Detecting and measuring the β-delayed α and γ decay of ^{20}Na

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Things you won’t learn from this talk

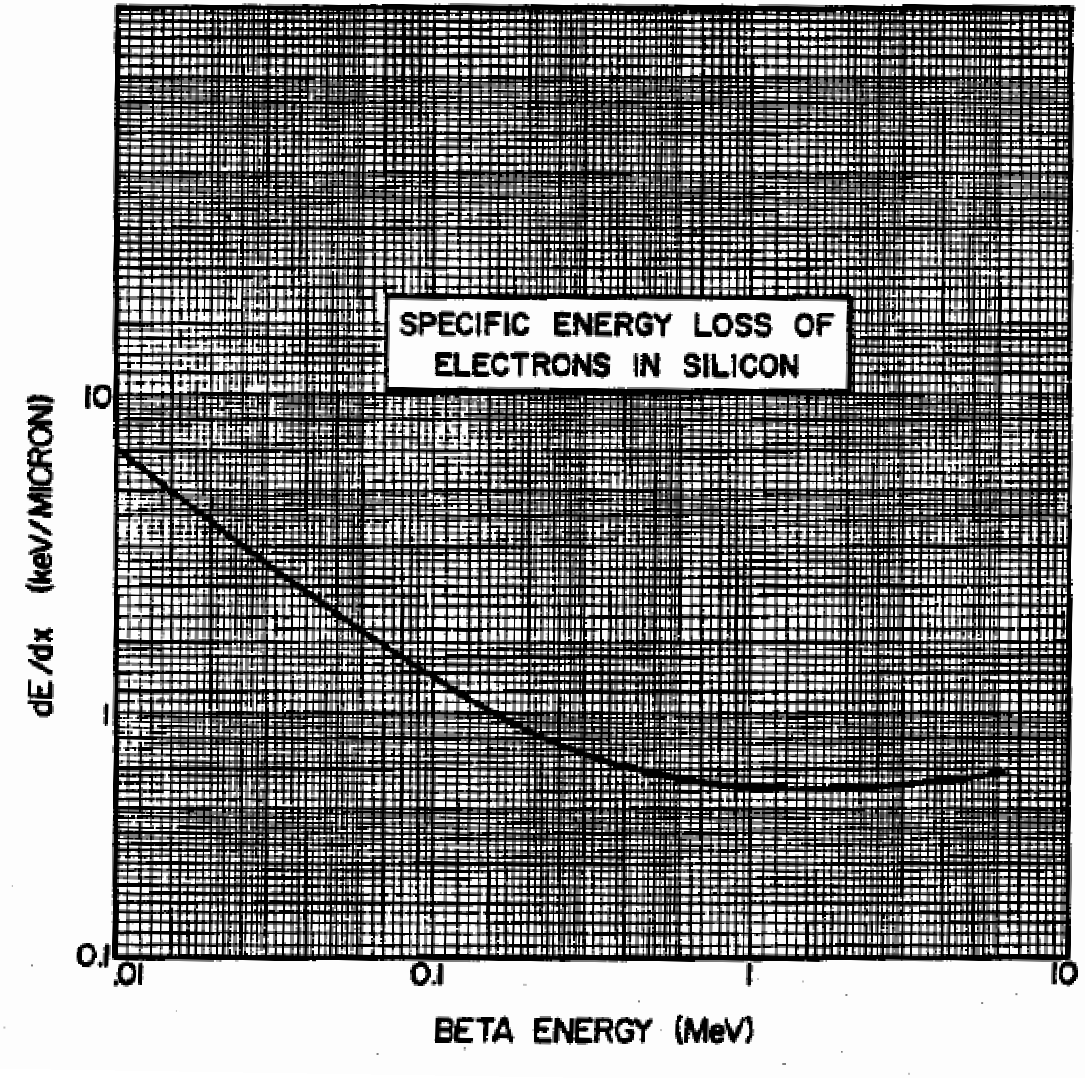
- How we produce the ^{20}Na and separate it using MARS (Brian/Alex will cover/have covered this)
- How Si and HPGe detectors work (Ellen will cover this)

So accept that ^{20}Na makes it to our detector system with about 20 MeV/nucleon and that the detectors produce a signal the integrated current of which is proportional to the energy lost in the detector

Background: Charged particle interaction with matter

- Charged particles lose energy in matter through interactions with the electrons clouds and nuclei of the material being traversed
- For this experiment we are concerned with the rate of energy loss of betas, alphas and heavy ions in matter
  - Betas: lose energy in collisions with atomic electrons of the target material
  - Alphas and heavy ions: lose energy in collisions with atomic electrons and also through much shorter ranged nuclear interactions (only at high energy and high target density)

Energy loss of electrons in Si



Energy loss of heavy ions in matter

For non-relativistic HI:

$$-\frac{dE}{dx} \propto \frac{z^2}{v^2} = \frac{z^2 M}{2E}$$

Energy loss also depends on the z and density of the material.

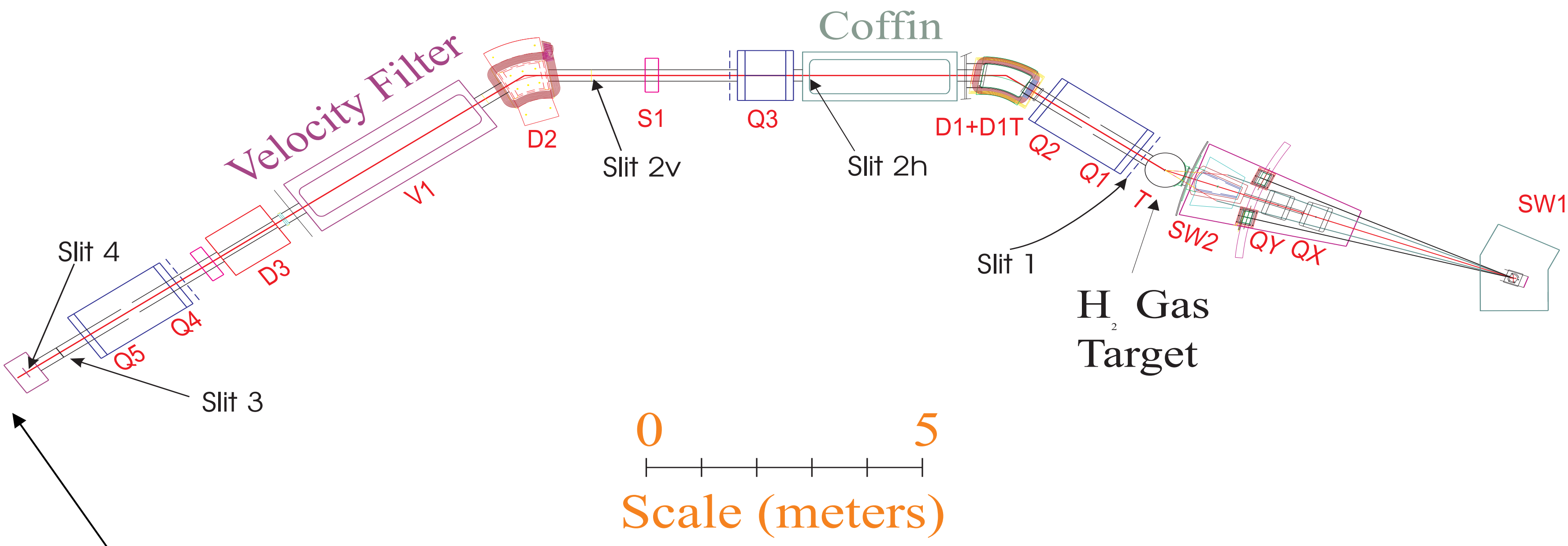
For 25 MeV/nucleon ^{20}Na:

Range in Al: 562um

Range in Si: 618um

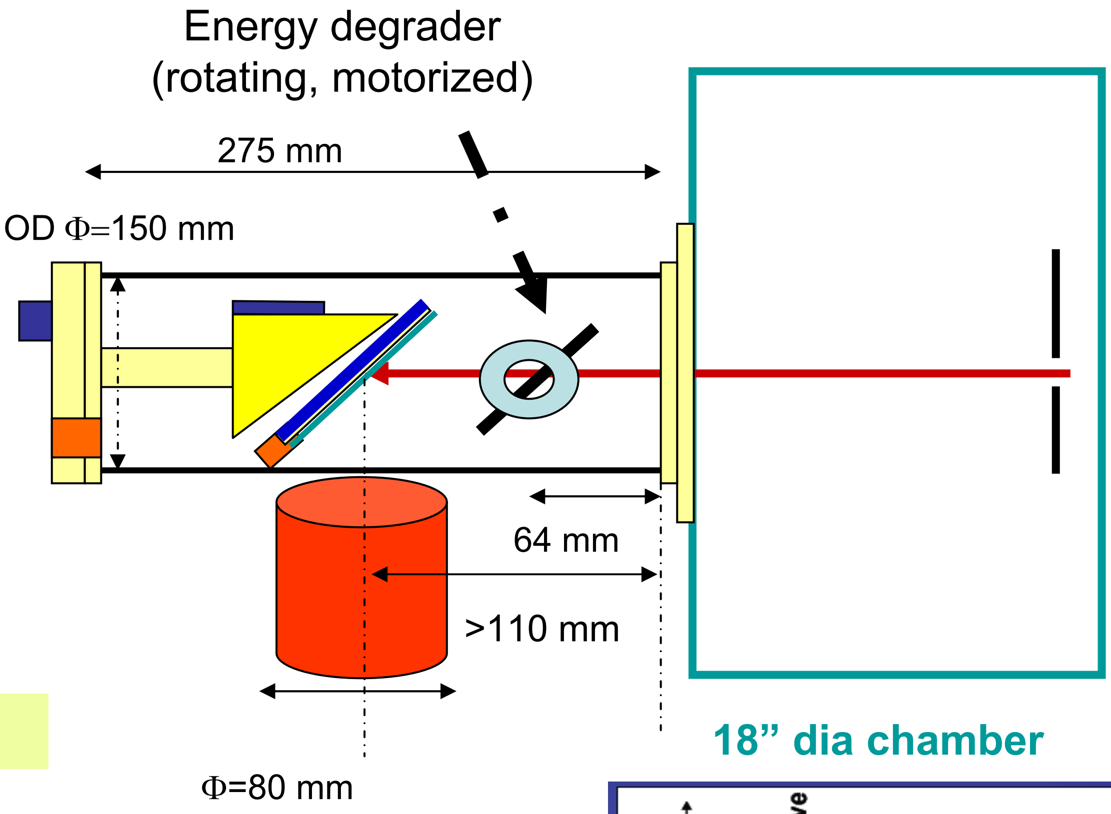
MARS beamline

Momentum Achromat Recoil Separator



We are here

Experimental setup

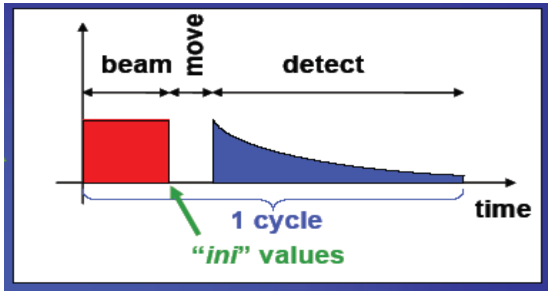


$$E=E_{\alpha}+kE_{recoil}+\langle\Delta E_{\beta}\rangle$$

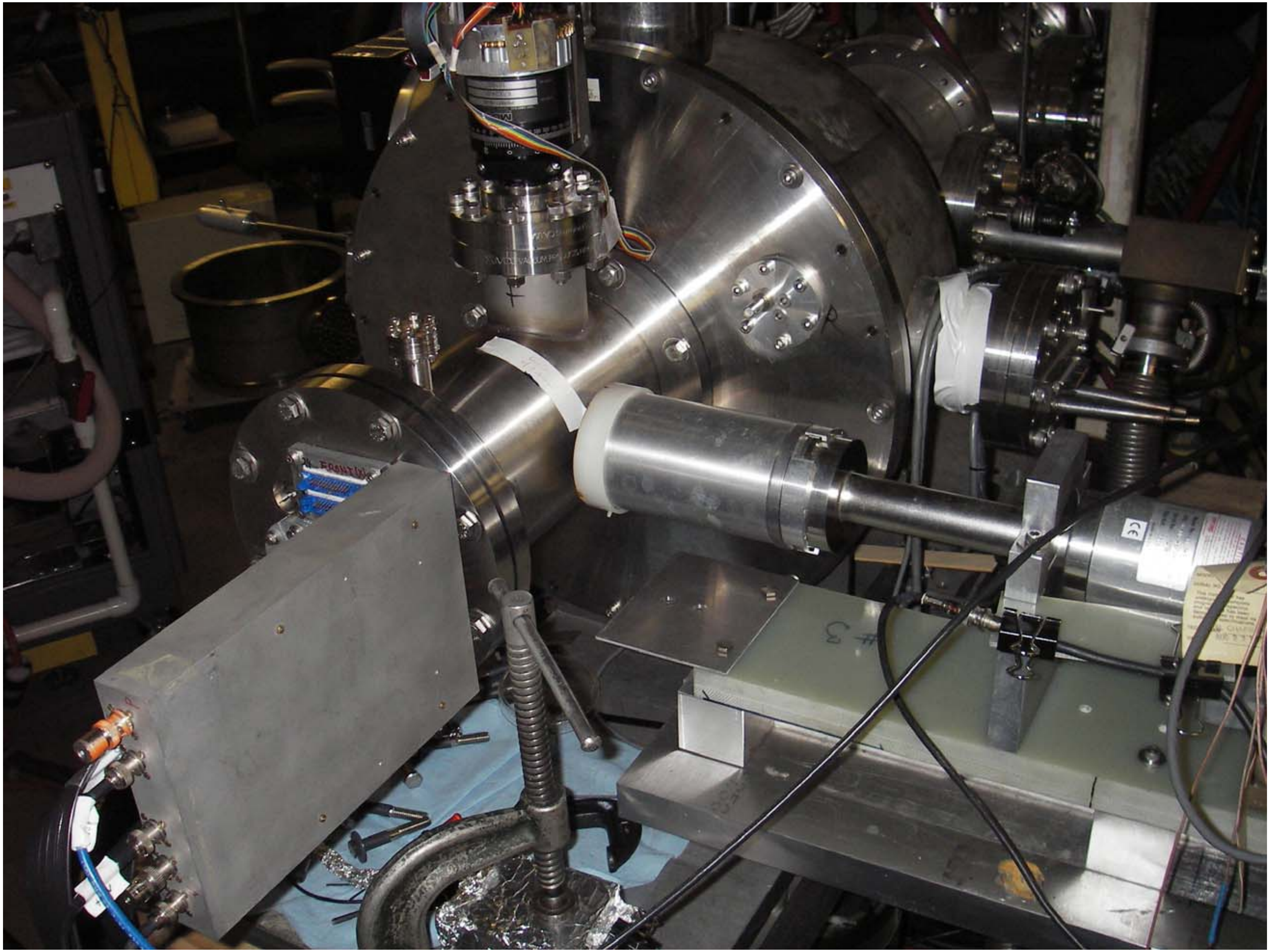
α-detector – v. thin Si strip 65 μm

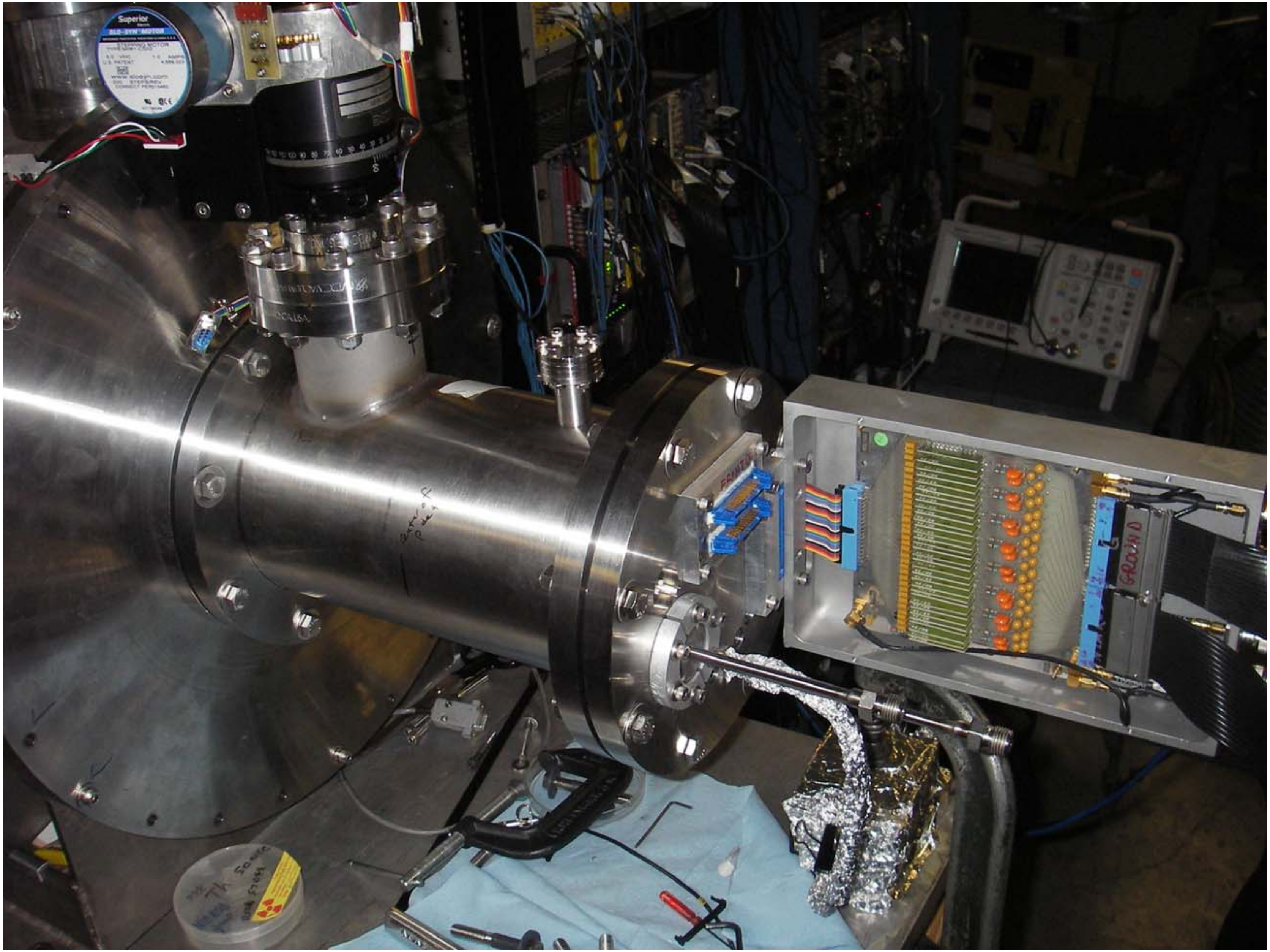
β-detector – thick Si det 1 mm

γ-detector – HPGe 70% effic



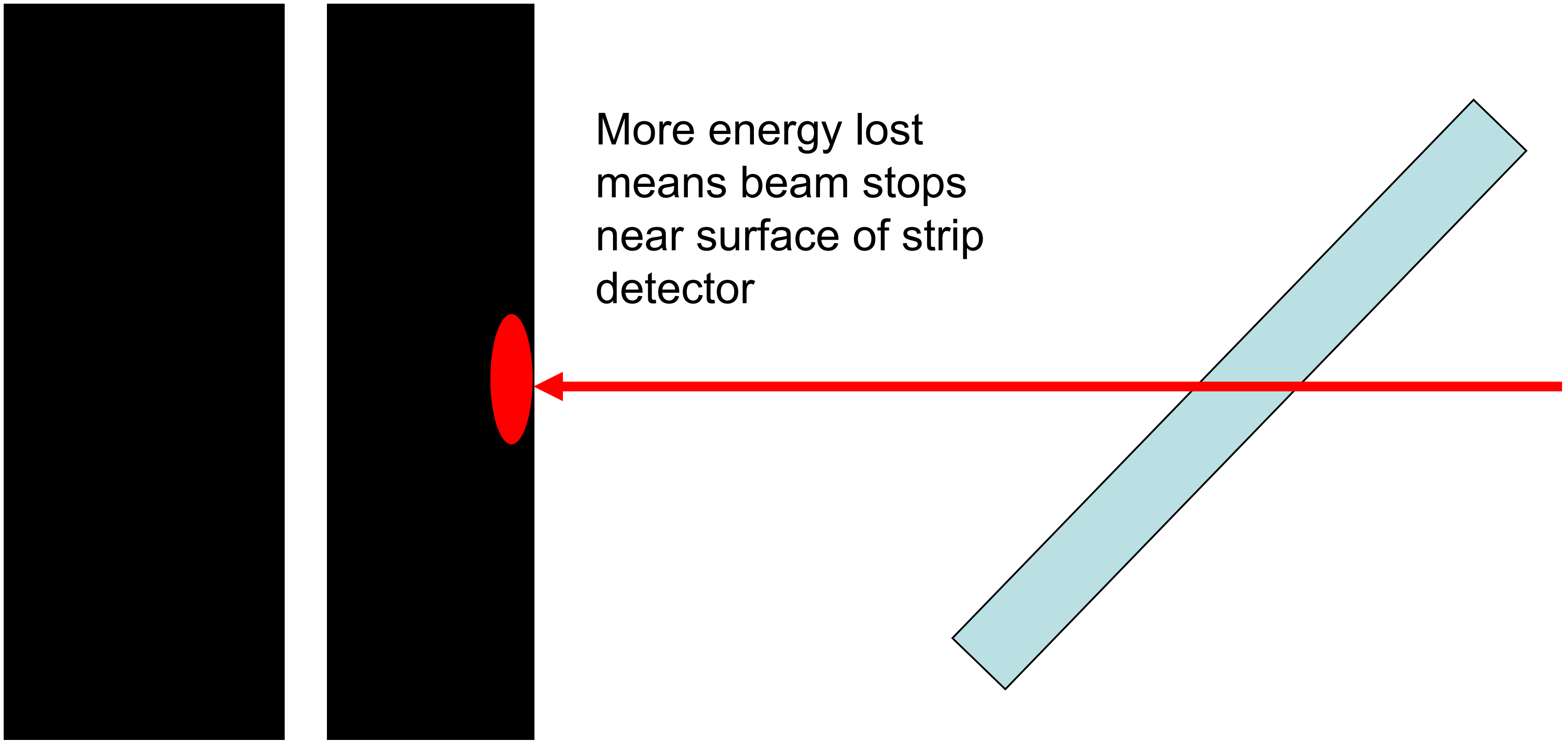
Pulsed beam




Superior Electric
SLO-SYN MOTOR
GROUND

Determining degrader angle

Step one: increase degrader angle until beam stops in degrader



More energy lost means beam stops near surface of strip detector

B detector
(1mm thick)

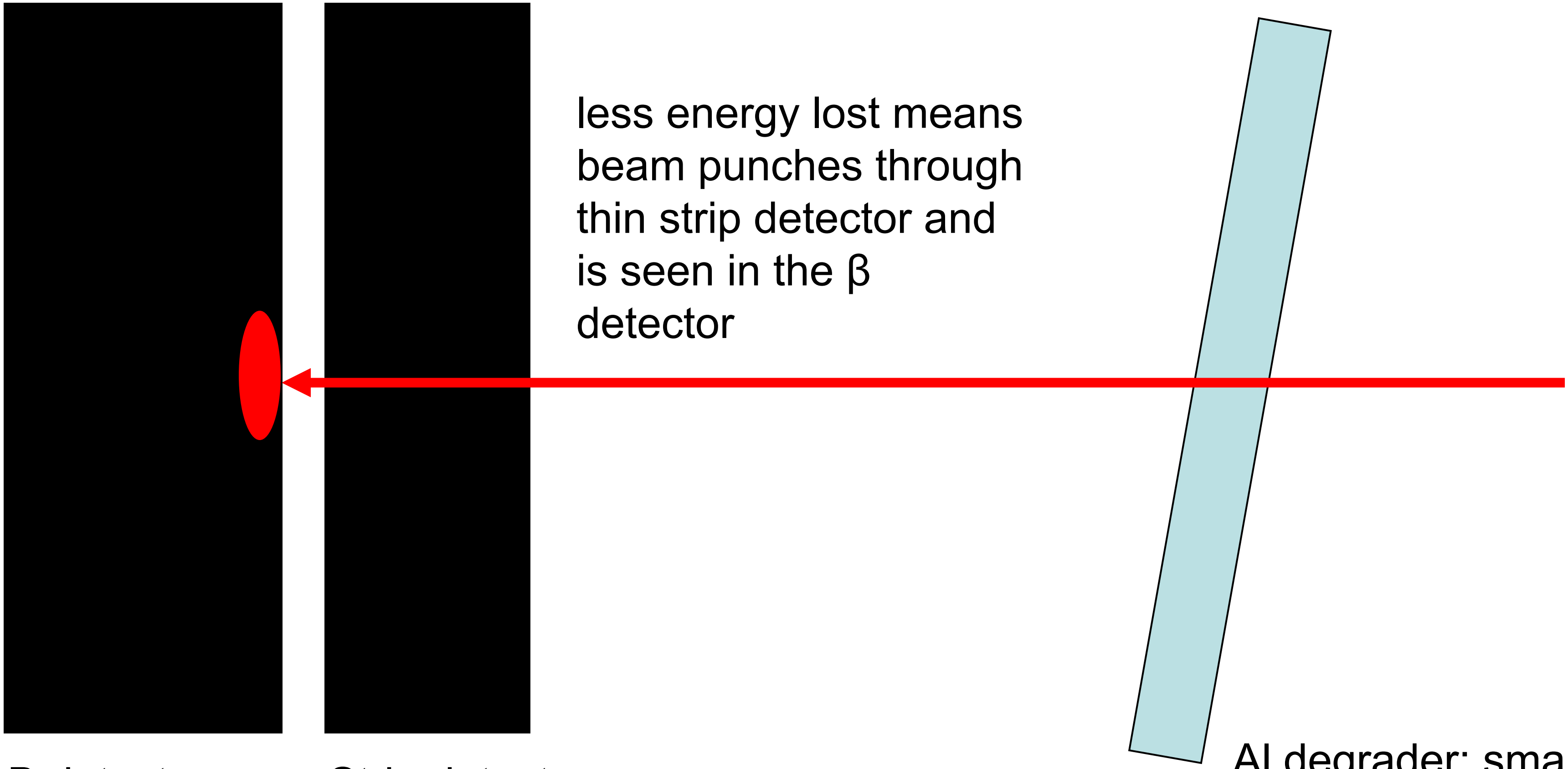
Strip detector
(65 um thick)

Al degrader: large angle means HI beam sees thicker degrader and thus loses more energy

(not even remotely to scale)

Determining degrader angle

Step two: decrease degrader angle until beam penetrates strip detector and is implanted into β detector



less energy lost means beam punches through thin strip detector and is seen in the β detector

B detector
(1mm thick)

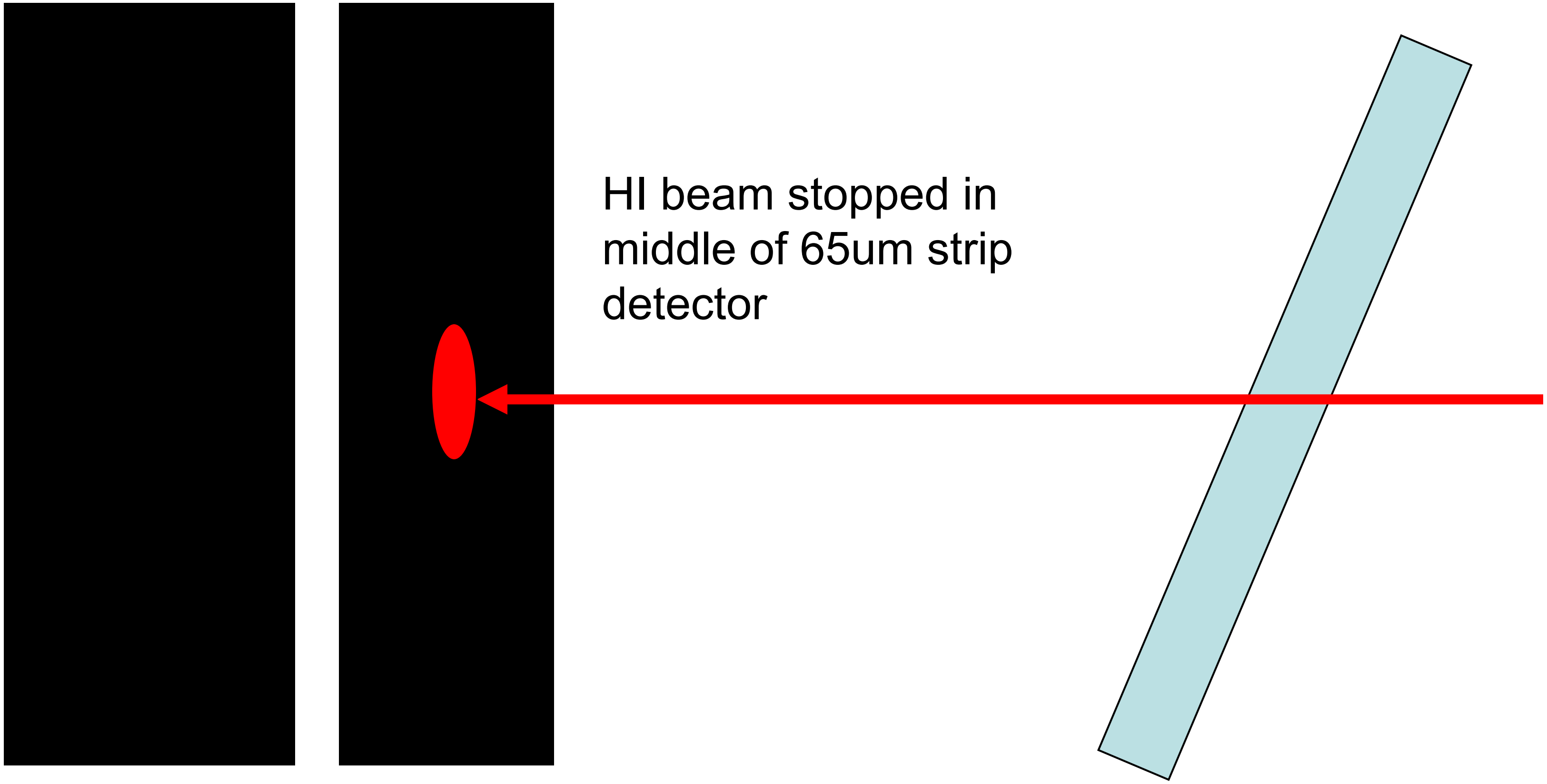
Strip detector
(65 um thick)

Al degrader: smaller angle means HI beam sees less degrader and thus loses less energy

(not even remotely to scale)

Determining degrader angle

Step three: set degrader angle in between previous two values



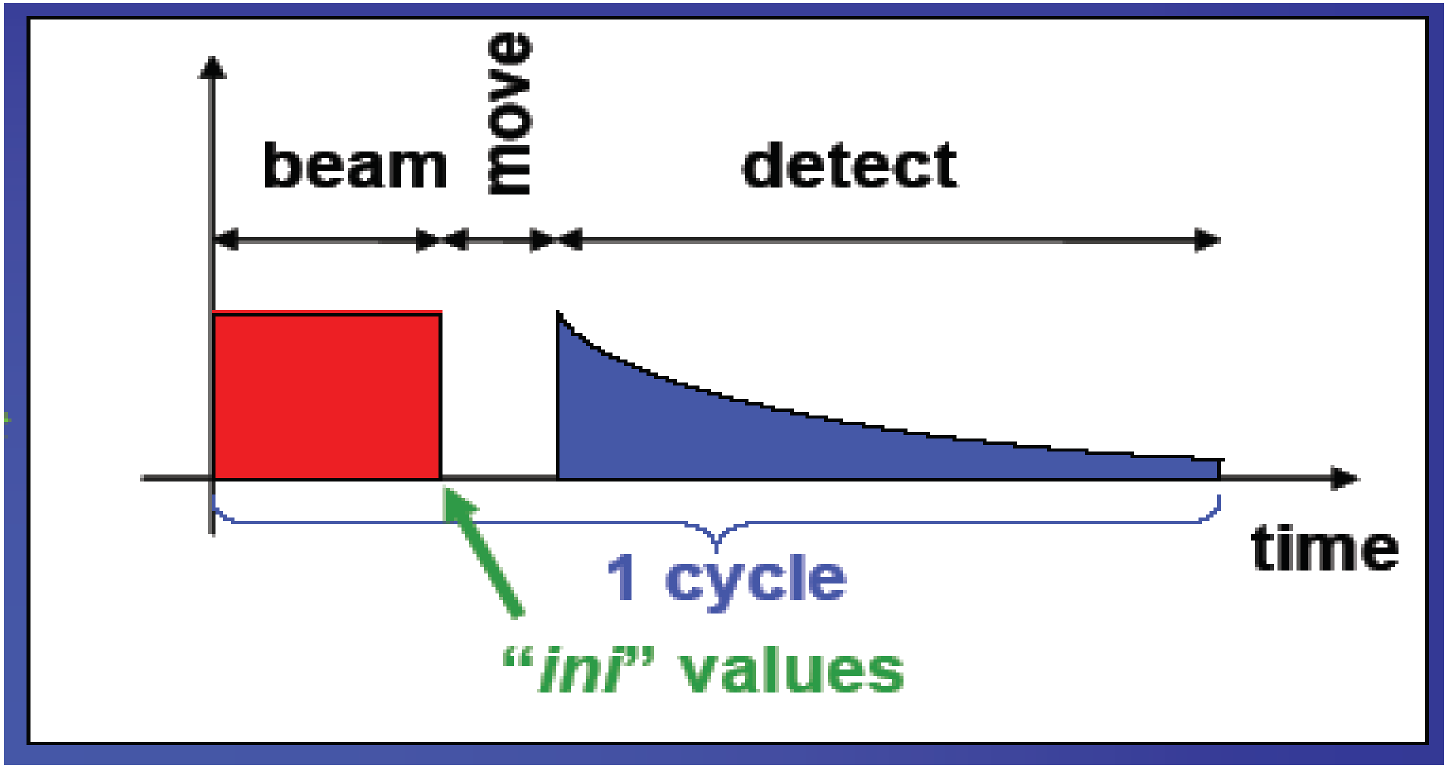
HI beam stopped in middle of 65um strip detector

B detector (1mm thick)

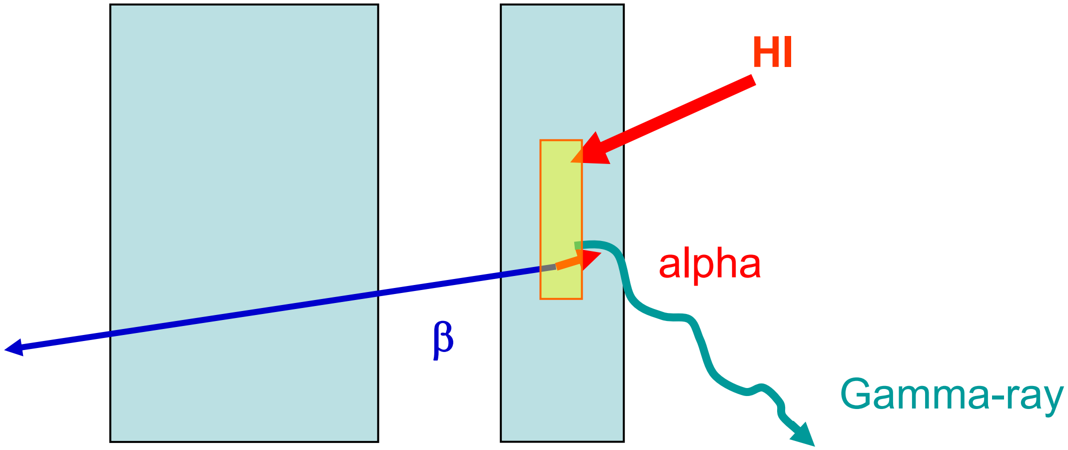
Strip detector (65 um thick)

(not even remotely to scale)

Beam pulsing



Decay of implanted ^{20}Na



HI

alpha

β

Gamma-ray

Signal=ΔE_β

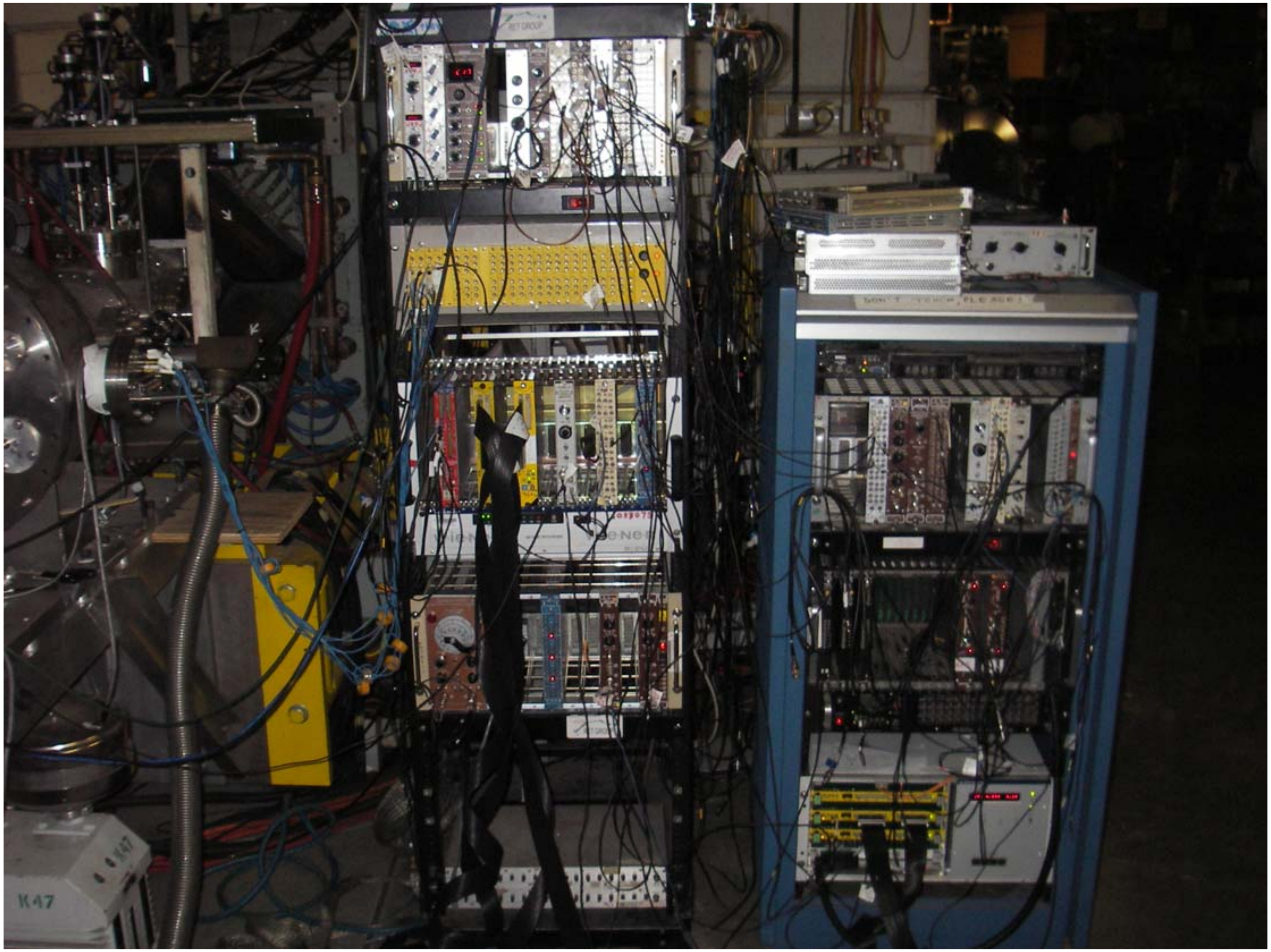
Signal=$E_\alpha + \Delta E_\beta$

“β-α mode”

measure simultaneously:

- β-α and
- β–γ coinc.

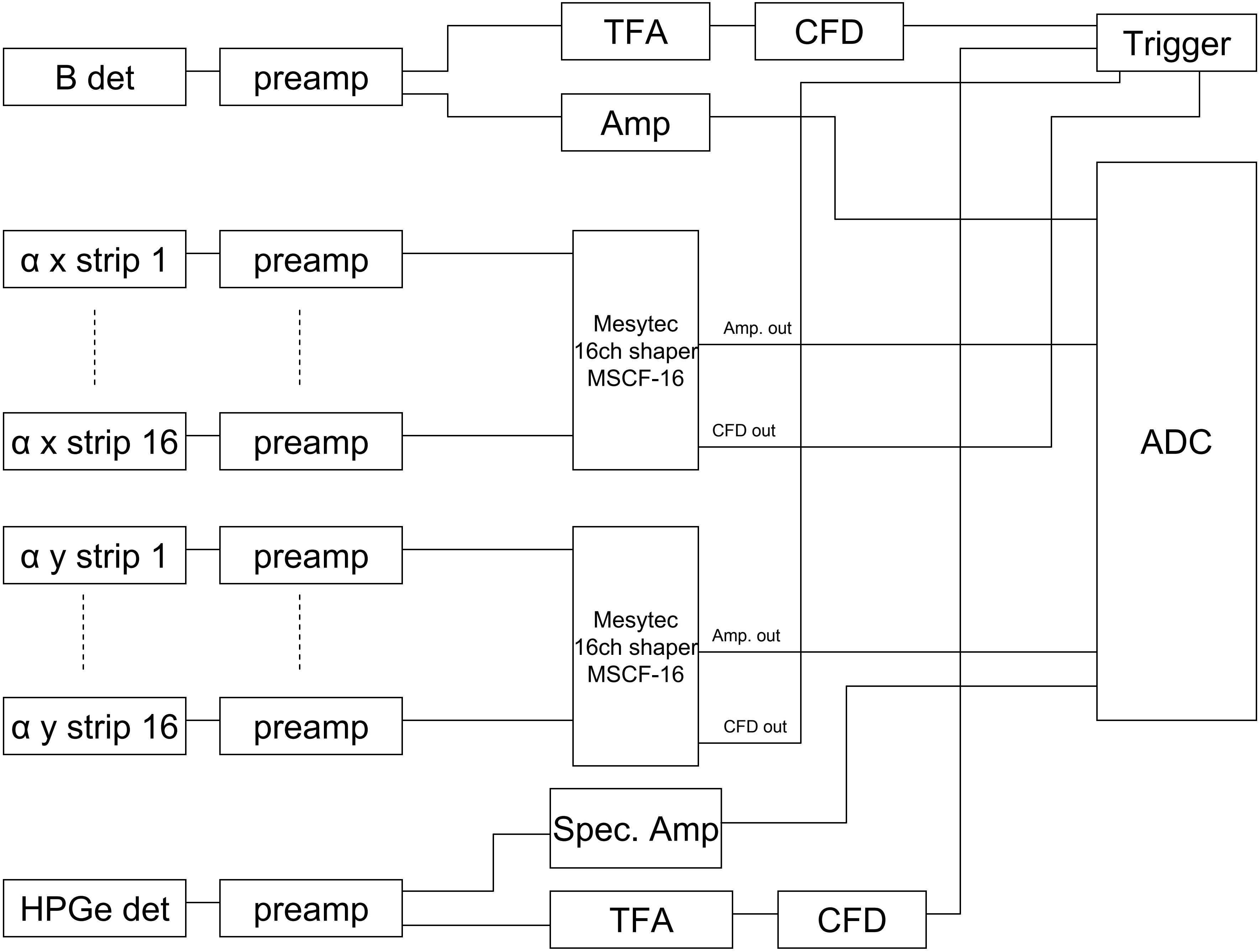
Signal processing and data recording



Components

(there will be a quiz at the end)

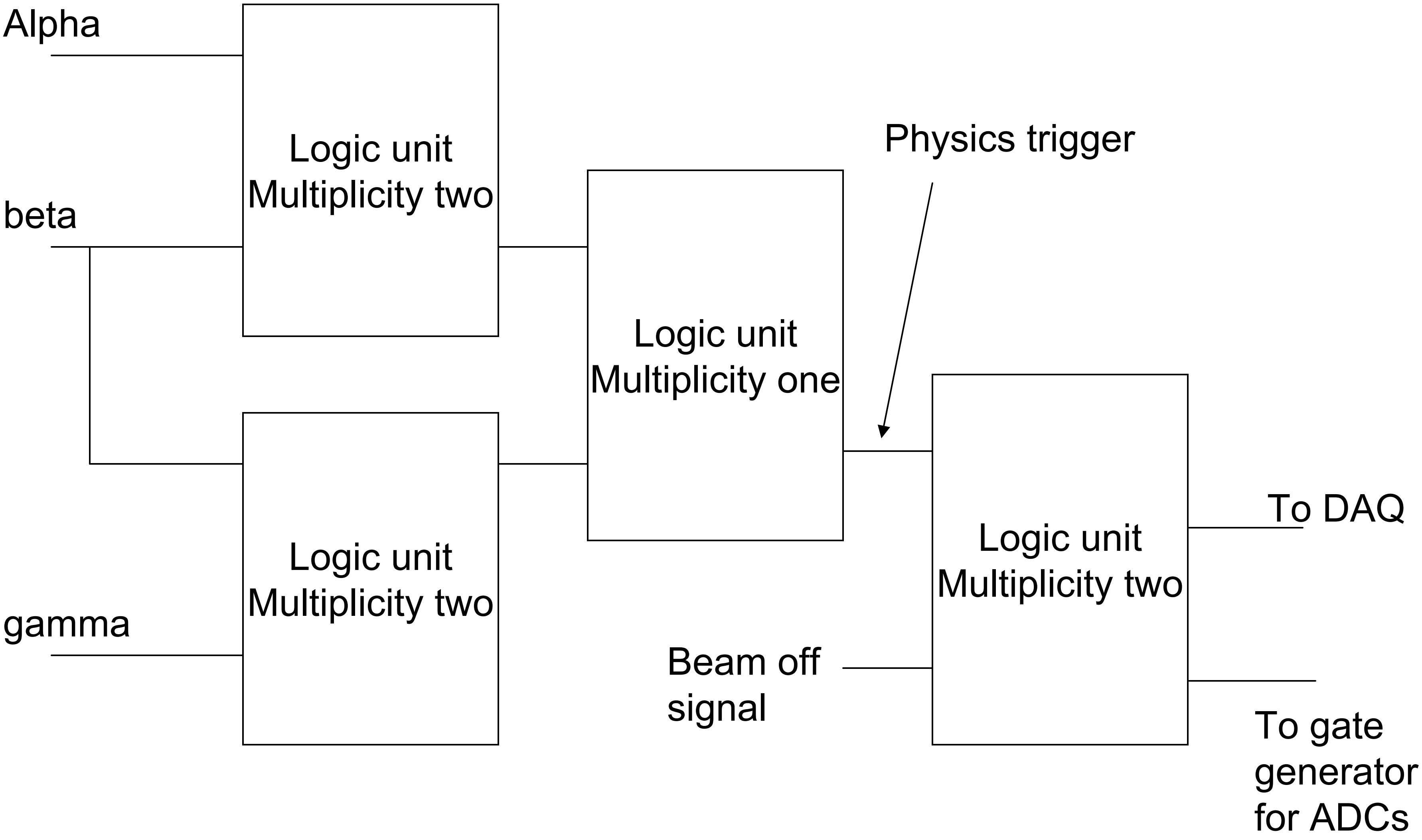
- Preamplifier:
  - Fast rising output. Amplitude is proportional to charge collected from detector
- Amplifier/shaper:
  - Amplifies pulse from preamp. Output is gaussian in shape and the amplitude is proportional to the amplitude of the preamp output
- Timing filter amp (TFA)
  - Fast amplifier used for timing. Leading edge is used to trigger the CFD
- Constant fraction discriminator (CFD)
  - Gives logic signal when leading edge has reached a predetermined fraction of the total amplitude (around 10-15%)
- Analog to digital converter (ADC)
  - Converts the pulse amplitude into a number which can then be stored on the computer


B det
preamp
TFA
CFD
Trigger
Amp
ADC
α x strip 1
preamp
Mesytec 16ch shaper MSCF-16
Amp. out
CFD out
α x strip 16
preamp
α y strip 1
preamp
Mesytec 16ch shaper MSCF-16
Amp. out
CFD out
α y strip 16
preamp
Spec. Amp
HPGe det
preamp
TFA
CFD

Trigger

- Need beta-alpha coninc.
- Need beta-gamma coninc.

To achieve this use four input logic unit that has a multiplicity level that can be set from one to four, and put in CFD timing outputs with appropriate delays added to take into account the response time of the different detectors/electronics


Alpha
beta
gamma
Logic unit
Multiplicity two
Logic unit
Multiplicity two
Logic unit
Multiplicity one
Physics trigger
Logic unit
Multiplicity two
Beam off
signal
To DAQ
To gate
generator
for ADCs