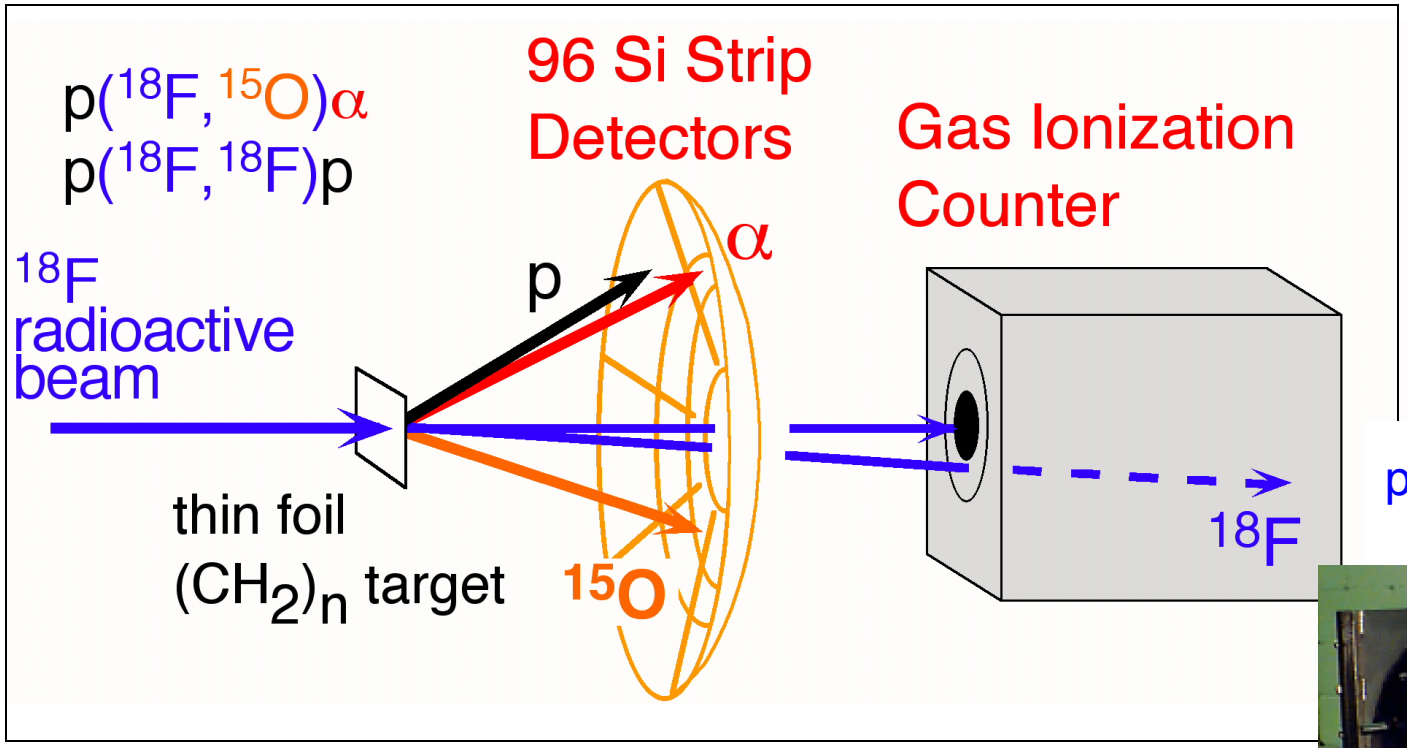
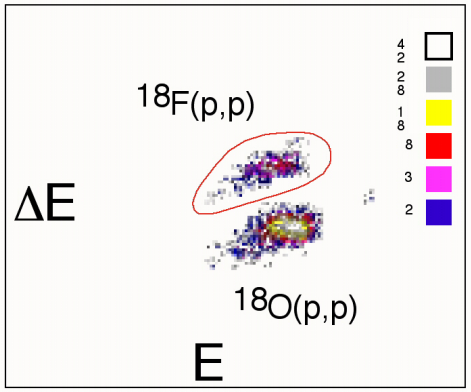
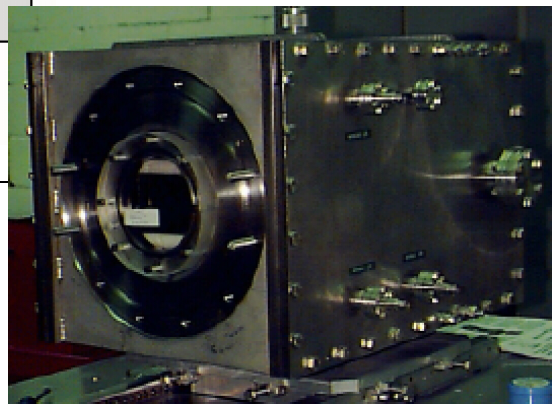
p-induced reaction measurements



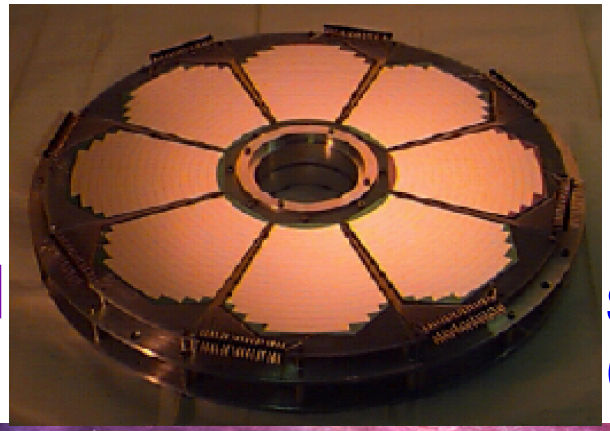


particle identification



dealing with low purity

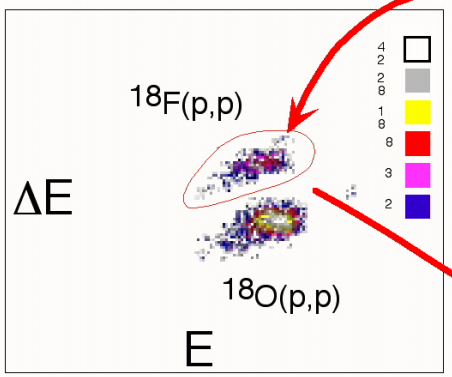
make kinematically complete [coincidence] measurements



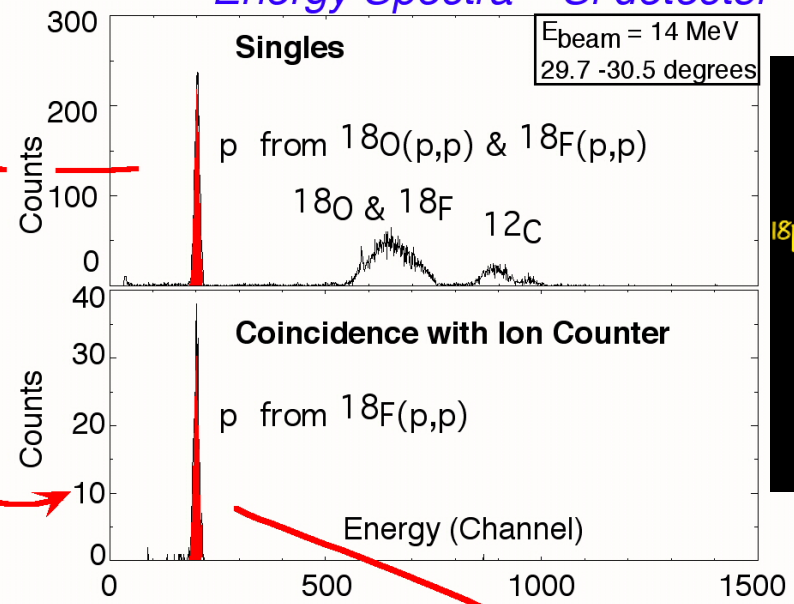
Silicon Detector Array (SIDAR)

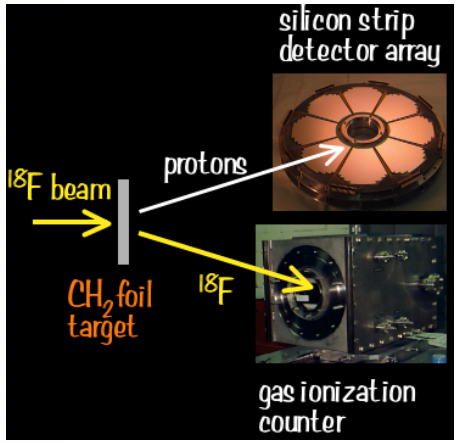
p-induced reaction measurements

Gas Ionization Counter – Particle Identification

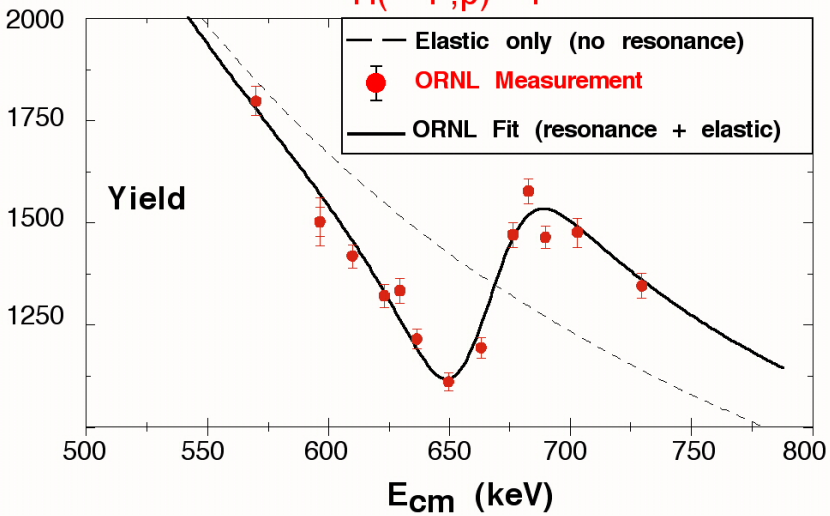


Energy Spectra – Si detector



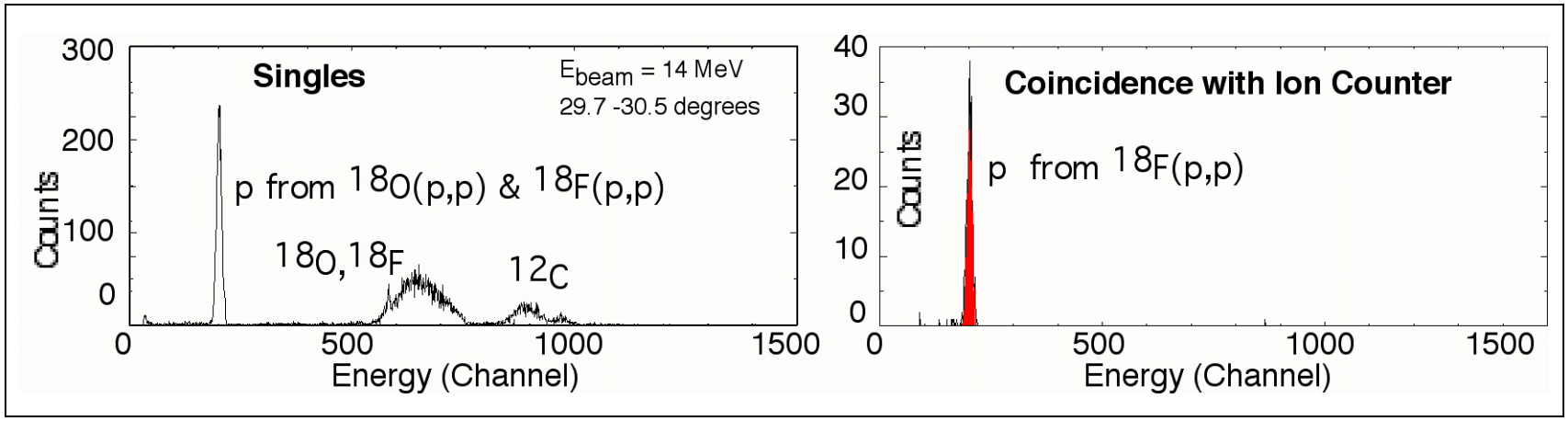


^{1}H(^{18}F,p)^{18}F



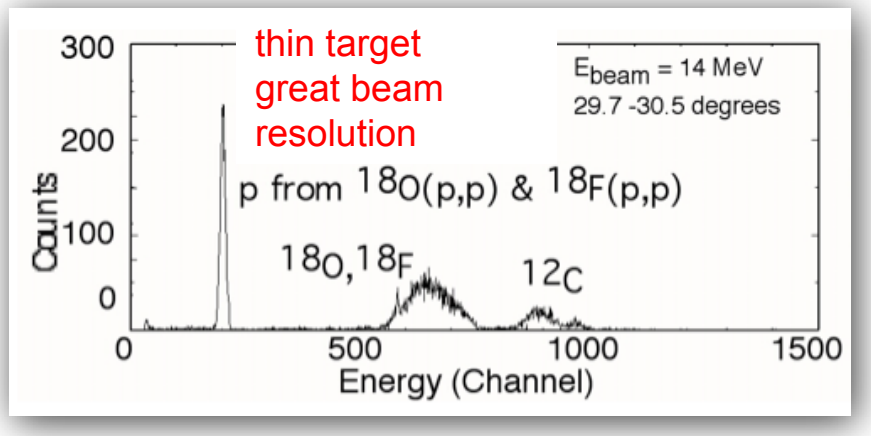
- Nearly background-free yields
- Use of impure beams possible
- Measure low cross section reactions with low RIB intensities in **fine energy steps**

p-induced reaction measurements



- Utilize Kinematically complete experiments whenever possible
  - greatly reduce backgrounds
  - reduce ambiguities in data
- Such techniques enable measurements beyond “first generation” radioactive beams experiments …

p-induced reaction measurements



dE_{beam} small, dE_{tgt} small

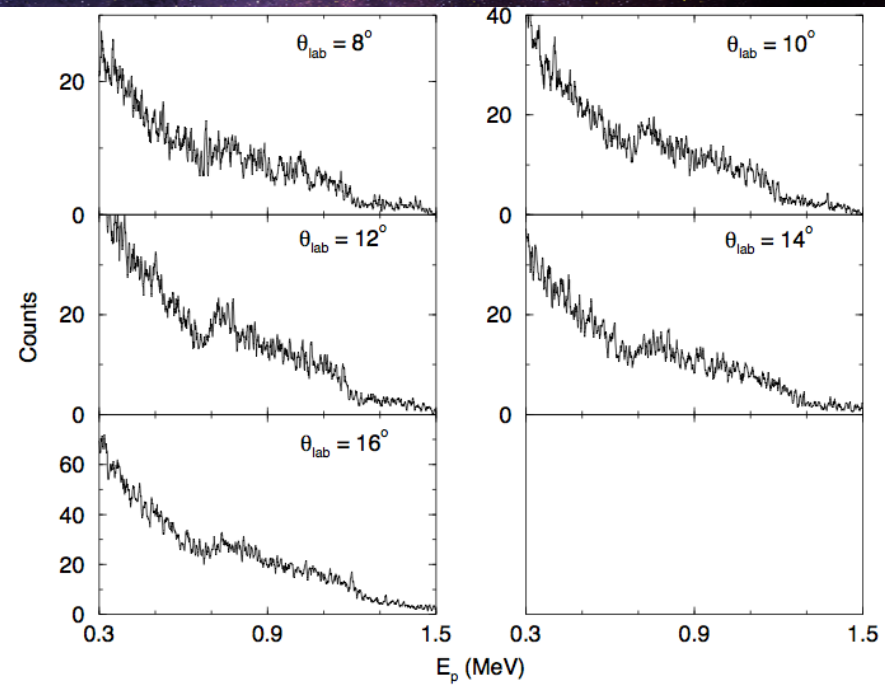


Figure 1. Proton energy spectra from the $^1H(^{18}F,p)^{18}F$ reaction.

dE_{beam} large, dE_{tgt} small **thin**

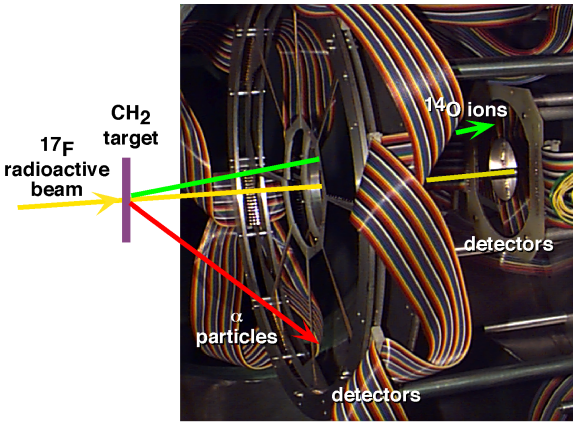
dE_{beam} small, dE_{tgt} large thick

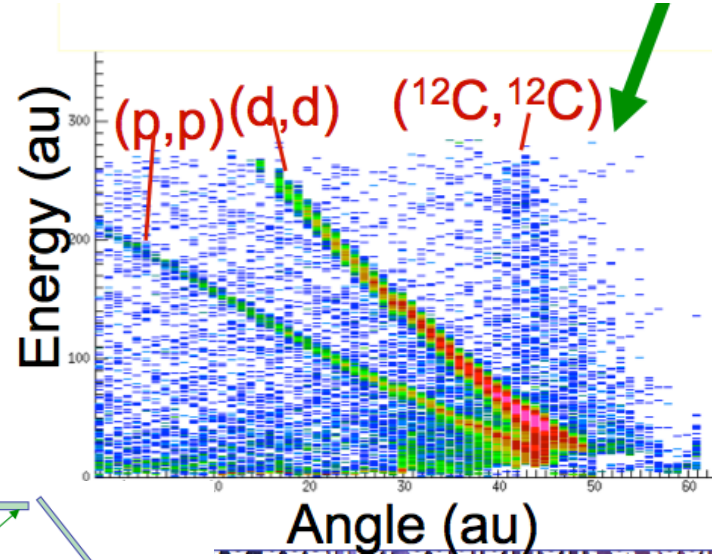
dealing with poorly defined energies

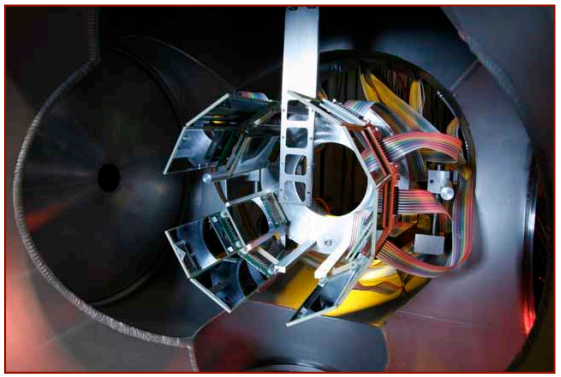
use **very thin targets** & kinematic reconstruction

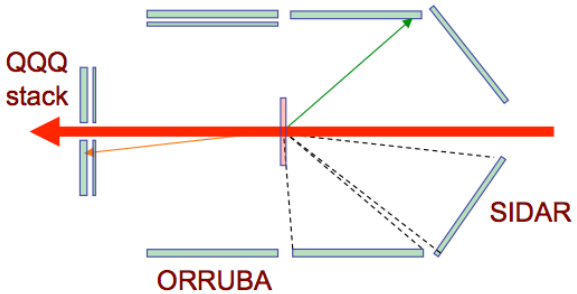
note: requires complex analysis, dramatically lowers yields

Si strip detector arrays





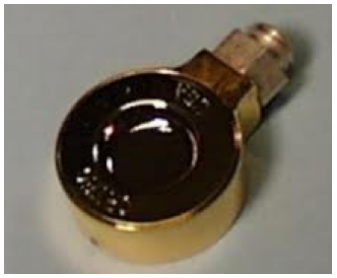




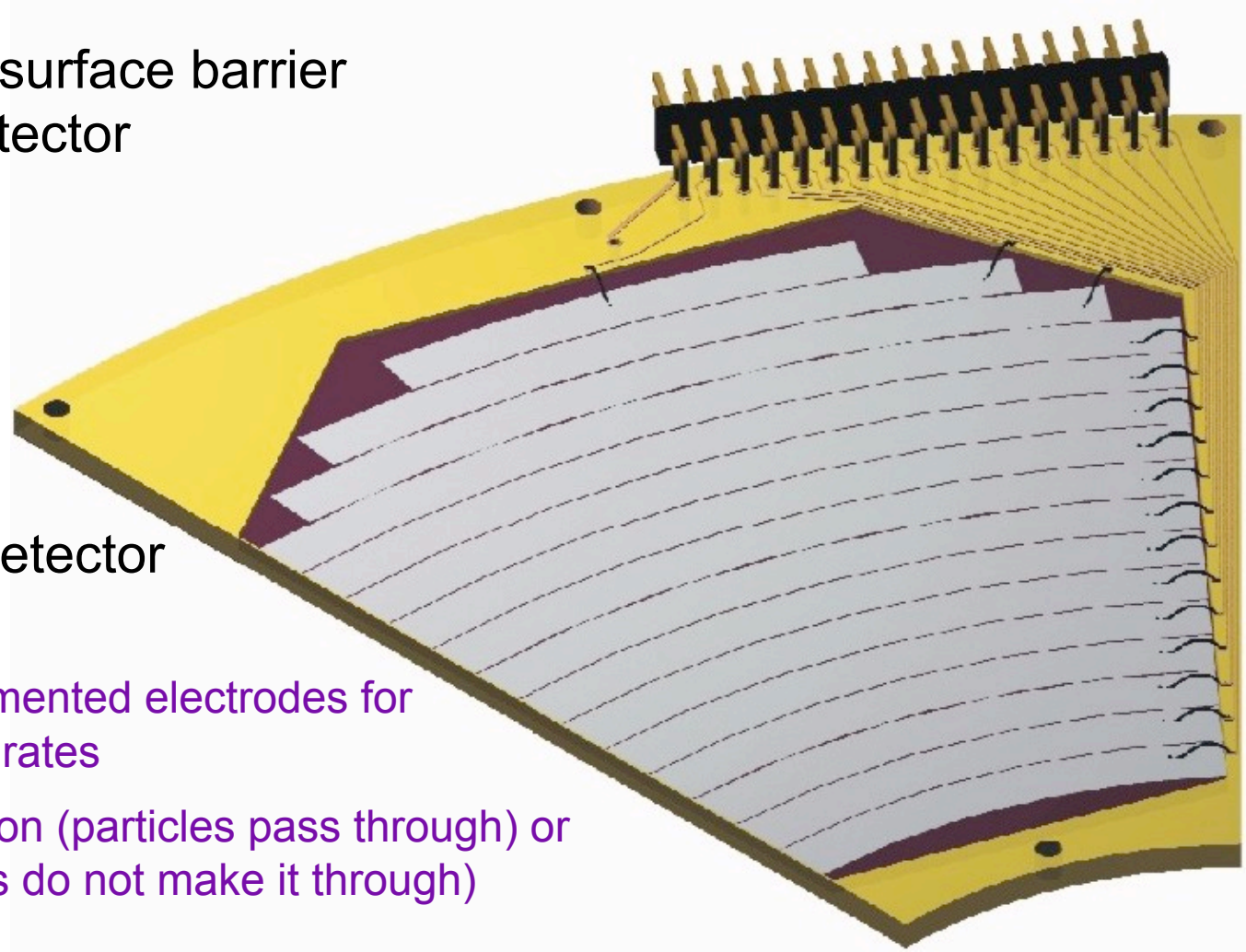
- incredibly useful for a wide variety of radioactive beam experiments
  … scattering, transfer, (p,α) and (α,p), inverse reactions …

- Micron Semiconductors [UK] provides almost all systems in use at major labs

Si strip detector arrays



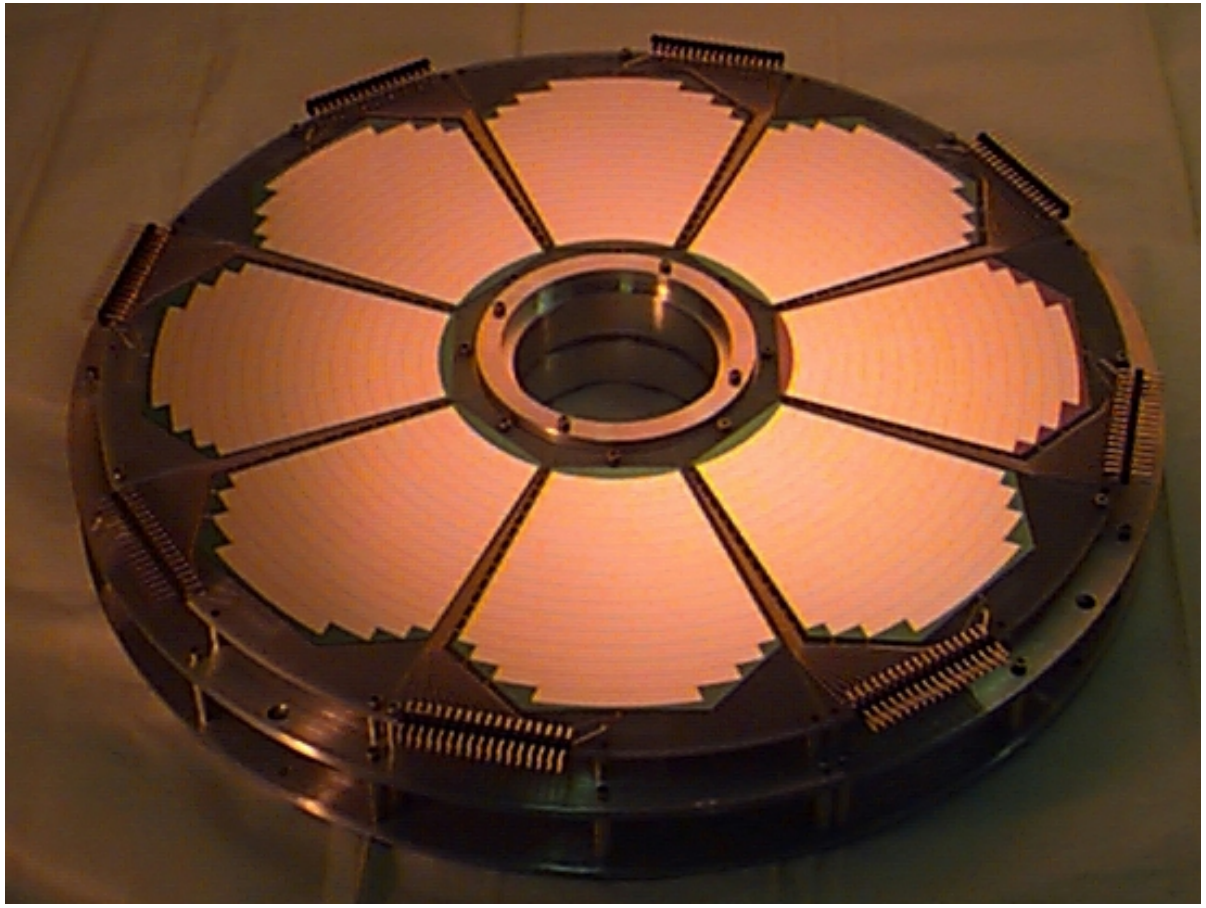
Si surface barrier detector



Si strip detector

- Si wafer with segmented electrodes for higher total count rates
- can be transmission (particles pass through) or stopping (particles do not make it through)
- signals transmitted along PCB (printed circuit board) to feedthru for ribbon cable connector

Si strip detector arrays



SIDAR
[Silicon Detector Array] at ORNL

8 detectors,
16 strips each,
128 channels

Commissioned ~ 1995

- arrays of Si strip detectors offer large solid angle coverage, high total count rates

Si strip detector arrays

VOLUME 83, NUMBER 1 PHYSICAL REVIEW LETTERS 5 JULY 1999

Observation of the Astrophysically Important 3^+ State in ^{18}Ne via Elastic Scattering of a Radioactive ^{17}F Beam from ^{1}H

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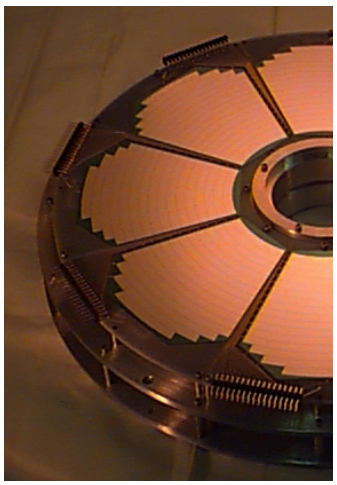
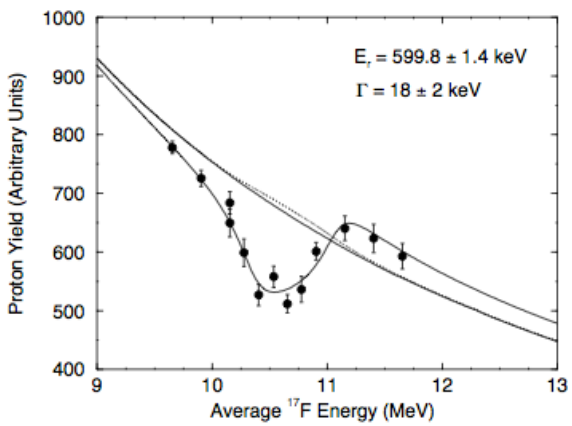
V.Y. Hansper,[1,3] M.A. Hofstee,[6] B.A. Johnson,[4] R.L. Kozub,[4] Z. Ma,[1,
M.T. Rabban,[1] A.C. Shotter,[5] M.S. Smith,[1] K.B. Swartz,[2] D.W.





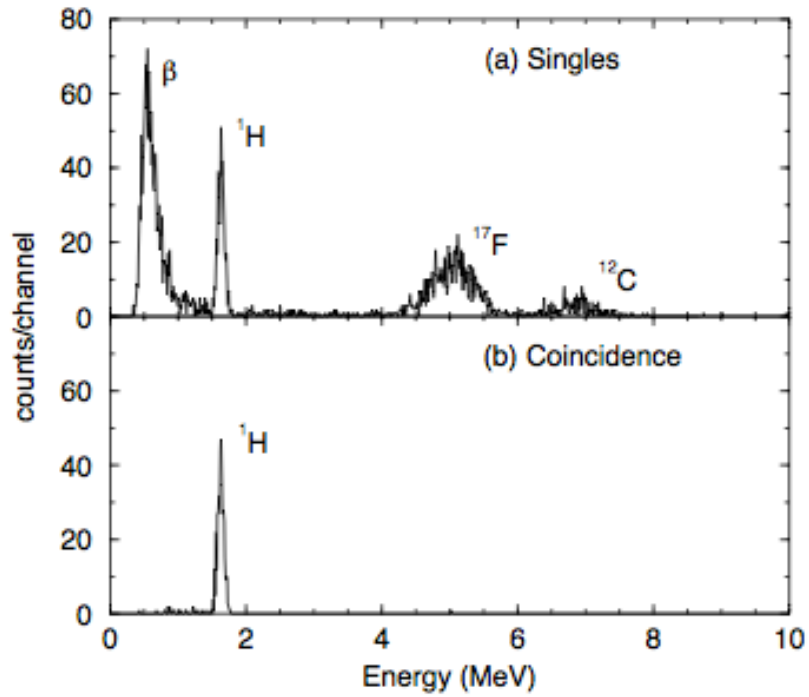


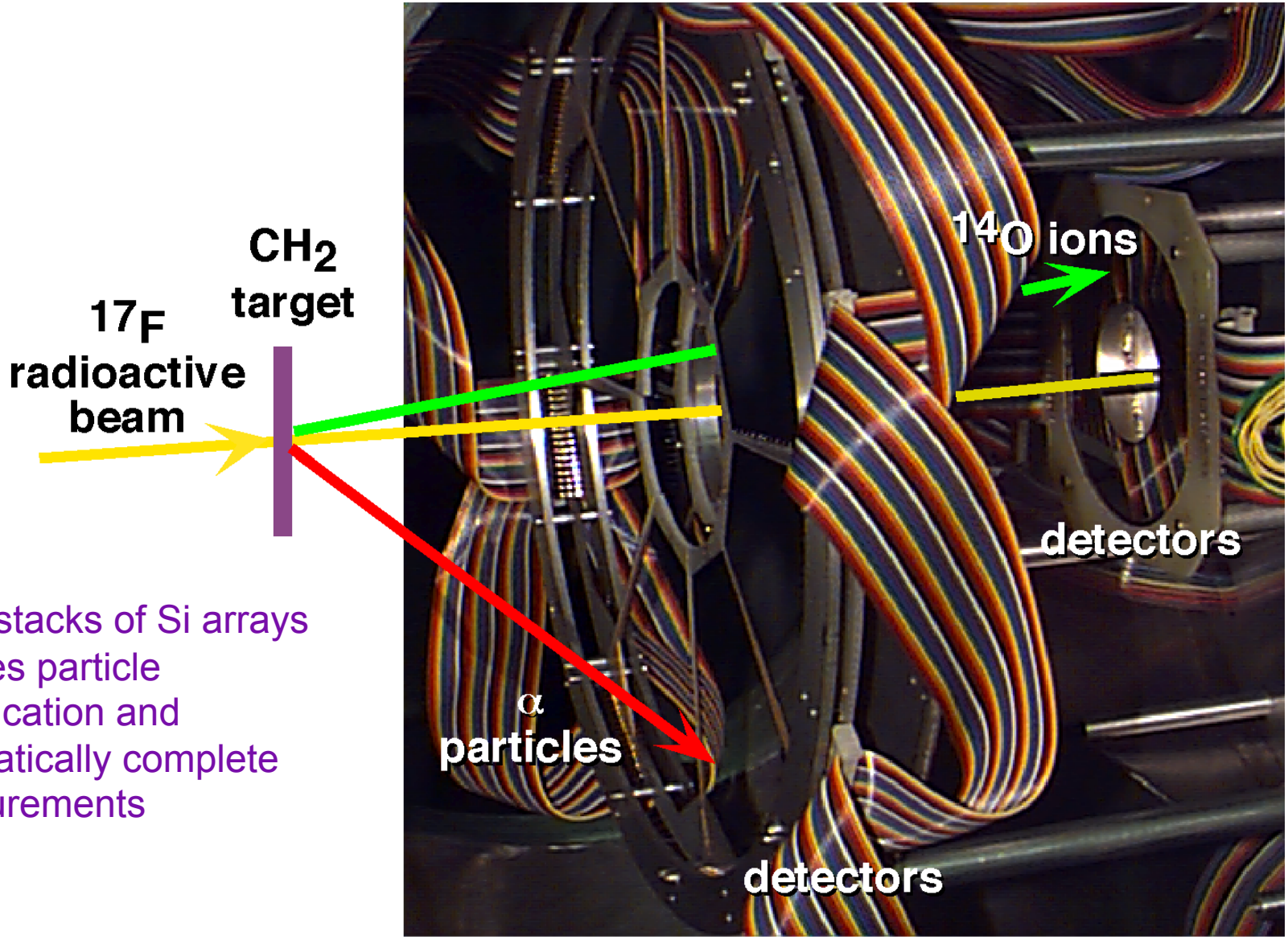
FIG. 2. (a) The raw particle spectrum from a ring of SIDAR strips at $\theta = 27.7°-29.9°$ is shown. A 10-MeV ^{17}F beam impinged on a 48-μg/cm^2 polypropylene target. (b) Same as (a) when coincidence with recoil ^{17}F ions in the ionization counter was required.

- our 1999 measurement of ^{17}F(p,p) with SIDAR determined the location, spin, and total width of the dominant resonance in ^{17}F + p burning

Si strip detector arrays – desired properties

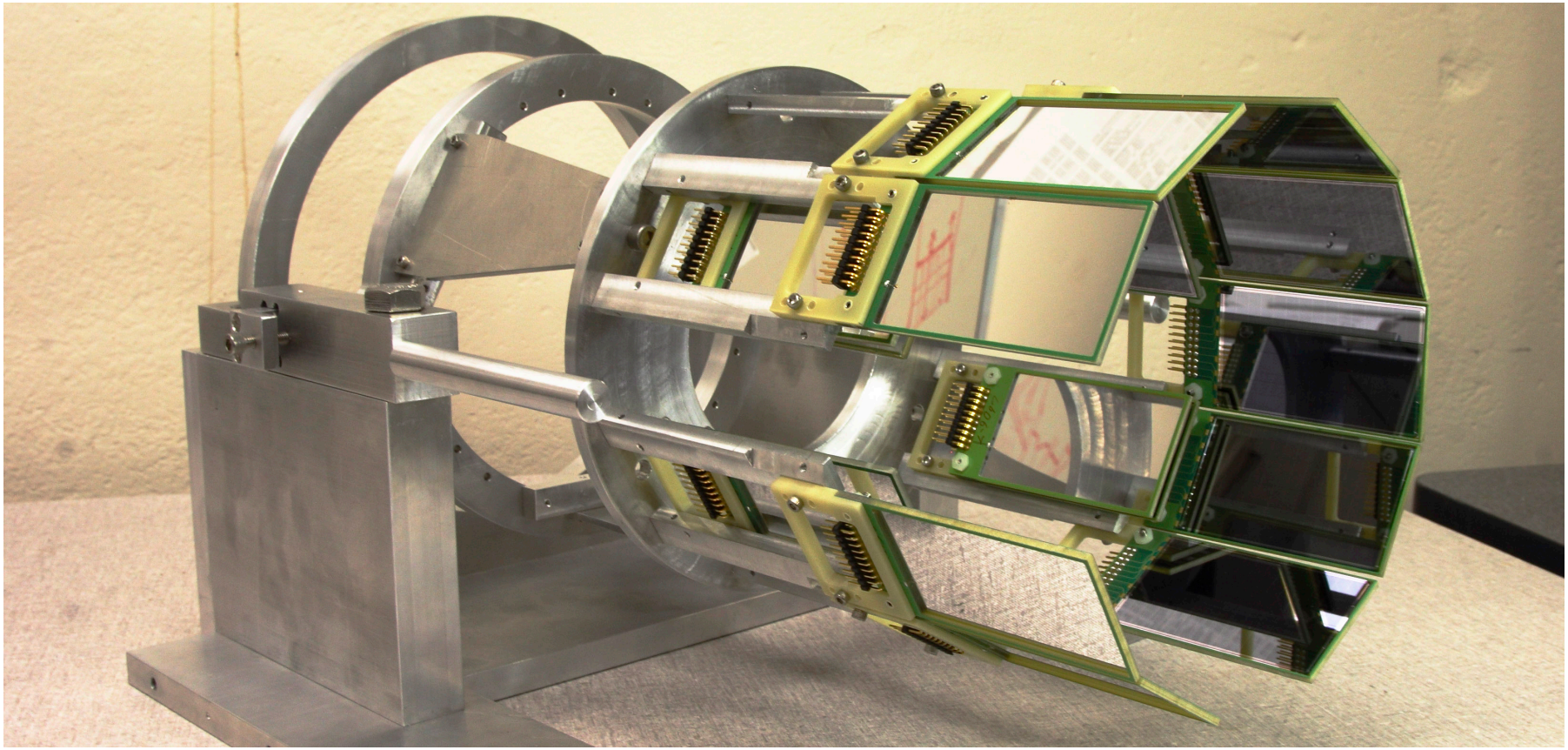
- large solid angle (75 % of reaction products)
- enable access to configure detectors both upstream & downstream of target
- high segmentation enabling count rates > 10 kHz
- energy resolution of ~ 30 keV for particles with energy ~ MeV
- computer adjustable gains & trigger thresholds
- telescope arrangements dE - E for particle ID
- flexible geometry to accommodate extra detectors [e.g., Z-tagging with downstream gas ionization counter, gamma detectors]
- high-density modular electronics [ASICS]
- preamps closely coupled to Si detectors to reduce noise
- examples: SIDAR & ORRUBA [ORNL]; LEDA [Louvain]; TUDA [ISAC]; YLSA [Yale]; cost ~M$

Si strip detector arrays



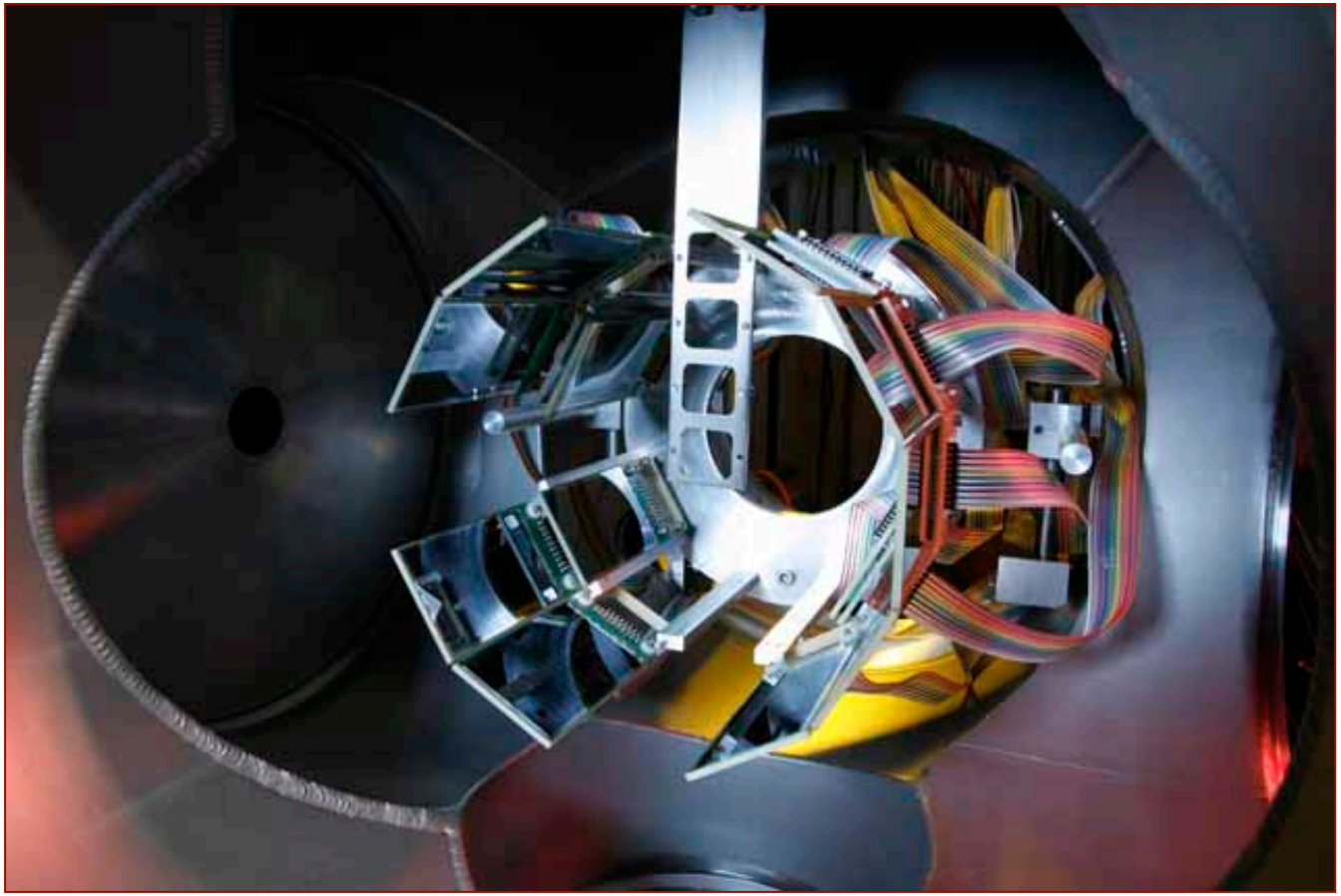
- using stacks of Si arrays enables particle identification and kinematically complete measurements

Si strip detector arrays



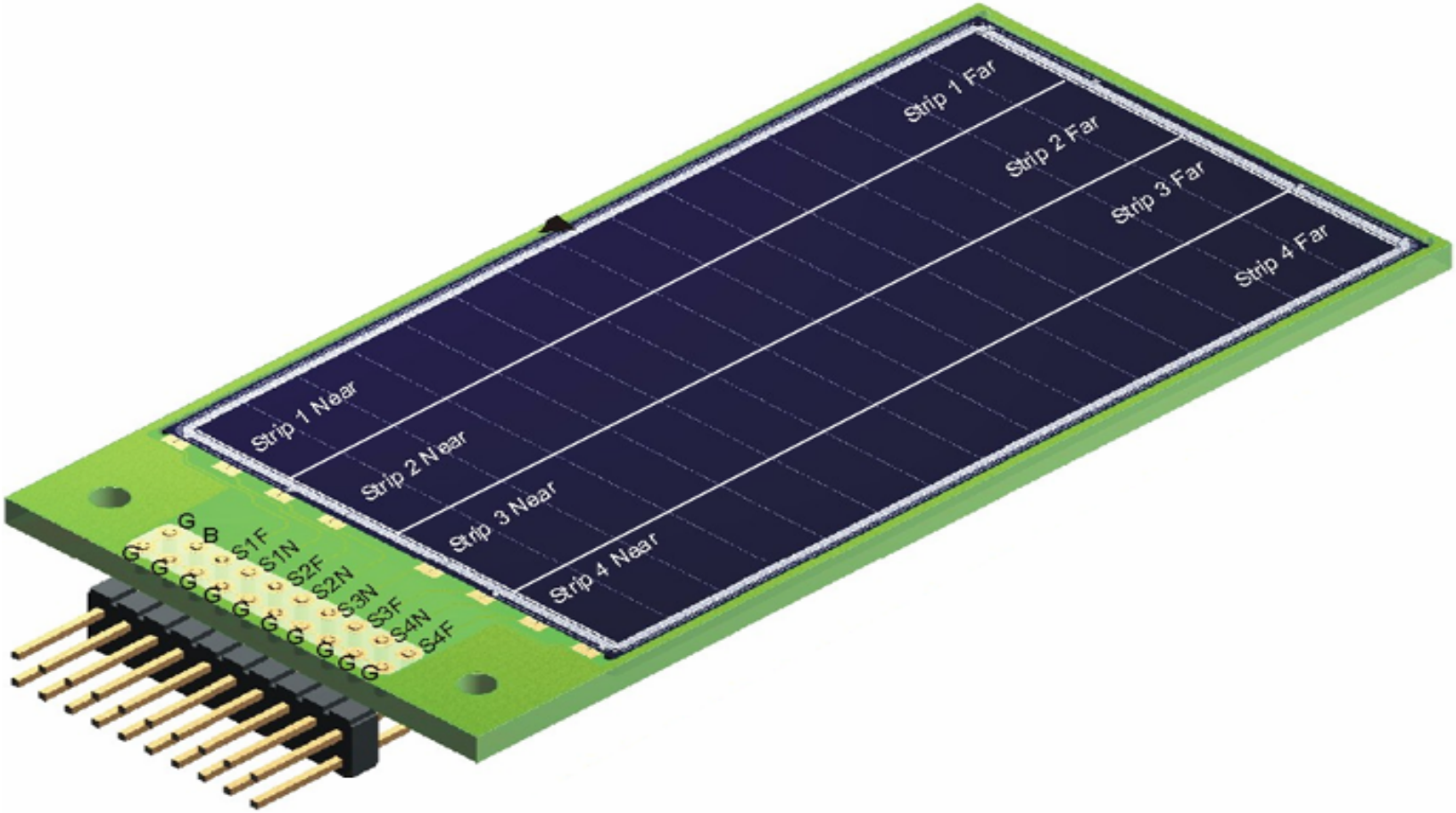
- the Oak Ridge Rutgers University Barrel Array ORRUBA has 24 dE – E Si strip detector “telescopes” optimized for (d,p) reaction measurements at 90 degrees to the beam axis

Si strip detector arrays



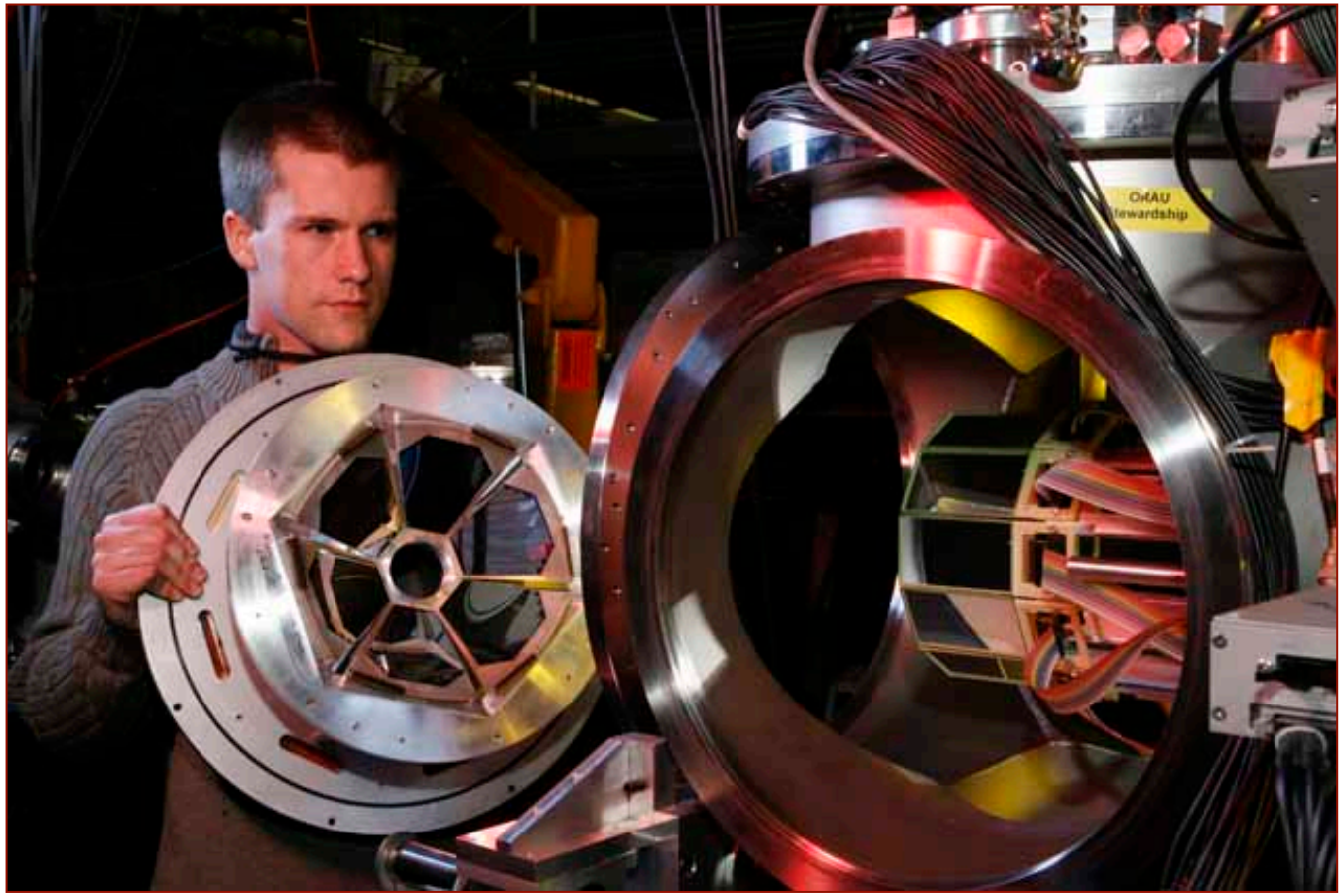
- ORRUBA target chamber showing target ladder, cabling, support structure

Si strip detector arrays



- Si strip detectors come in a variety of geometries … and can be custom designed [for a price !]
- this detector was custom for the ORRUBA system
- segmented on the front side, charge division resistive layer on the back
- this uses less electronic channels, at the price of poorer energy resolution

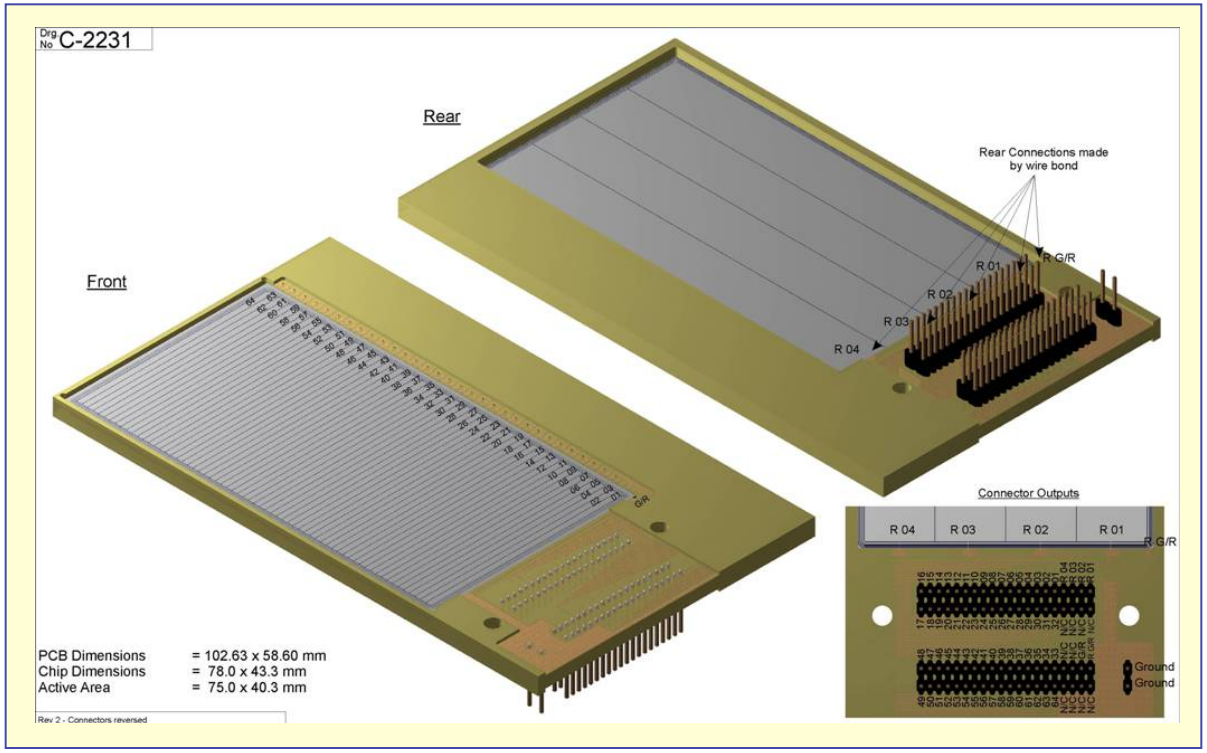
Si strip detector arrays



- combined arrays – ORRUBA, SIDAR …
- higher solid angle coverage

Si strip detector arrays

Steve Pain, ORNL



- Improved energy resolution (~60 keV to ~30 keV)
- Improves position resolution at low energy (no energy dependence)
- Lower thresholds (no position dependence)

SuperORRUBA system

Exchange resistive strips (8 channels per detector) for pixelized non-resistive detectors (68 channels per detector)

Almost an order of magnitude channel increase

ASICs (WashU system) deployed with HRIBF DAQ

for more info

Smith_Rehm.pdf

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NUCLEAR ASTROPHYSICS MEASUREMENTS WITH RADIOACTIVE BEAMS*

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Key Words nucleosynthesis, radioactive ion beams, laboratory techniques, experimental facilities

■ **Abstract** Radioactive nuclei play an important role in a diverse range of astrophysical phenomena including the early universe, the sun, red giant stars, nova explosions, X-ray bursts, supernova explosions, and supermassive stars. Measurements of reactions with beams of short-lived radioactive nuclei can, for the first time, probe the nuclear reactions occurring in these cosmic phenomena. This article describes the astrophysical motivation for experiments with radioactive beams, the techniques to produce these beams and perform astrophysically relevant measurements, results from recent experiments, and plans for future facilities.

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