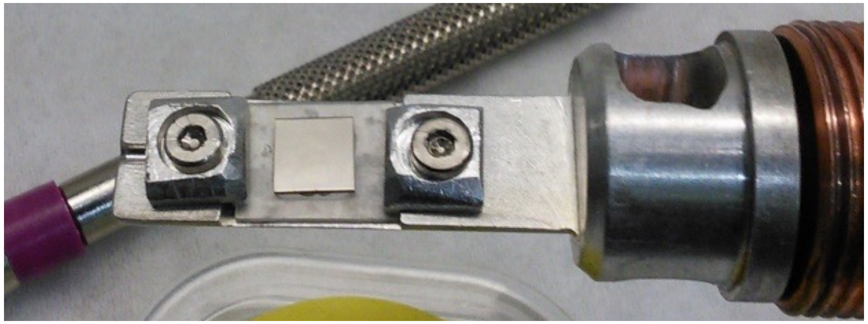

ISAC-1 Low Energy Area
Titan
POLARIMETER
βNQR
βNMR
Osaka

Scientific Objectives

Local magnetic probe with
nanometre depth resolution

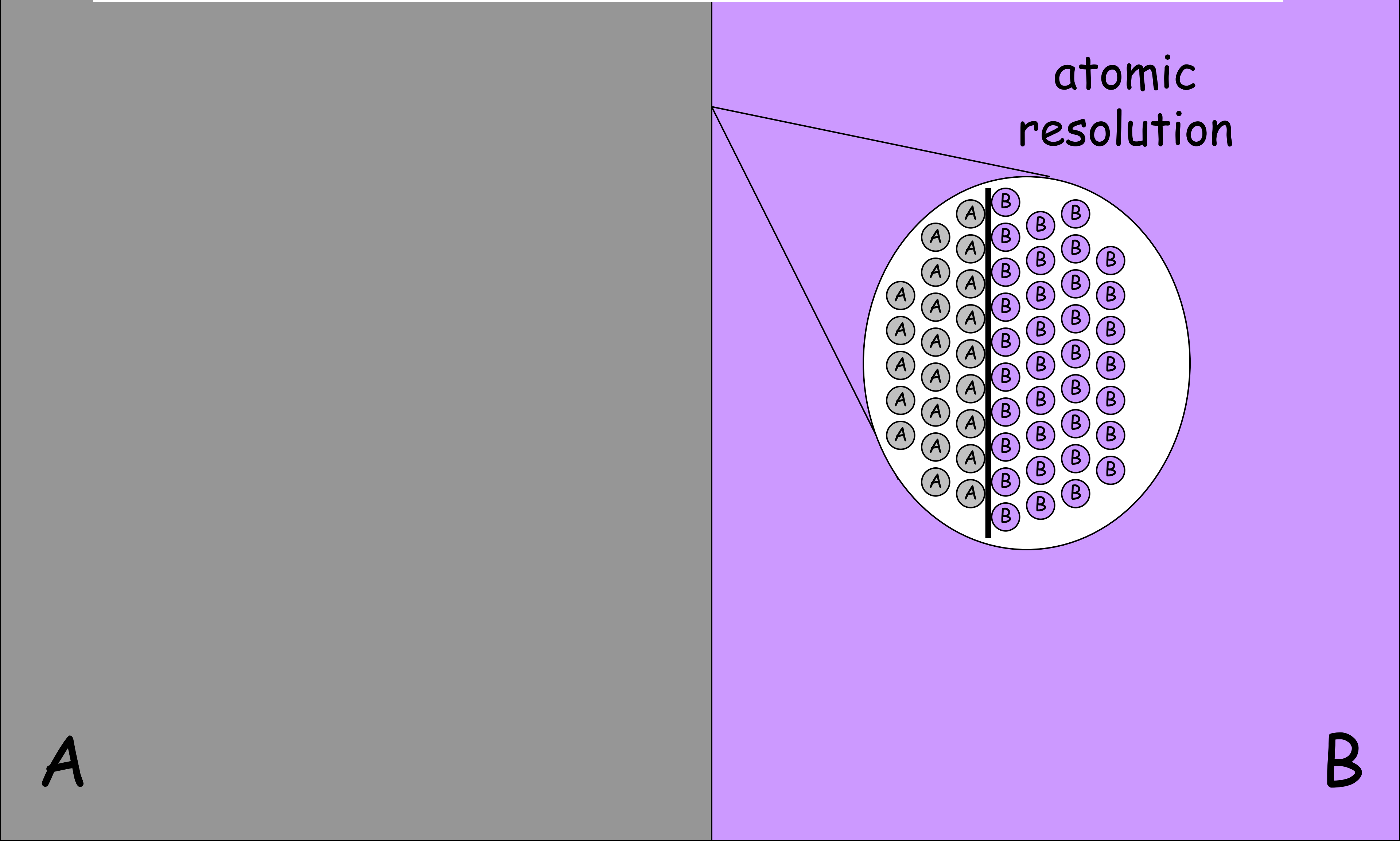
(thin films, multilayers, propagation of surface effects into the bulk)

38 nm Film on LSAT

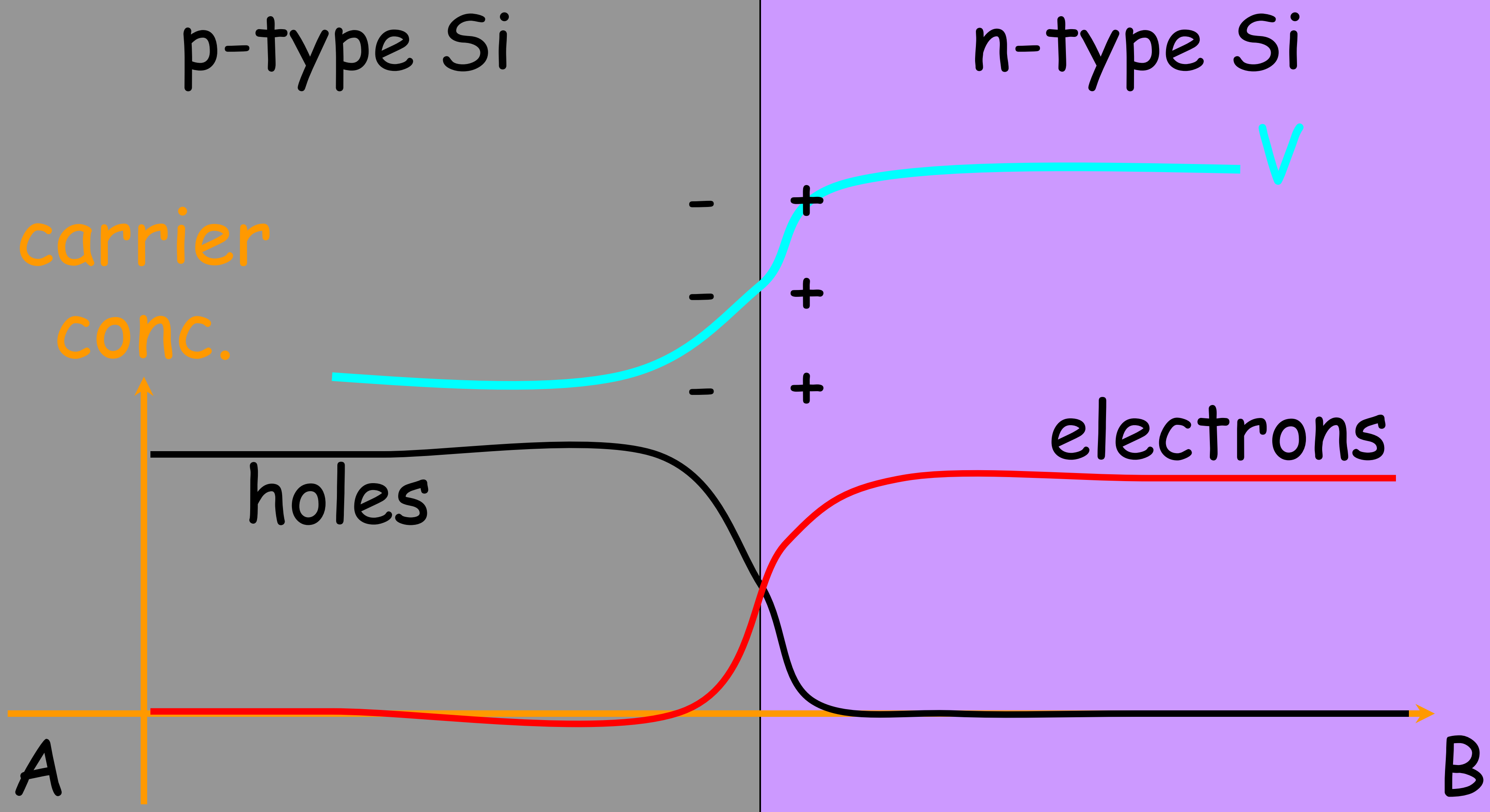


G. Cristiani
MPI-FKF Stuttgart

Solid Interfaces



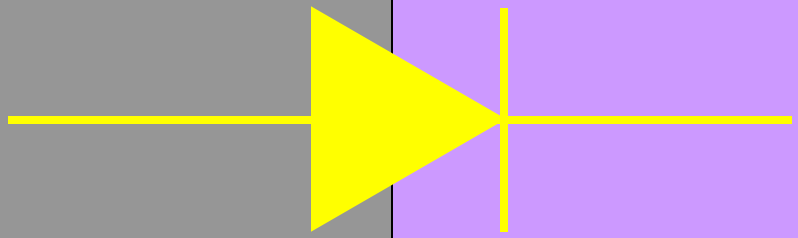
An Example



This is a DIODE

p-type Si

n-type Si



A

B

Further Objectives:
NMR when NMR is not Possible

Isolated ideally dilute defects

(including atomic mobility)

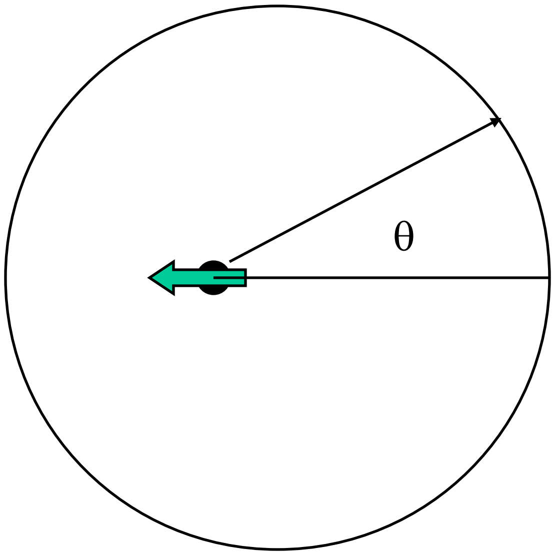
Unfavorable isotopes ^{31}Mg vs ^{25}Mg

Why is ^{8}Li the Best βNMR Nucleus

- lightest βNMR isotope
- easy to polarize
- easy to make a very pure high intensity beam
- can be produced by many different targets
- convenient lifetime 1.2 sec
- effectively single step decay: leaves only α
- significant experience is available
- chemically simple Li^+

β–decay of ^{8}Li

$^{8}Li \rightarrow {}^{8}Be + e^{-} + \bar{\nu}_e$



polar plot of the anisotropic beta emission

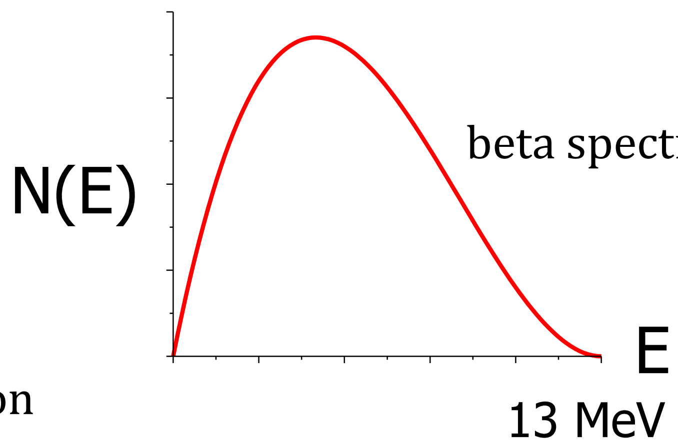
Nuclear Properties

Spin=2, Q=+32 mb

γ =6.3 MHz/T

Asymmetry=-1/3

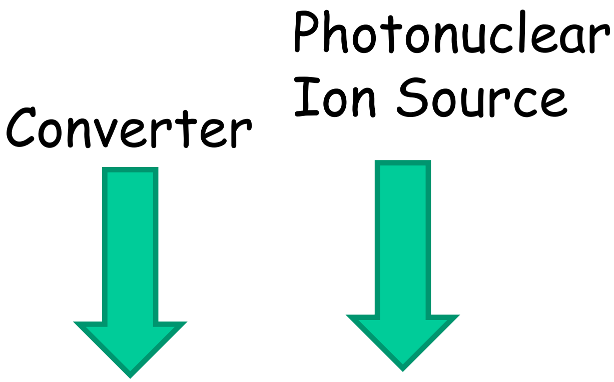
τ= 1.2s



Context: Production of ^{8}Li

1. ^{7}Li (n,γ)
2. Tilted Foil Reactions
3. ^{7}Li (d,p)
4. ISAC Fragmentation
   - $p^{+} \rightarrow Ta \rightarrow {}^{8}Li \rightarrow$ Collinear Polarizer $\rightarrow$ Sample
   - High intensity, highly polarized, keV beams
   - Stopping on the nm scale, e.g. in thin films

Production of ^{8}Li at ARIEL



- $e^{-} \rightarrow \gamma \rightarrow {}^{9}\mathrm{Be} \rightarrow {}^{8}\mathrm{Li} \rightarrow$ Polarizer $\rightarrow$ Sample
- High intensity, highly polarized, keV beams
- Stopping on the nm scale, e.g. in thin films

Present Status (BL2A/ISAC)

5 weeks of ^{8}Li beamtime per year

for the entire programme

~1 week per year developing other isotopes like ^{31}Mg

A Typical Experiment

Variables: Temperature, Implantation Energy, Magnetic Field, …

24 – 48 hours for a single sample

A Typical Beam Period

- Typically a block of ~10 days
- 1 day is spent obtaining tunes which are always a compromise between tuning time and measurement time
- Retuning is almost always necessary after maintenance
- Some 5-10 different experiments are scheduled

Compromises

- Very few control measurements
- Tunes are not fully optimized (especially limiting for systematic depth dependence)
- Very little time for technical development
- Very little time to pursue unexpected behaviour

The Bright Future:
ARIEL will provide (3×) more weeks of ^{8}Li beam

addresses the primary bottleneck in scientific productivity

What This Will Require

- Running the polarizer more
- More systematic semi-automated tuning
- Better diagnostics
- Resources from CMMS, DAQ, Controls, …
- Investment in end-station capabilities

To make the transition to a real user facility

The End