Beta decay of ^{11}Be

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ISOLDE and Neutron Time-of-Flight Experiments Committee Meeting
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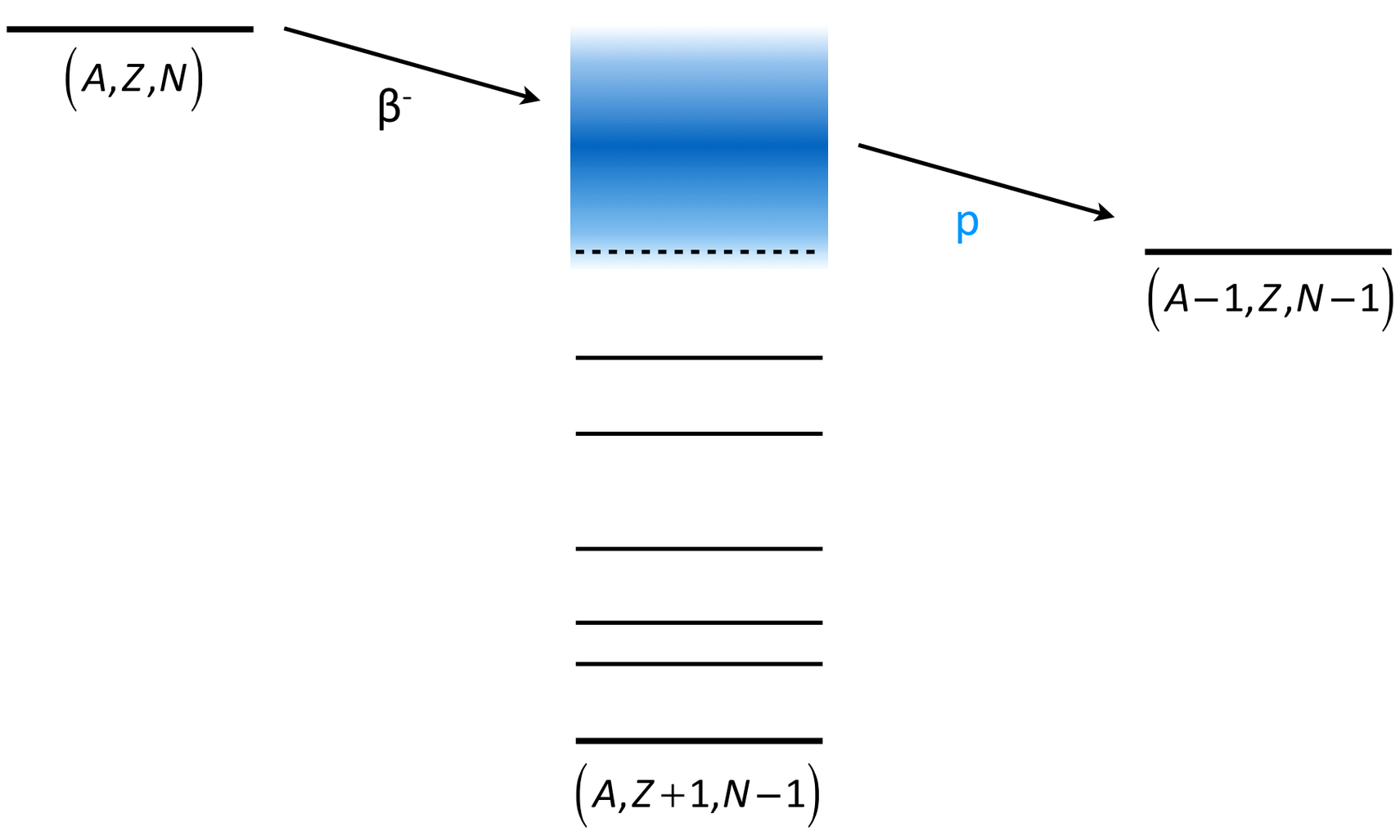
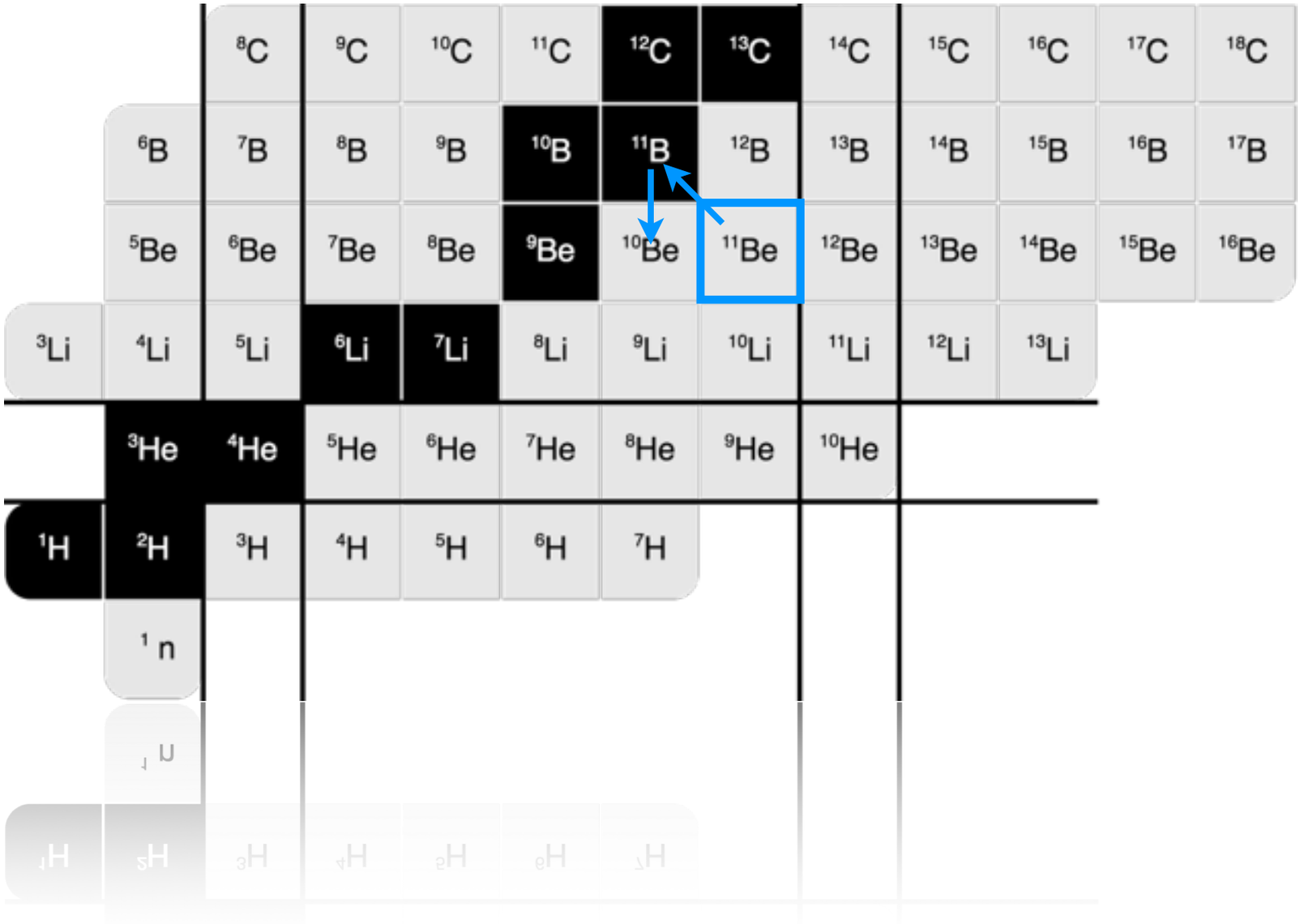
The physics case

- ✓ One-neutron halo nuclei:
  - β^-p decay possible:
    - low S_n ($Q_{\beta p}$=782 keV - S_n)
    - s.p. behaviour of halo nuclei
  - βp decay via continuum states in daughter

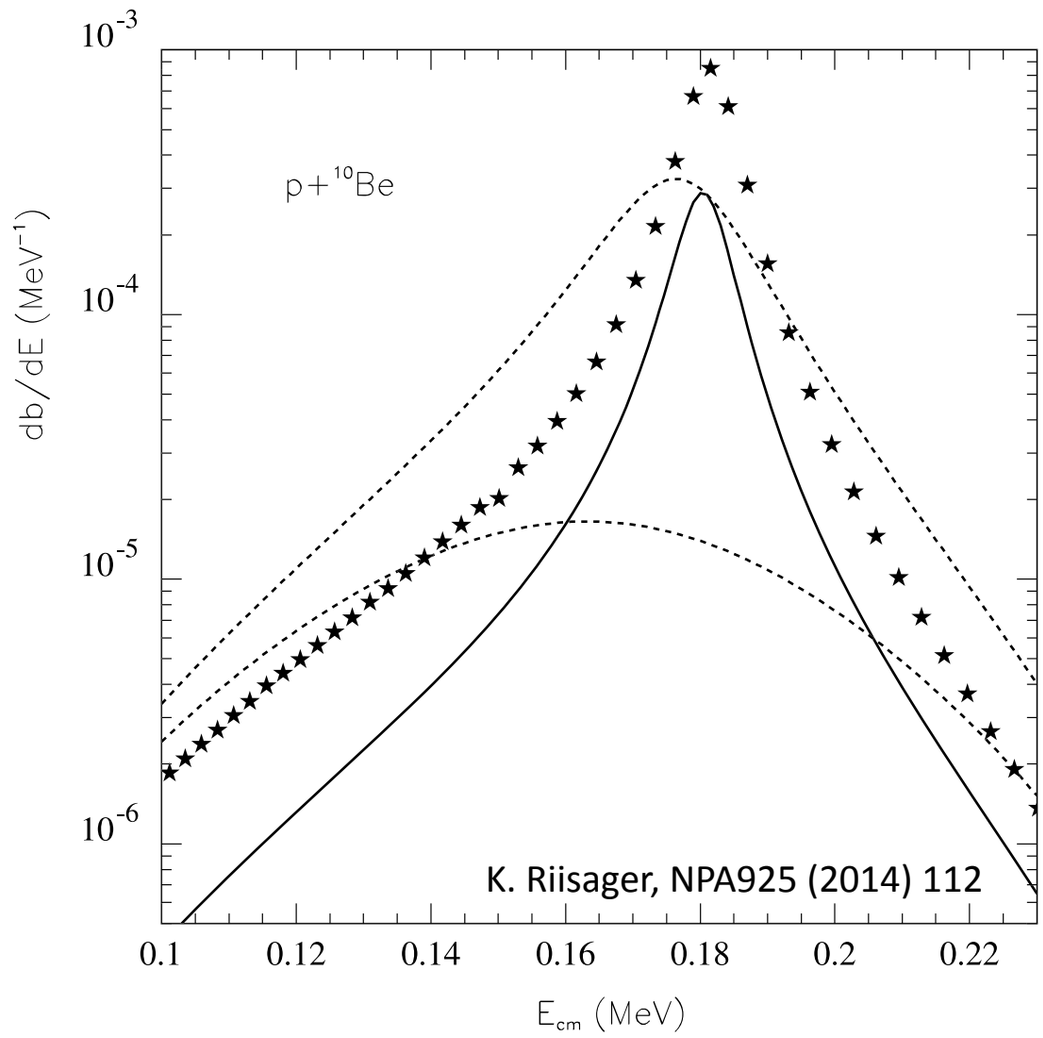


The physics case: βp decay of ^{11}Be



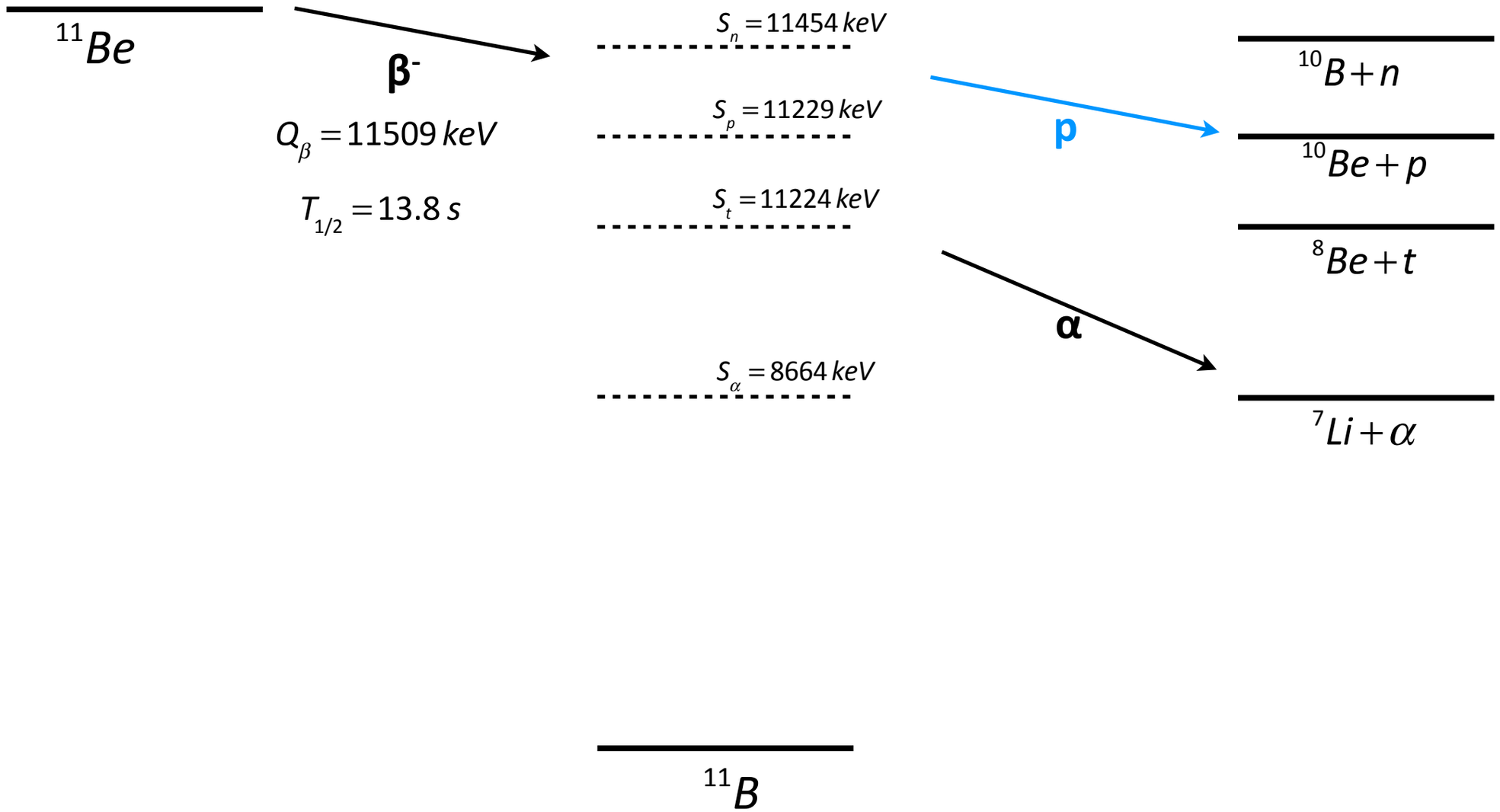
The physics case: βp decay of ^{11}Be

- ✓ Only known nucleus to decay by β^-p
  - several theoretical descriptions available
    - branching ratio ($2.5\cdot10^{-8}$ — 10^{-6}) and energy spectrum (E_{cm} = 150—200 keV)
- ✓ βp decay of ^{11}Be: discretised continuum direct decay (DCDD) formalism
  - initial state = s-wave neutron in potential of inert ^{10}Be core
  - final state = continuum wave function of s-wave proton in the ^{10}Be potential (Coulomb + nuclear)

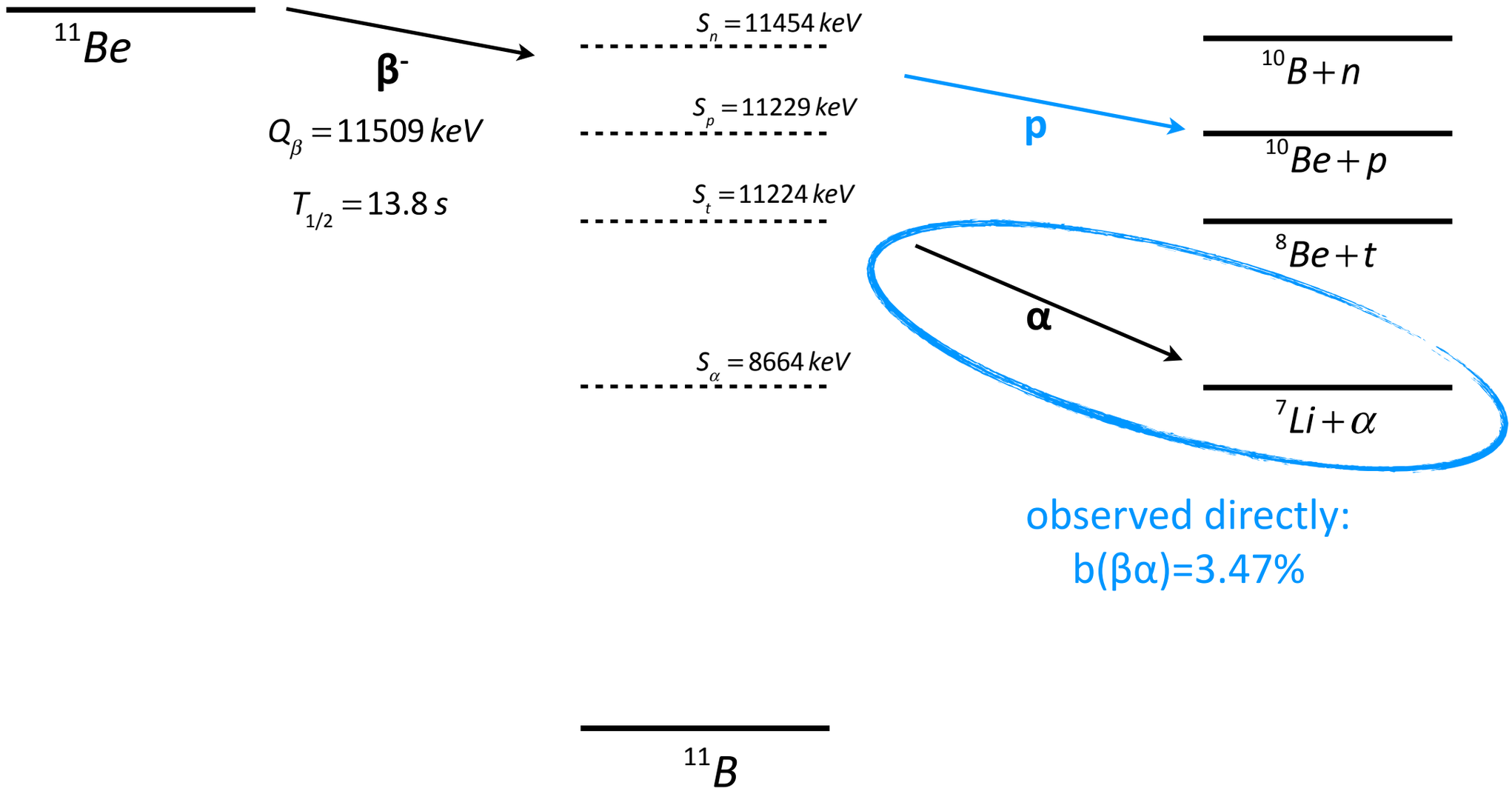


★ DCDD calculations
— R-matrix calculation
- - - α decay of the level included (width 0 and 100 keV)

The physics case: βp decay of ^{11}Be



The physics case: βp decay of ^{11}Be

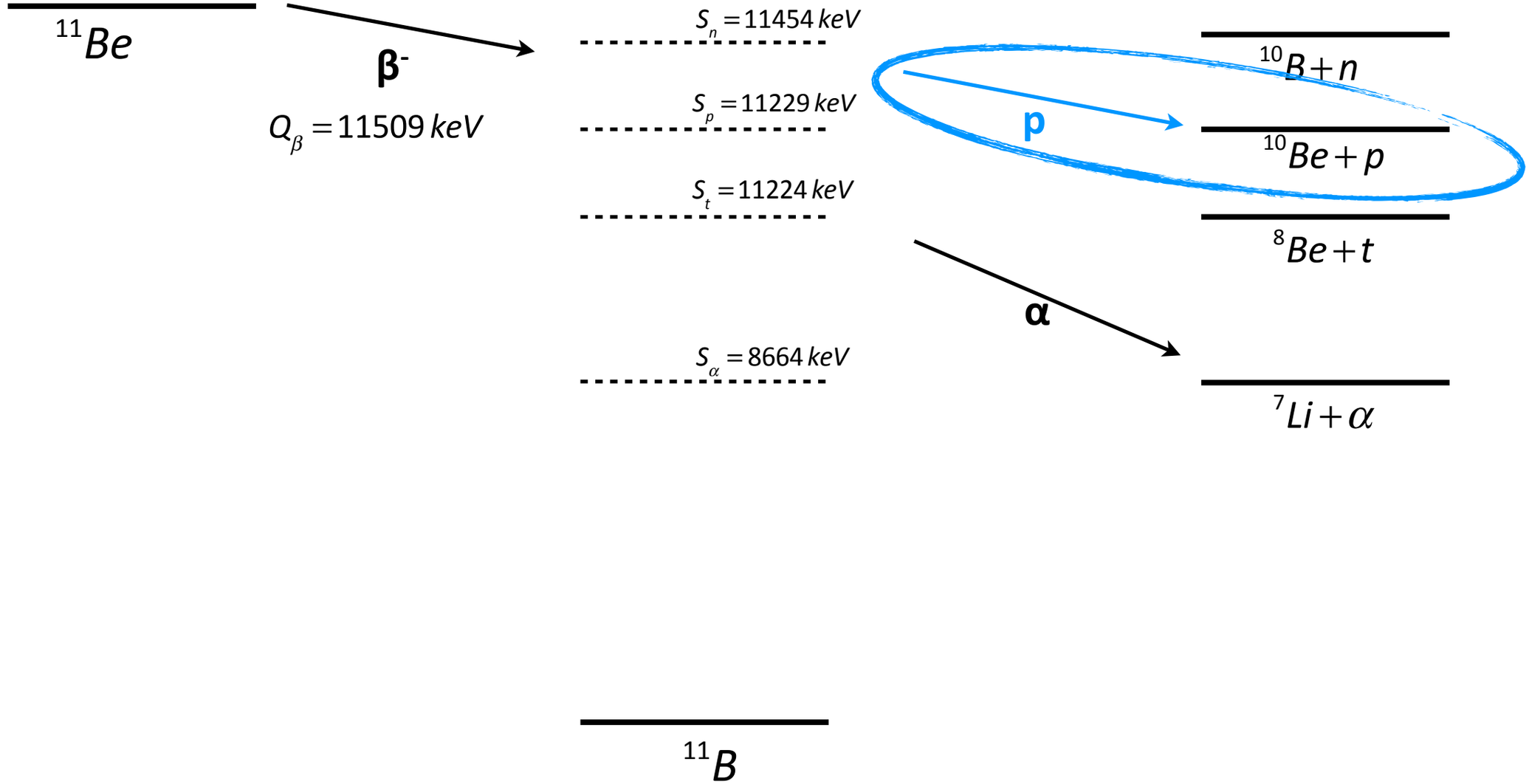


observed directly:
b(βα)=3.47%

J. Büscher, PhD thesis, KU Leuven, 2010

The physics case: βp decay of ^{11}Be

observed indirectly (AMS):
b(βp)=8.3·10^{-6}



K. Riisager et al., Phys. Lett. B 732, 305 (2014)

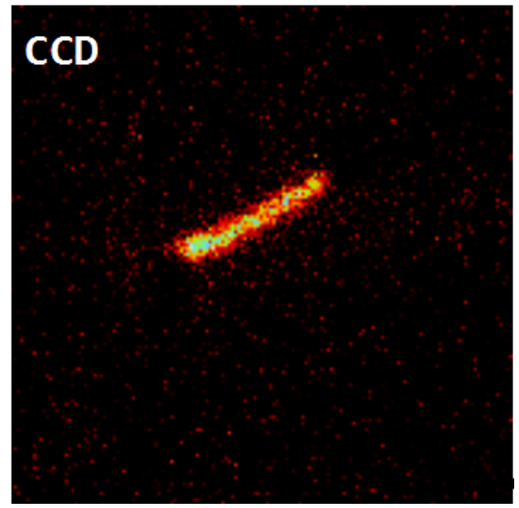
The physics case: βp decay of ^{11}Be

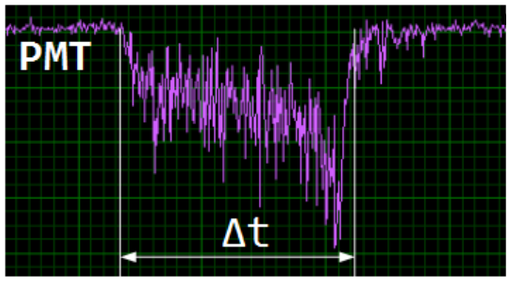
- ✓ Surprisingly large b(βp):
  - decay must proceed through new s.p. resonance in ^{11}B strongly fed in β decay
  - B(GT) ~ 3 (free neutron decay - halo neutron decaying into single-proton state)

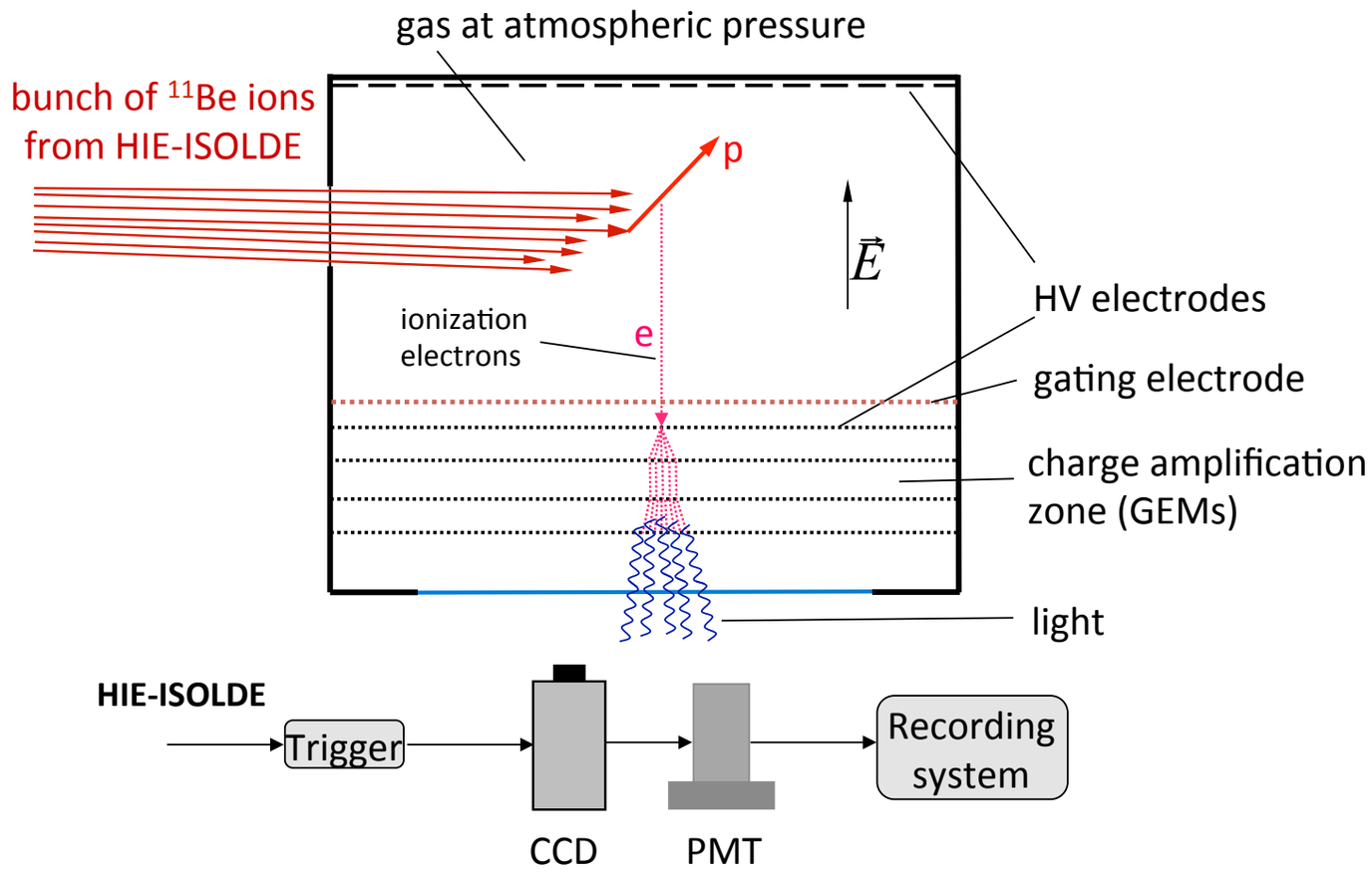
- ✓ **Goal:**
  - **first direct observation of its βp decay**
  - **βp energy spectrum measurement**
    - **GT strength distribution**
    - **test of calculations**

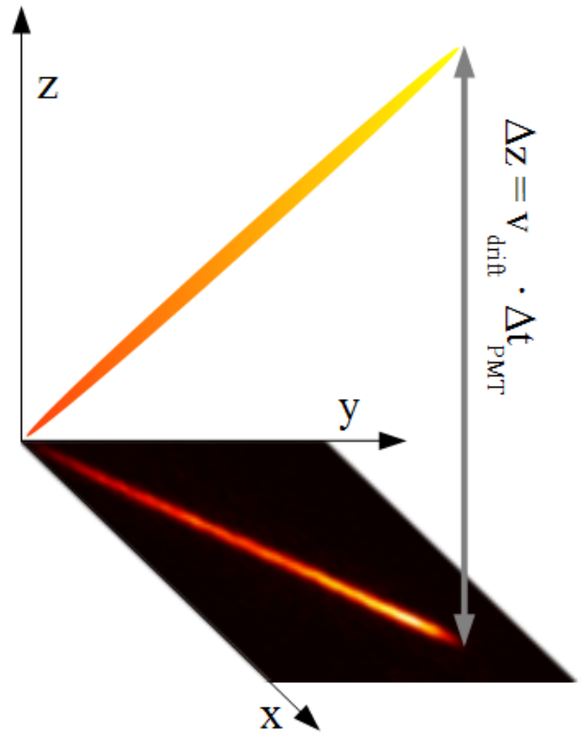
How?

- ✓ ^{11}Be beam @ISOLDE:
  - 1 GeV protons on UCx target + RILIS + GPS + HIE-ISOLDE
  - bunched beam
  - implanted into active volume of OTPC detector





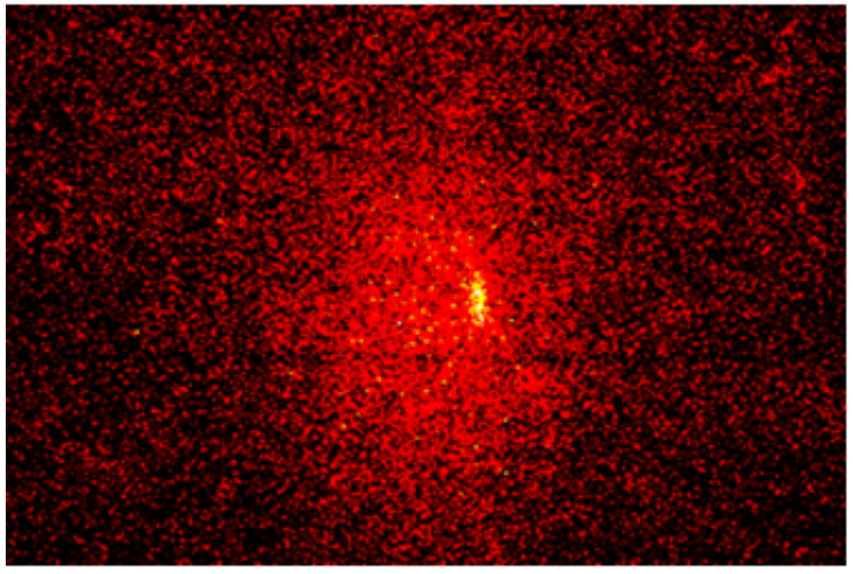


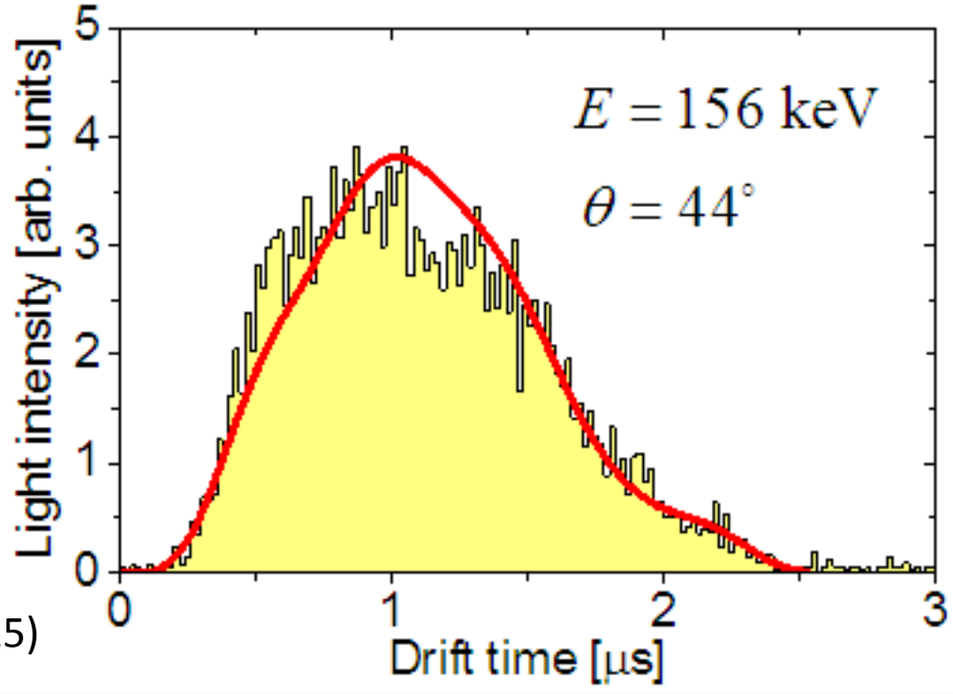


How?

- ✓ ^{11}Be beam @ISOLDE with OTPC:
  - low-density gas (He: ≥98%; N_2: ≤2%) @ atmospheric pressure
  - possible to observe low-energy protons (down to 100 keV)

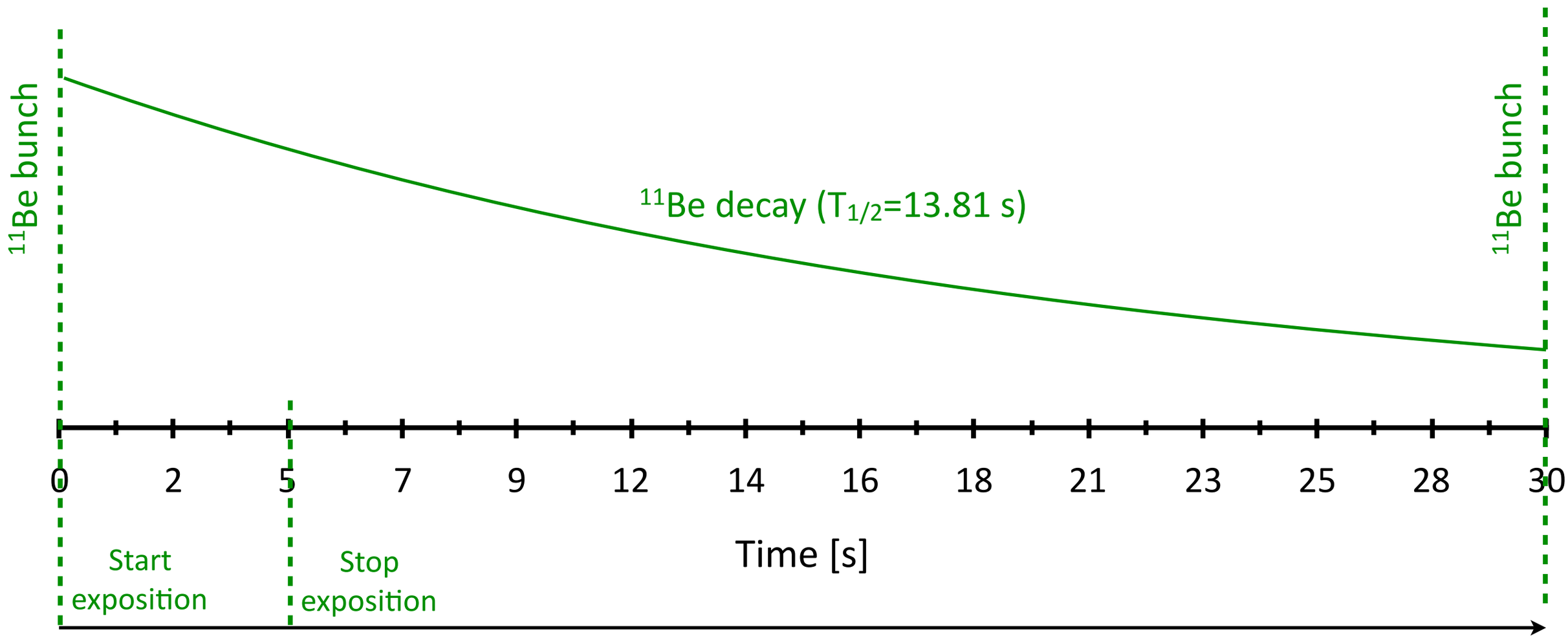
$$^{6}\mathrm{He} \xrightarrow{\beta} {}^{6}Li^{*} \rightarrow \alpha + \mathrm{d}, \qquad E_{\alpha\mathrm{d}} = 156 \text{ keV}$$





M. Pfützner et al., Phys. Rev. C 92, 014316 (2015)

How?


^{11}Be bunch
^{11}Be decay ($T_{1/2}$=13.81 s)
^{11}Be bunch
0
2
5
7
9
12
14
16
18
21
23
25
28
30
Start exposition
Stop exposition
Time [s]

Beamtime estimate and request

✓ ^{11}Be yield:

- **~10^4 ^{11}Be ions/s** (achieved a few 10^5 ions/s at REX-ISOLDE with a 1.9 μA proton beam, UCx target, RILIS ion source and GPS separator)
- **1 bunch/30 s**

✓ βp rate: ~**300 βp in 6 days** of beam-time

- confirmation of the branching ratio value (normalising the number of βp to the number of βα)
- measurement of the βp energy spectrum
- βα branching to be remeasured (elsewhere) with the same set-up

Requested shifts:

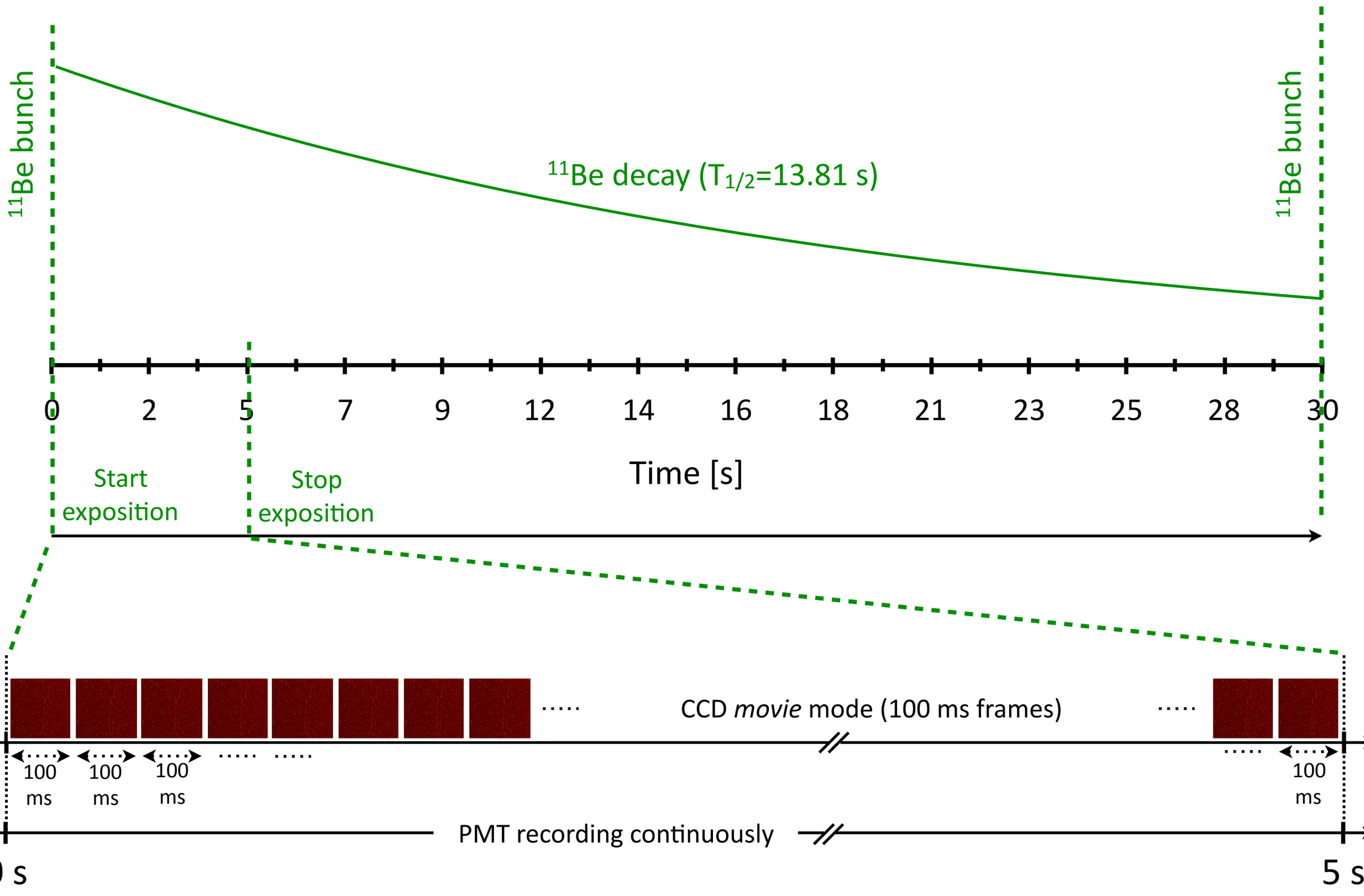
6 days **(18 shifts)** of **^{11}Be** beam at **7.0 A·MeV** at the HIE-ISOLDE second beamline

one day **(3 shifts)** for beam tuning

Total: 7 days (21 shifts)

August 2012: OTPC @ REX-ISOLDE

How?


^{11}Be bunch
^{11}Be decay ($T_{1/2}$=13.81 s)
^{11}Be bunch
0
2
5
7
9
12
14
16
18
21
23
25
28
30
Time [s]
Start exposition
Stop exposition
CCD *movie* mode (100 ms frames)
100 ms
100 ms
100 ms
100 ms
PMT recording continuously
0 s
5 s