Reflections of HINP project

I. **Some not so obvious considerations and problems**
II. **Collaboration sociology**
III. **Wings**
IV. **What is HiRA/HINP?**
    A High Resolution Array – where flexibility was a design constraint.

V. **Some results from the HiRA/HINP project**

VI. **Our Present problem requires**
    more dynamic range & less X-talk

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I. Some non-obvious considerations.

1. The **dynamic-range** needed in NP is often MUCH more than HE.
   - ➔ In HE one is usually dealing with MIPs (minimally ionizing particles = 104 keV/300 um Si).
   - ➔ In NP one often has high energy p's to low energy HI to deal with. This can lead to the requirement of a dynamic ranges exceeding several thousand.

2. With only a few exceptions (TPC's) the **channel count** is rarely more than a few thousand.

3. NP has a **tighter time line** than HE. Conceive, Build, Execute, Analyze & Publish in a few years.
   - ➔ incommensurate time scales : t(ele) >> t(think up good experiments)
   - ➔ Students are expected to execute all/most of this cycle.
   - ➔ They will not get a job if they are viewed as just a "cog" in a big experiment.
   - ➔ Short, mid, and long term science objectives

4. More than HE physics, NP is tied to applied areas➔ medical physics and "homeland security".

   Does the project have "**WINGS**" ➔ to other Basic or Applied Nuclear Science?

5. Schemes must be worked out so that **small groups at universities**, without a cutting edge accelerator complex, can make essential high-profile contributions. If one can find such schemes, the workforce is made larger, stronger and more sustainable. In the USA EACH NP'ics group to make significant contributions, i.e. to publish work that is identified with a group.

II. Collaboration sociology

There must be independence ($) and continuity ($) at every stage.

Physics

drives

Initial design

Washington University in St. Louis

Small groups

SIU Southern Illinois University Edwardsville

Design inspires

Future physics

"dreams".

NSCL

Accelerator Laboratories
With
Physics goals of their own

ATM

Large laboratory

mid-sized laboratory

II. Sociology continued
How did it work? How is the effort sustained?

➔ Initial funds from an NSF MRI.

Electronics development, creation, implementation about 150 k$ out of 500 k$ for the HiRA device.

➔ For these funds we got a working chip and did some science, publications and PhD's.

➔ This success attracted other interest and funds.

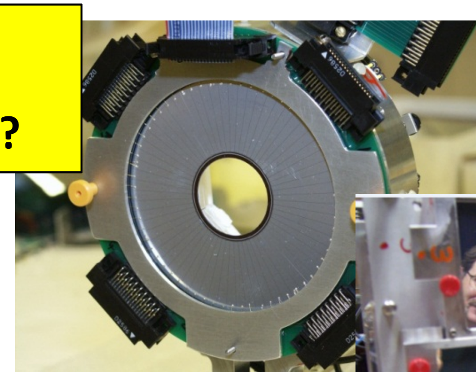
➔ Now 4 other devices use (or will shortly use) this chip.

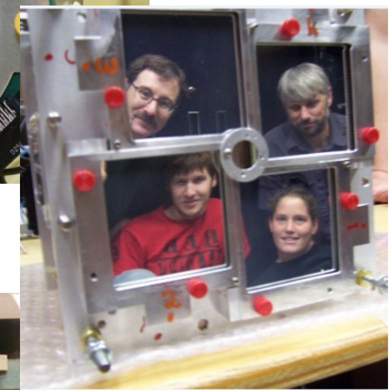
Each project contributes to the common effort of expanding the capabilities of the chip. (Each project contributes $'s to the chip fabrication runs.)

➔ A comment on sustainability. Money must be continuous or the effort will dissipate.

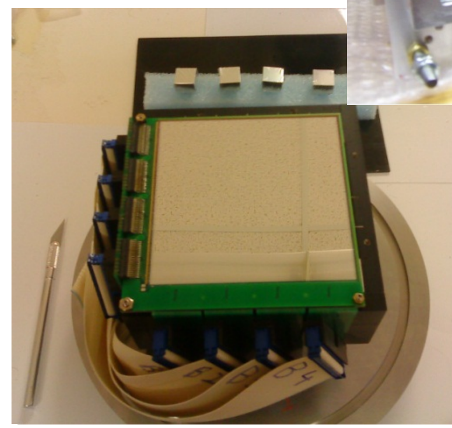
III. WINGS:

Can the electronics be used with other detector systems ?



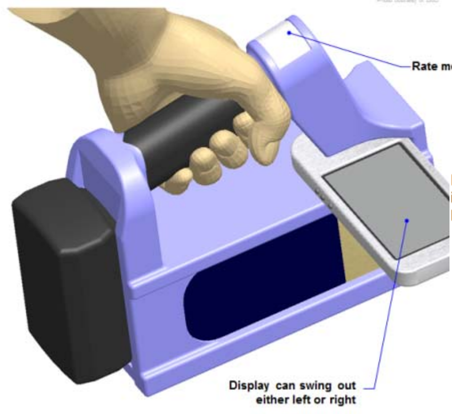


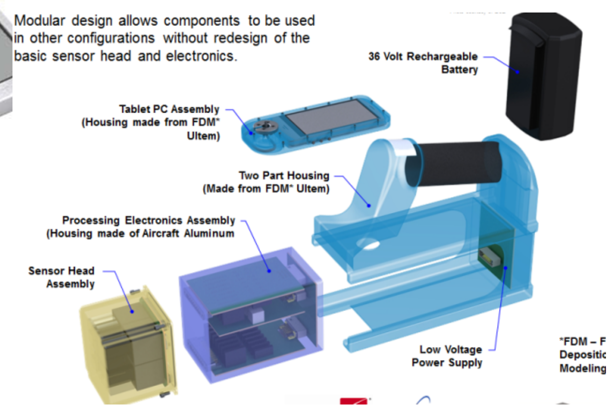
Is the electronics portable to it can easily be used at other laboratories with different detectors? ➔

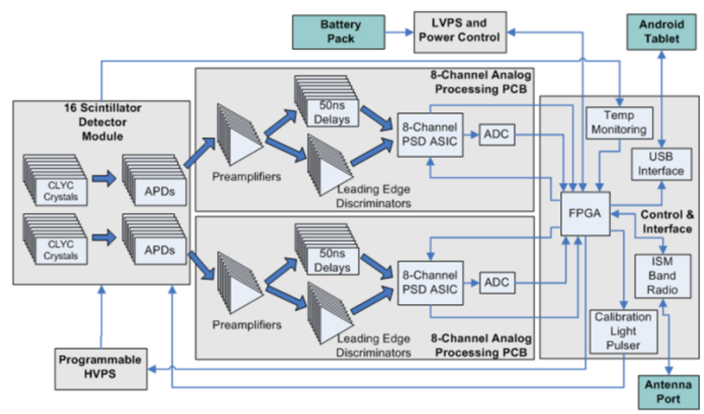


Can the electronics be used in non-NP applications?

New PSD and directional radiation monitor designed by LANL uses our PSD chip (and CLYC)

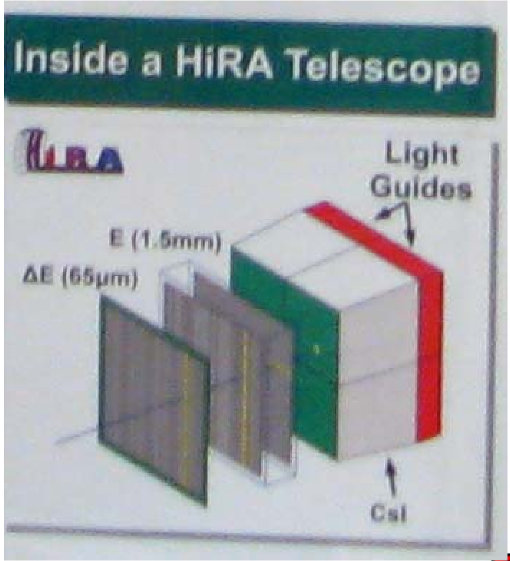




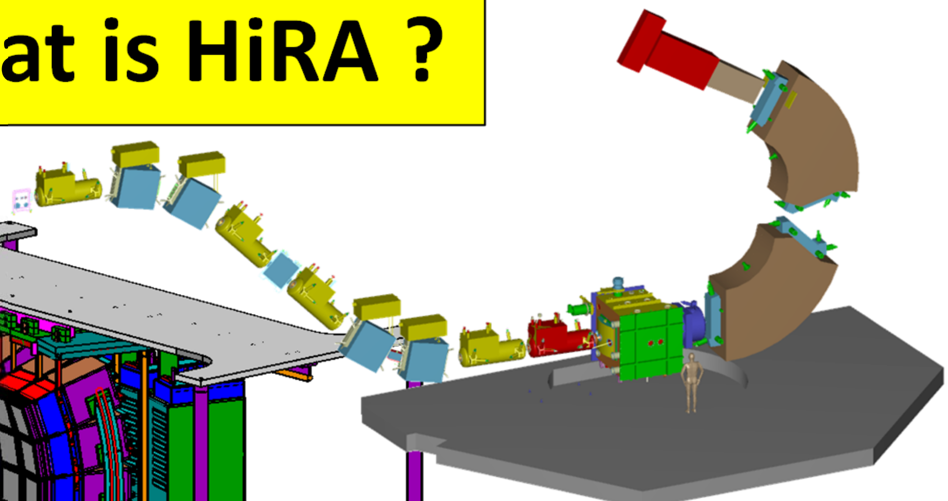


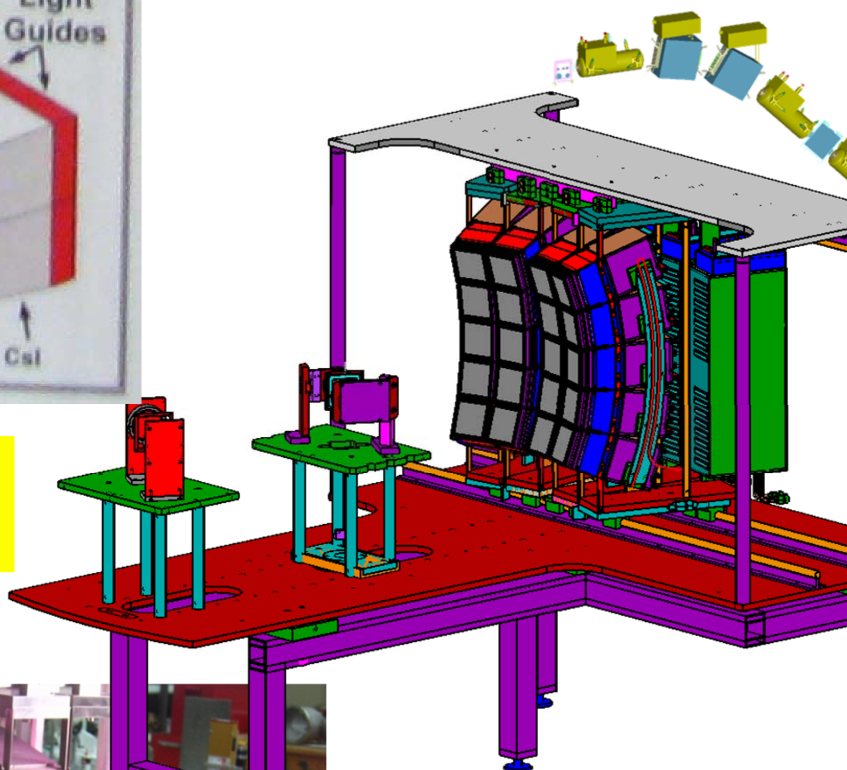
Los Alamos
NATIONAL LABORATORY
EST. 1943

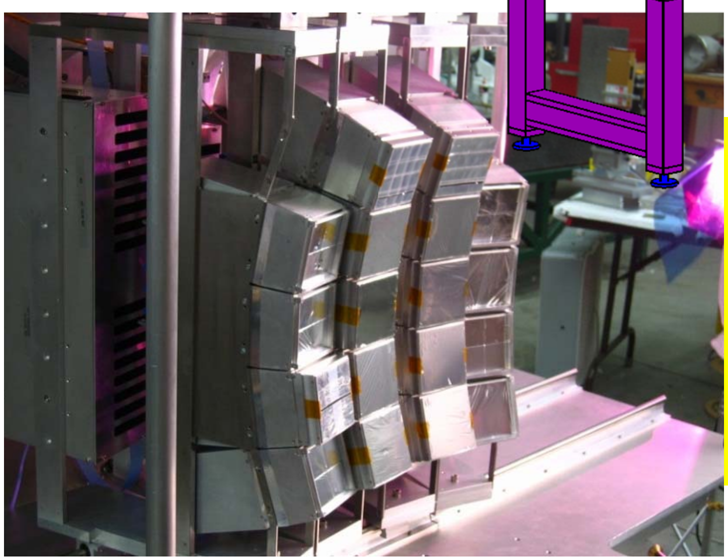
IV. What is HiRA ?

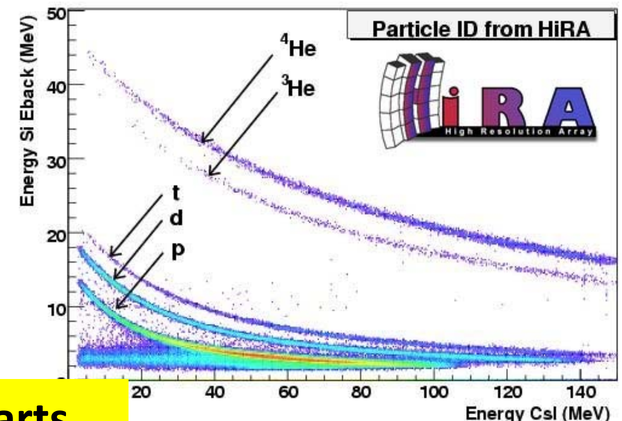


A modular Si-Si-CsI(Tl) array





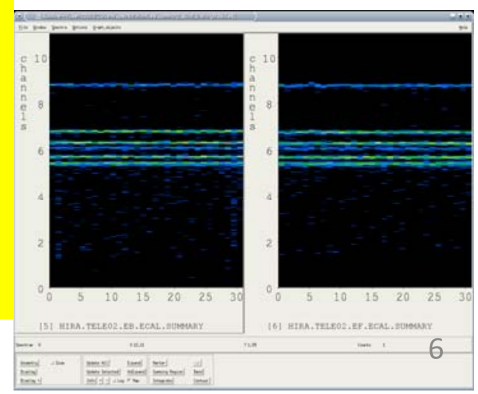




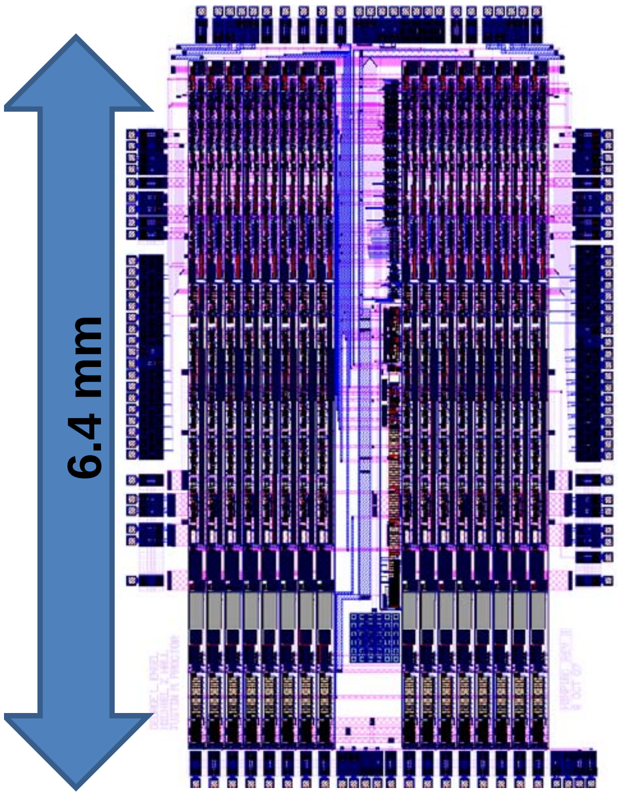
It can/has been used in parts

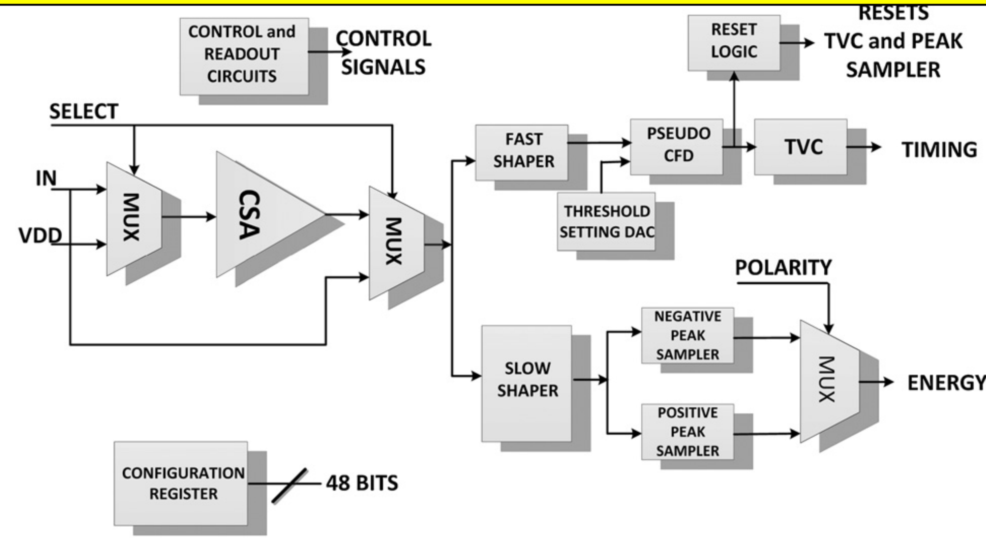
It can/has been used with many other devices

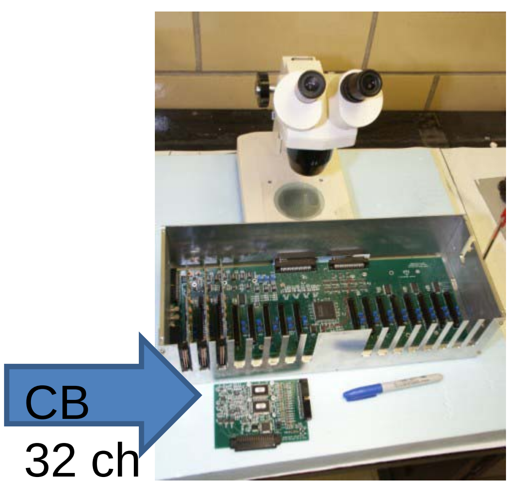
It can/has been used at several accelerator labs

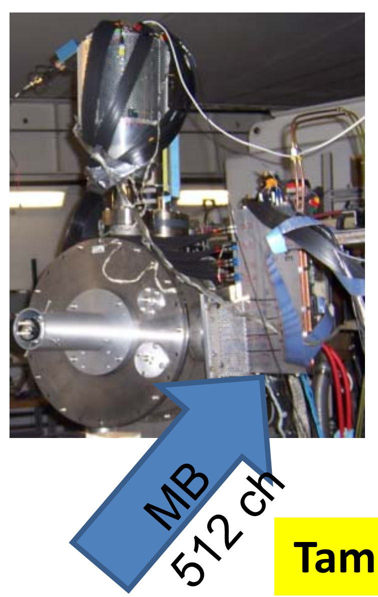


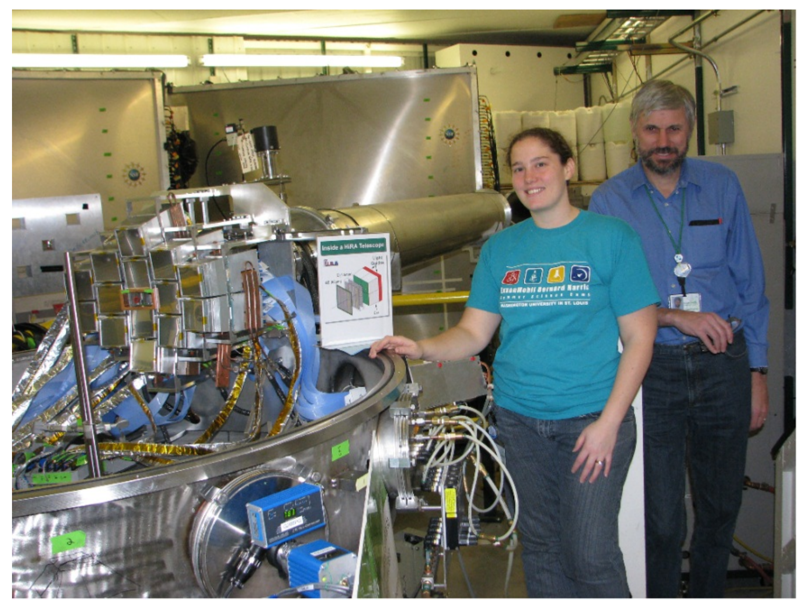
Work made possible by a CMOS signal-processing chip



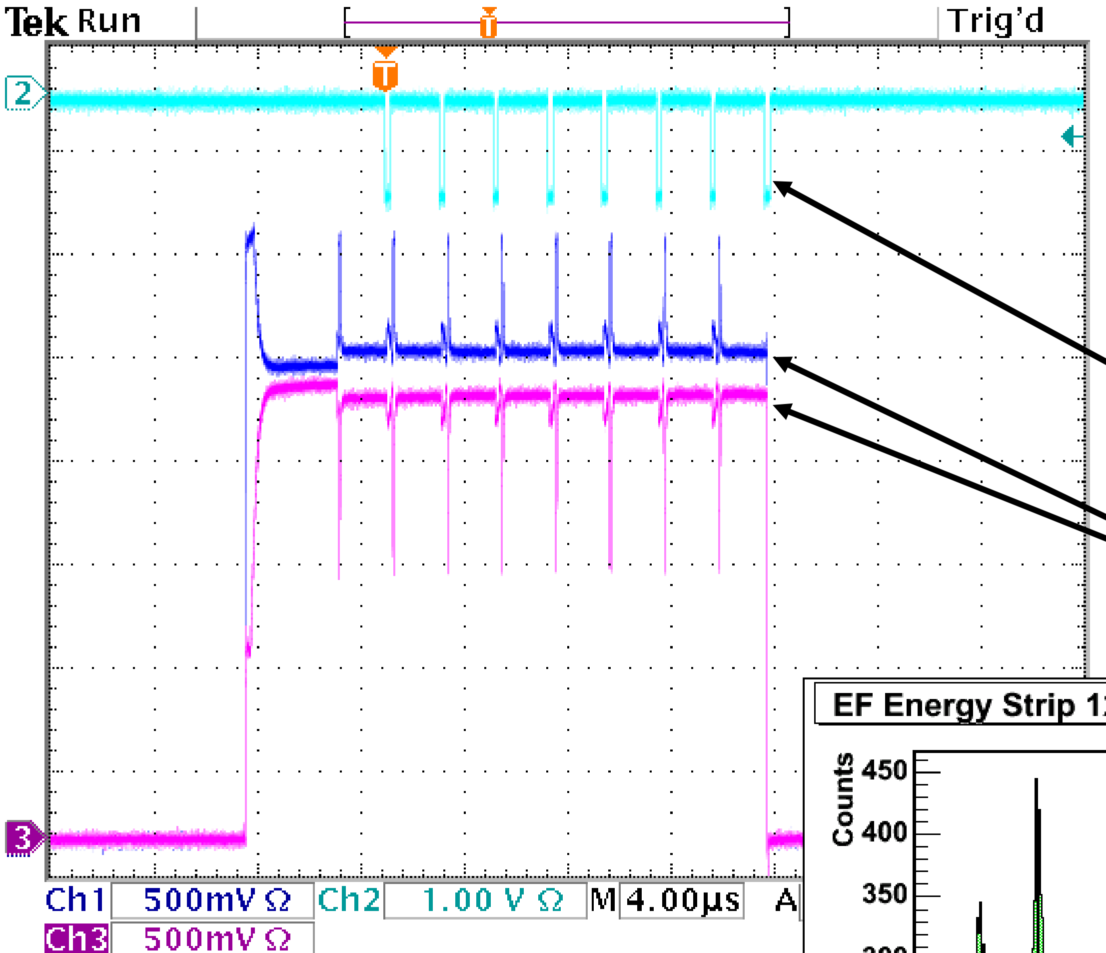








Tamu **MSU**

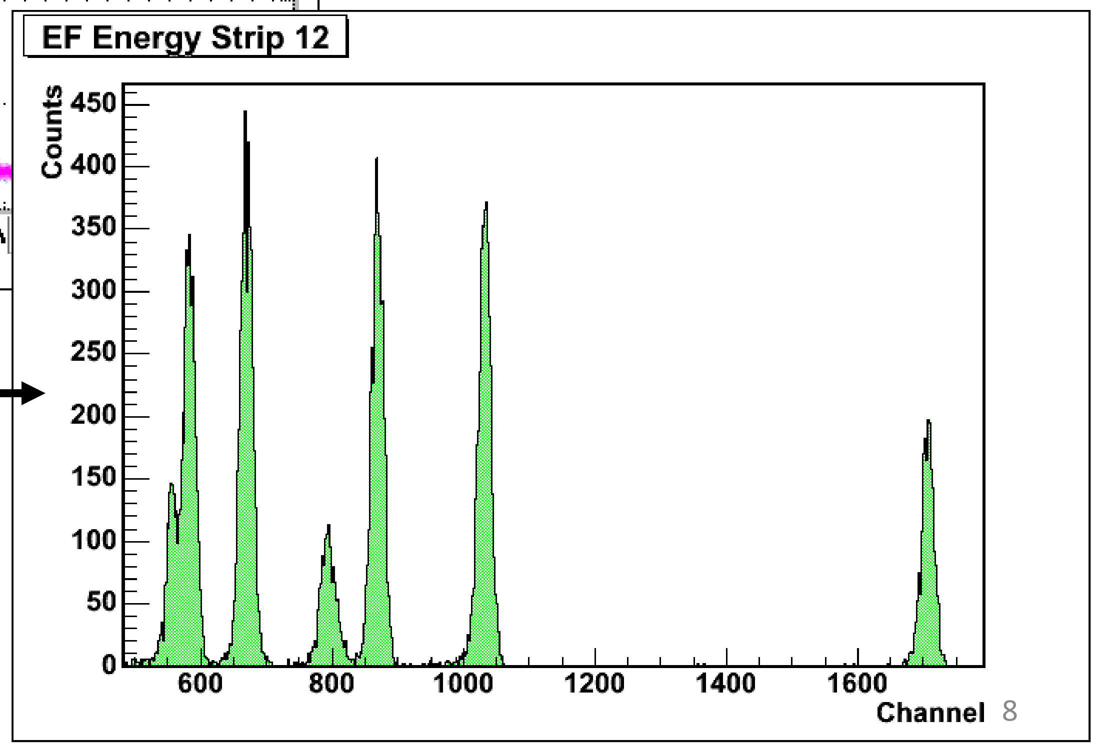


The Signals go from the ASIC chip to a differential amp and then to a pipeline ADC.

Strobes to pipeline ADC

Differential Signals

α spectrum: ^{228}Th source



INTERNAL High-Gain CSA

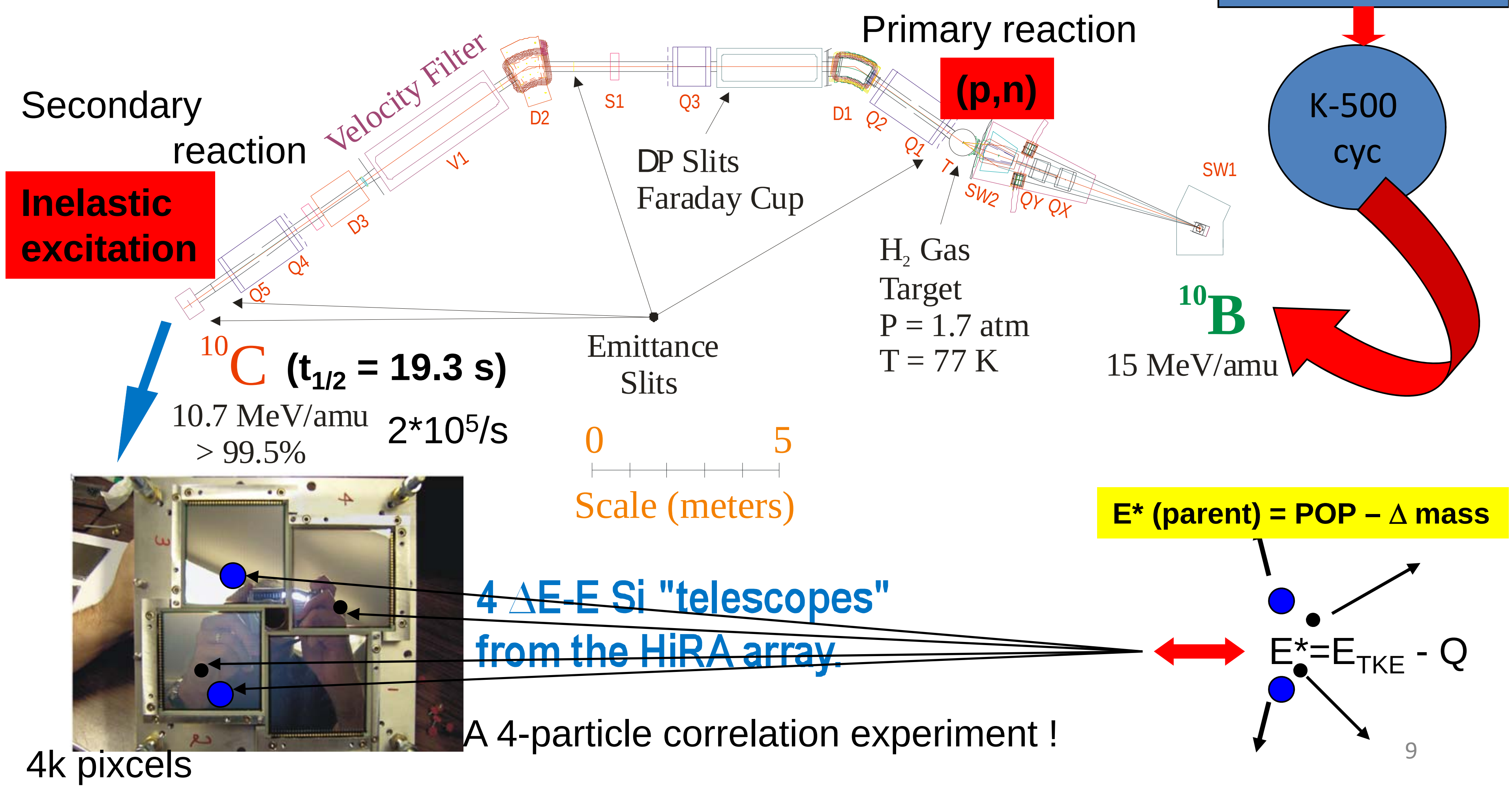
Thres	res	range
~ 250 keV	~ 50 keV	~ 80 MeV

II. Experimental logic: Example #1

➔ TAMU using K500 cyclotron and the **MARS** separator

From enriched Carborane $C_2[^{10}B_{10}]H_{12}$

ECR source



V. Some results

A. ^{10}C decay

B. ^{8}C decay

C. Isospin symmetry breaking in A= 8

D. $^{8}B_{IAS}$ decay

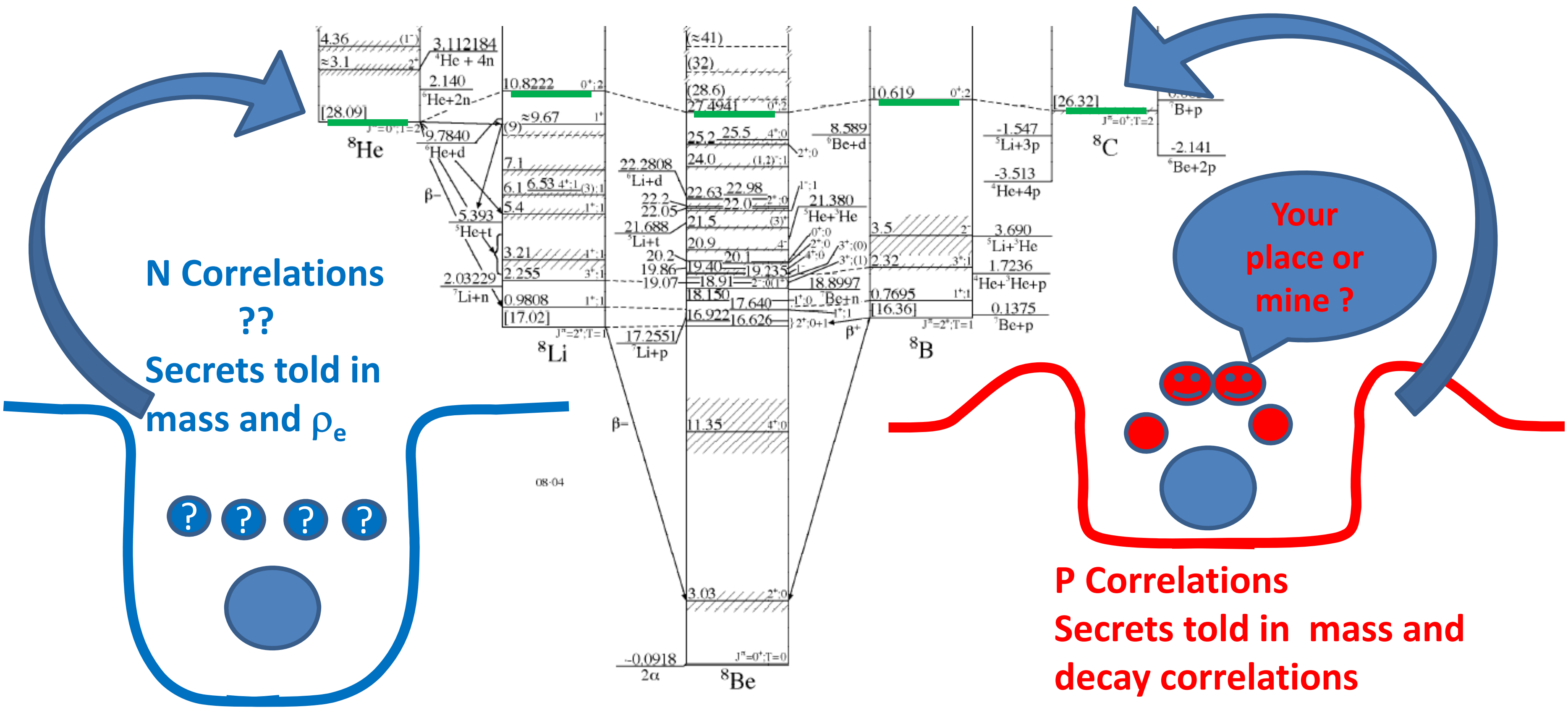
E. $^{12}C_{7.6}$ (Hoyle state) decay.
Is there ANY 3-body? ➔Si-Si + HiNP provide the resolution.

F. A state in ^{9}LI that might be the analog of ^{9}He.

G. A menage a quatre state in ^{10}C

I. Physics overview:

1. Multiple proton decay at the drip-line Pushing nuclear structure into the continuum
2. Isospin Symmetry Breaking
3. Peering in at nucleon-nucleon correlations (in the medium) by “pushing” Fermi surface to (or into) the continuum.



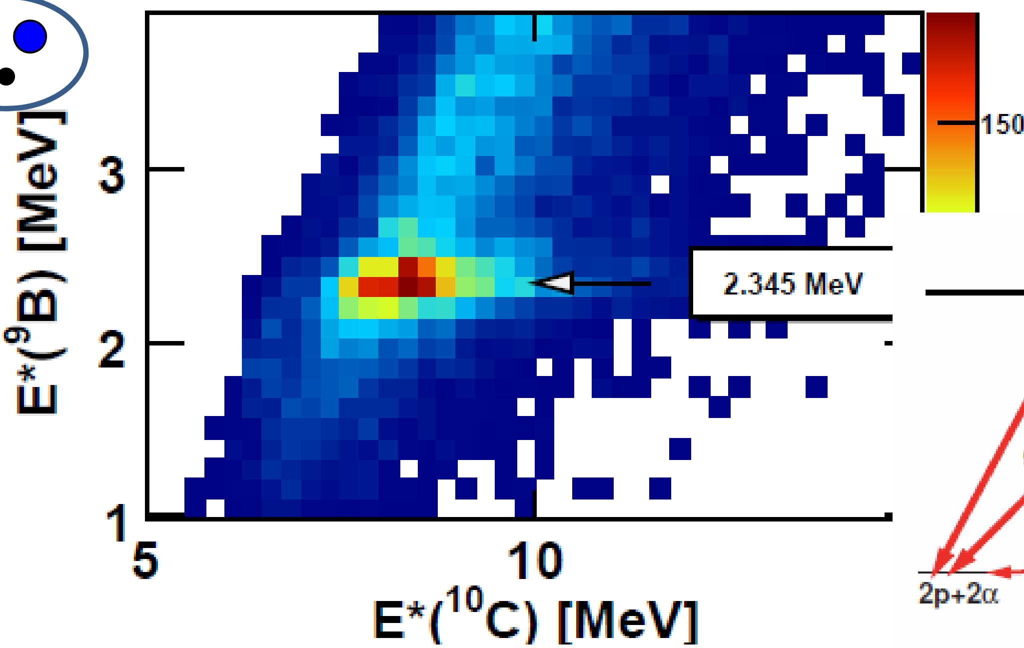
A. Excited states of ^{10}C and how they decay.

One of the new excited states we found in ^{10}C.

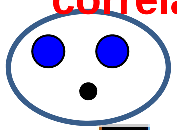
This one at E* = 8.4 MeV.

It decays through the an excited state in ^{9}B.

Three-particle Relative Energy correlation

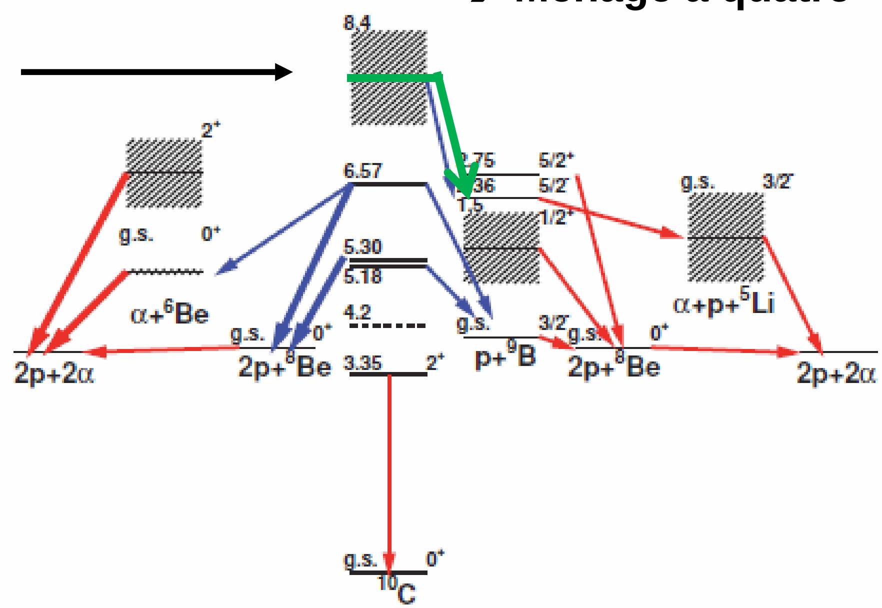


4-particle relative energy correlation



Another new state at 9.7 MeV

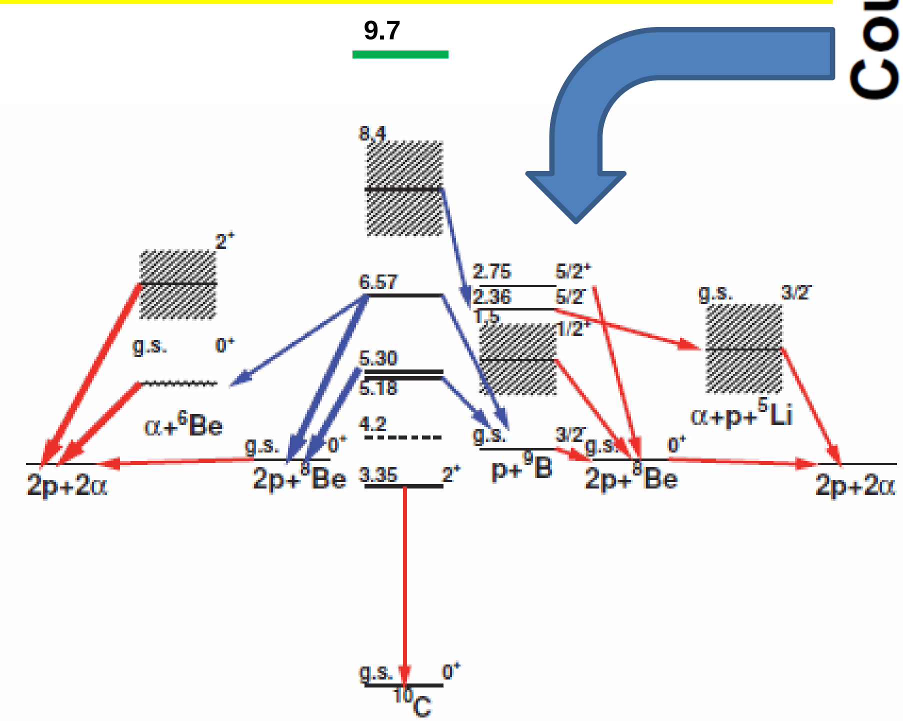
➔ Menage a quatre

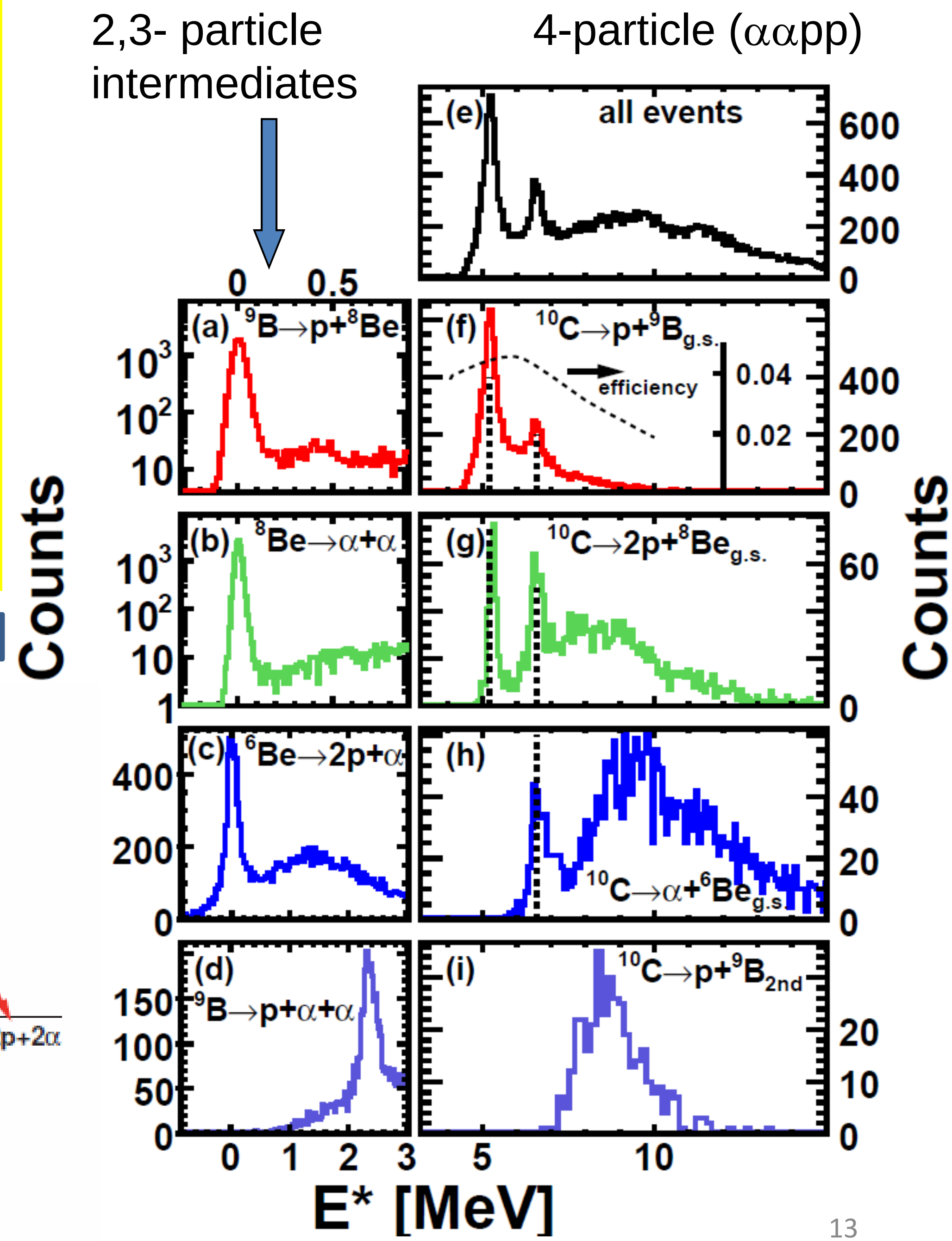


➔Determined the decay paths for known levels in ^{10}C using….

two-, three-, and 4-particle energy correlations.

➔Found two new states (@ 8.4 and 9.7 MeV)





Before moving on to ^{8}C ➔ some Combinatorics

1. The excitation of any unbound species can be reconstructed from the relative energy of the fragments corrected for the decay Q-value.

   a) $E^*(^8C) = E_{TKE}(\alpha+4p) - Q_{decay}$

   b) $E^*(^6Be) = E_{TKE}(\alpha+2p) - Q_{decay}$

   Note we can prepare ^{6}Be cleanly from 1n removal from ^{7}Be beam!

2. **IF** ^{8}C decays via $^8C \rightarrow [^6Be] + 2p \rightarrow [\alpha+2p] + 2p$

   there will be **two** protons from the first step and **two** from the second.

First step .... **IF** ^{8}C decays $^8C \rightarrow [^6Be] + 2p \rightarrow [\alpha+2p] + 2p$

There are **6 ways** to choose **two protons** from **a set of four protons** : 6= 4!/(2!2!).

If we construct $E^*(^6Be)$ from E_{rel} of α+2p, from all 6 combinations

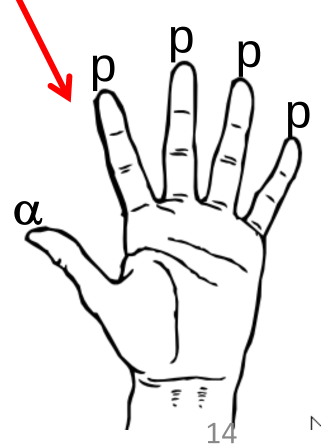
ONE will be correct and **FIVE** will be wrong

Construct $E^*(^6Be) = E_{TKE}(\alpha+2p) - Q_{decay}$

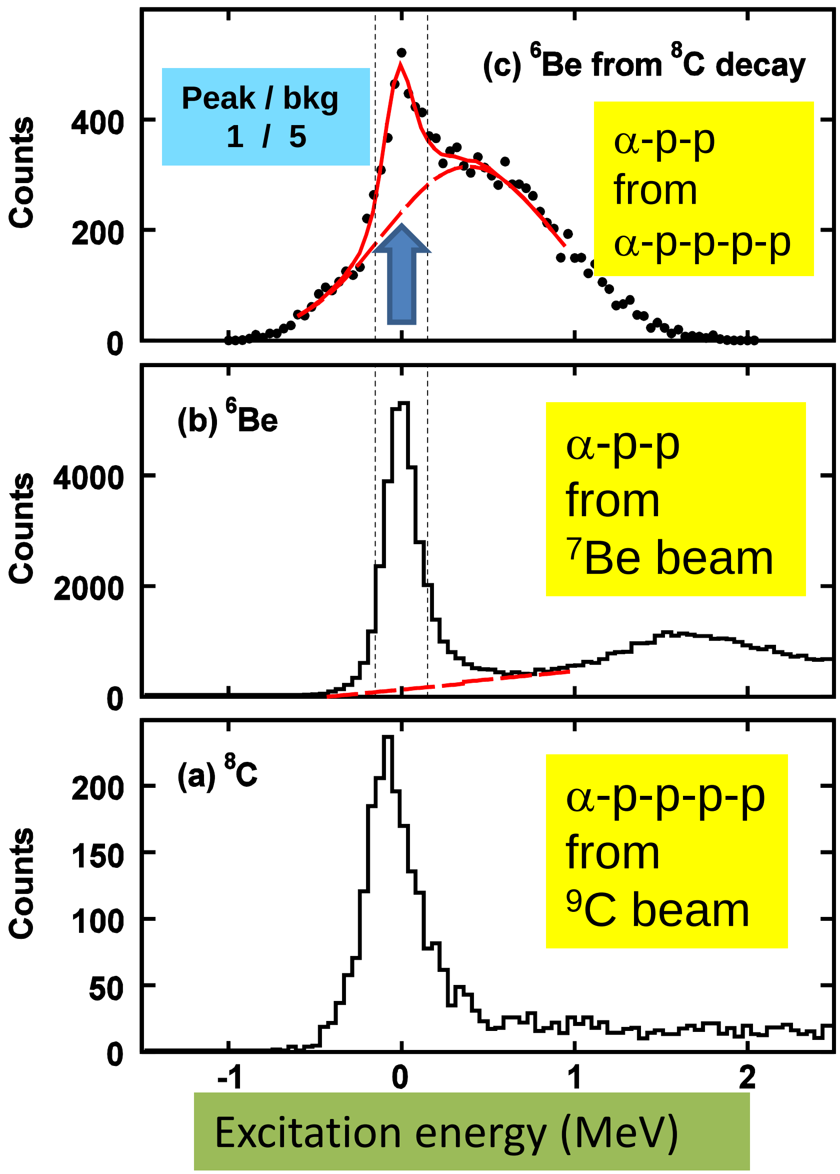
and increment a histogram once for EACH combination.

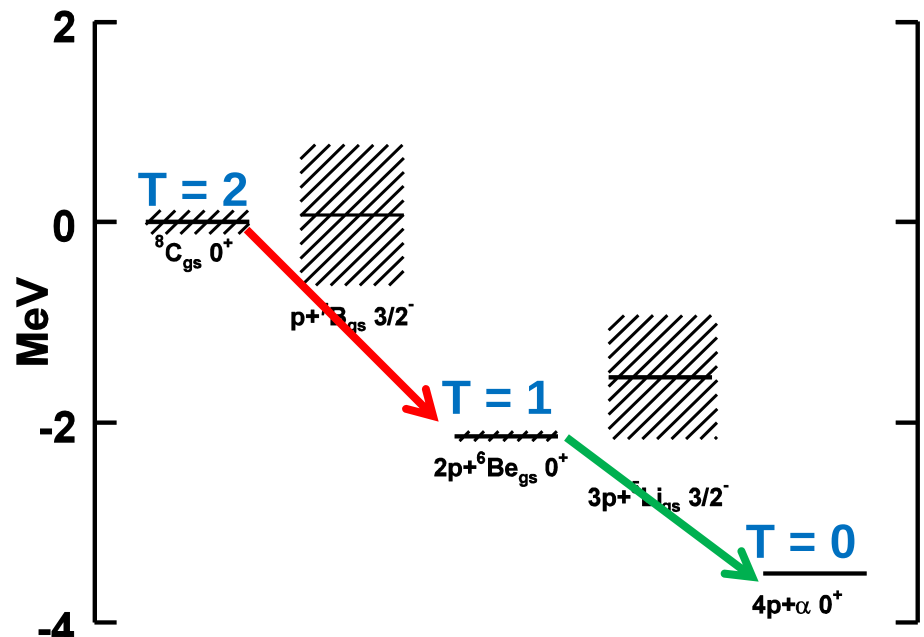
(Six times per event.)

5 – particle correlation
“like your hand”



B. ^{8}C decay – as simple as 1 out of 6.





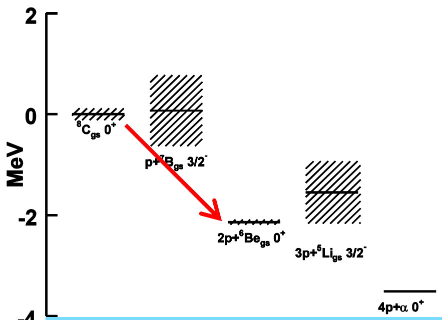
^{6}Be is the (7 zs) intermediate, i.e.
^{8}B ➔ [^{6}Be] + 2p + [α +2p] +2p

Now on to correlations between p's in first and second steps.

In ~ 1/3 of the events only ONE of the six combinations lies in the ^{6}Be peak. For these events we can assign protons to first and second steps.

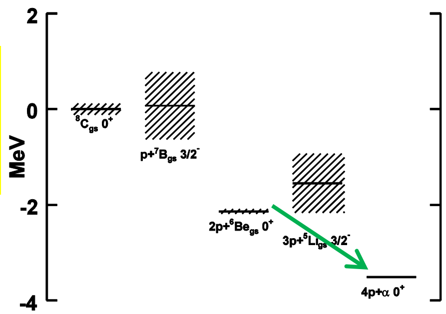
DECOMPOSITION "T" system

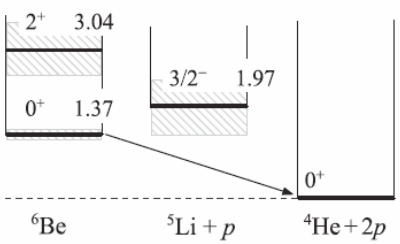
1st



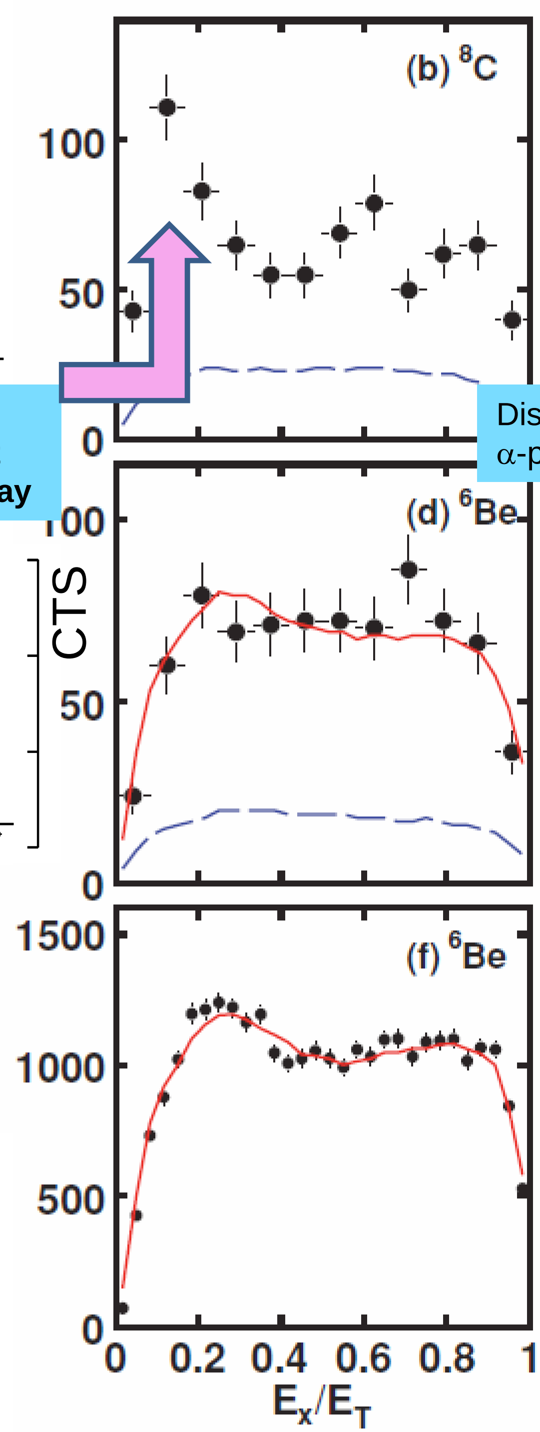
This time there is a "diproton"enhancement
➔ in first step of ⁸C decay

2nd





Clean 1-step 3-body decay



[⁶Be]-p-p from α-p-p-p-p

Dissected steps from α-p-p-p-p

2nd α-p-p from α-p-p-p-p

α-p-p

Energy variable
= **fraction of E in p-p rel. motion**

C. New ^{8}C mass and uncertainty + since last fit new ^{8}He mass and correct error in previous fit.

1. If isospin is a good quantum number, in the absence of Coulomb forces
   ➔ the energies of a multiplet should be independent of T_z.
2. In **first-order perturbation** theory or if charge dep. forces only **two-body**
   ➔ the masses should if fit with a quadratic IMME.

$$M(T,T_z) = a + bT_z + c\,T_z^2$$

3. Isospin symmetry breaking will show up with need for dT_z^3 and eT_z^4 terms.

TABLE I. Mass excesses for the A=8 isospin T=2 quintet and the coefficients obtained from quadric, cubic, and quartic fits.

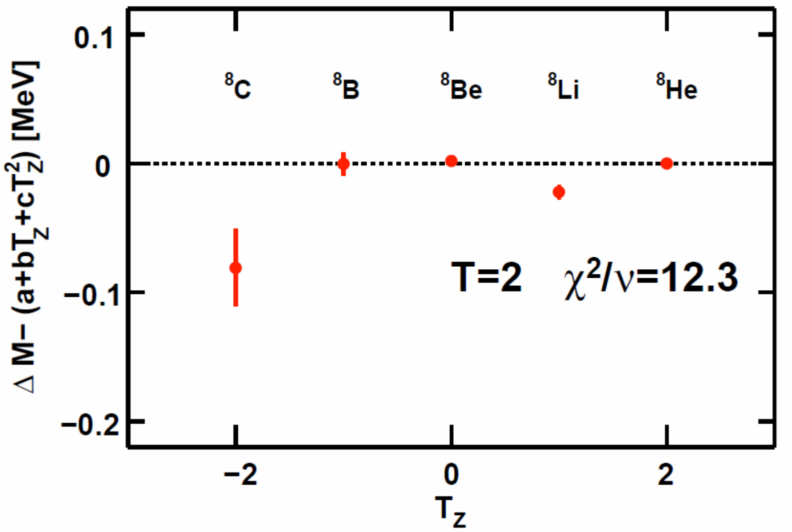
Nucl.	T_Z	Mass Excess [keV]	a, b, c [keV]	a, b, c, d [keV]	a, b, c, d, e [keV]
He	2	31609.7(1)	a=32433.9 (17)	a=32435.5 (17)	a=32435.7 (18)
Li	1	31768.0(55)	b=-875.3 (43)	b=-898.1 (63)	b=-896.6 (75)
Be	0	32435.7 (18)	c=231.6 (22)	c=220.3 (32)	c=217.7 (75)
B	-1	33540.5 (90)	χ^2/n=12.3	d=11.1 (2.3)	d=10.4 (3.1)
C	-2	35030 (30)		χ^2/n=0.1	e=0.8 (2.2)

New since last fit - ours - previous fit used wrong mass uncertainty.

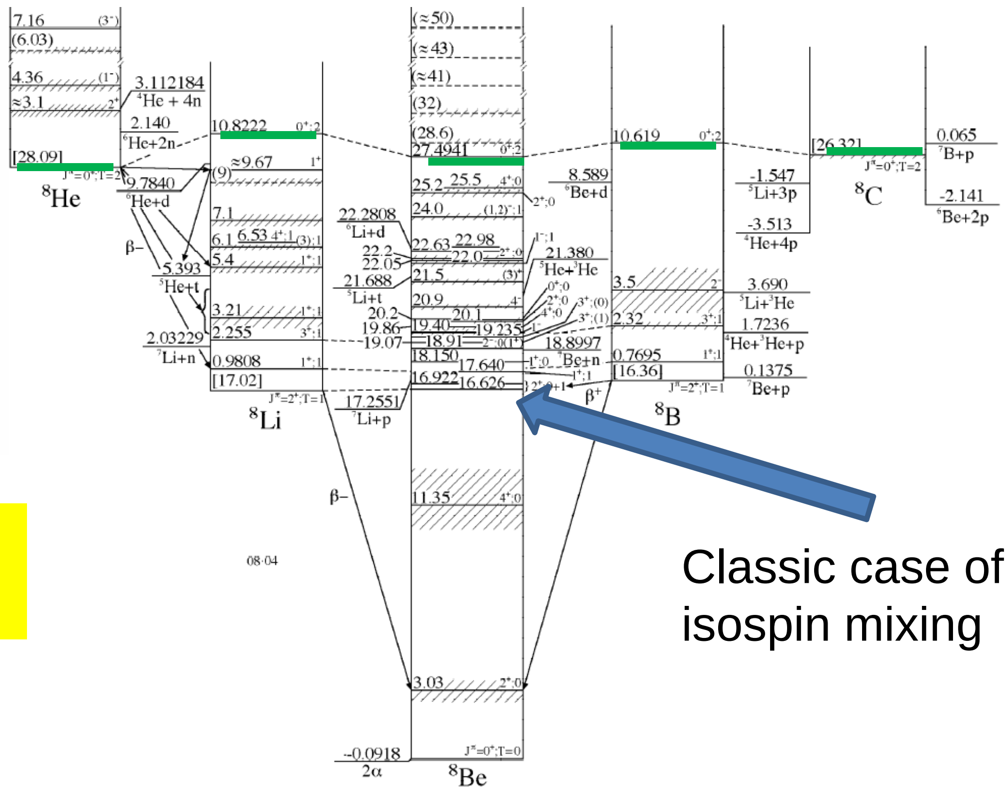
Needs d term (as does A = 32 but much larger in magnitude) SO either
➔ Isospin mixing with other 0+ states (as suspected in A = 32 case) or
➔ Perhaps a continuum effect?

Confirmation* of Isospin symmetry breaking in A = 8

The fit



are there 0+'s up here with small energy denominators?



Classic case of isospin mixing

Needs d³ term (as does A = 32)
Does not need an e⁴ term.

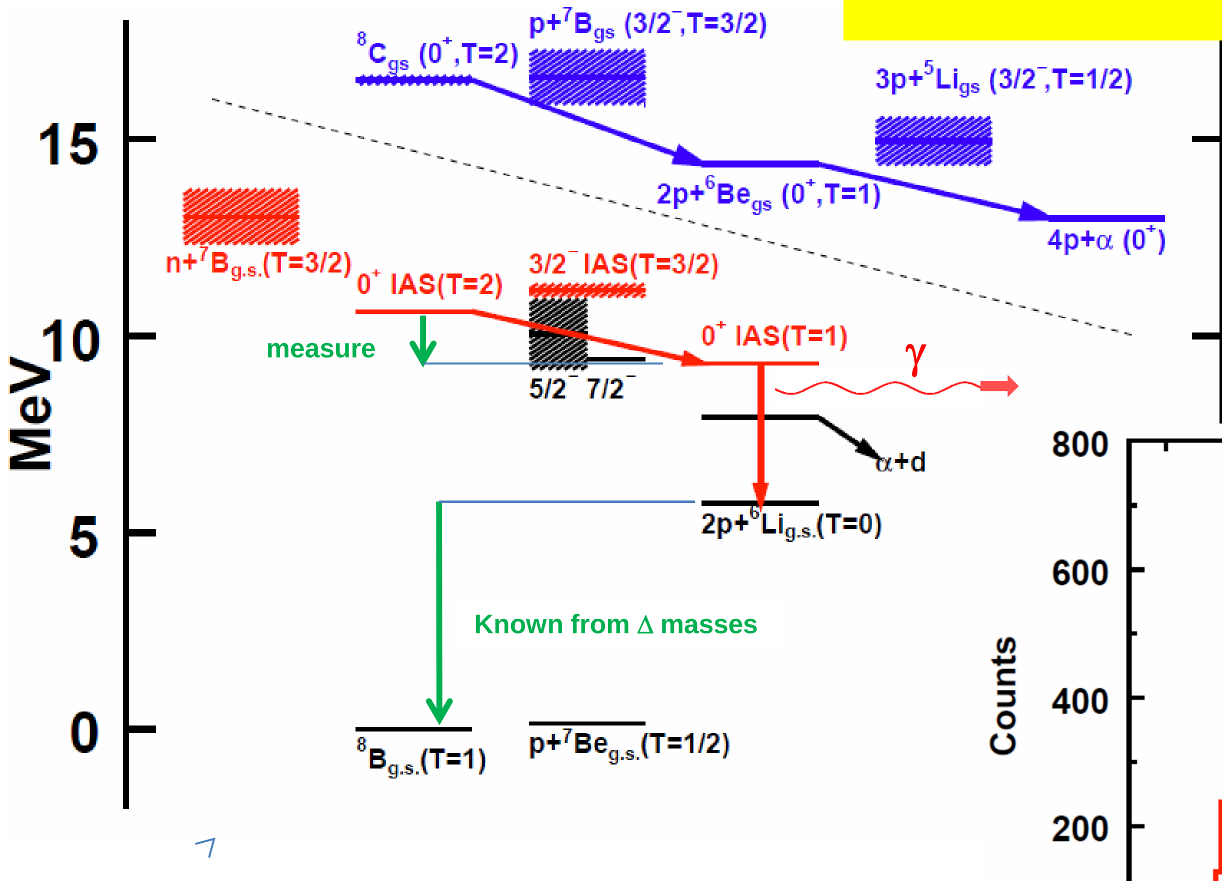
***NOTE:**

Previous work suggested isospin symmetry breaking in A = 8, **but** they used an uncertainty of the ^{8}Li$_{IAS}$ energy 10x too small. **Confirmed with authors**.

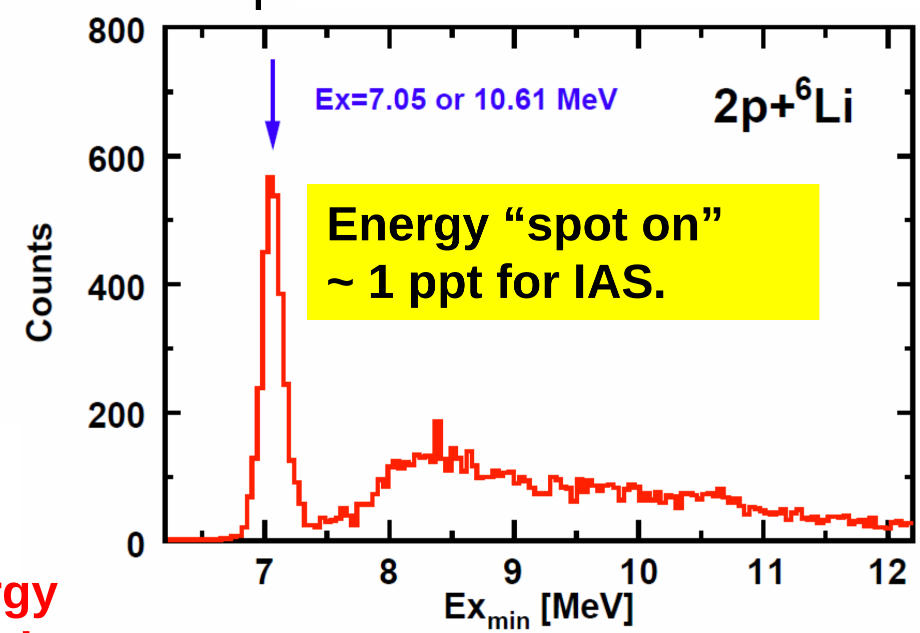
J. Britz, A. Pape, and M.S. Antony, Atomic Data and nuclear Data Tables **69,** 125 (1998).

D. A new 2p decay mode

TOP $^{9}C \rightarrow {}^{8}C_{gdst}$ (0+, T=2) +n
BOT $^{9}C \rightarrow {}^{8}B_{IAS}$ (0+, T=2) +p



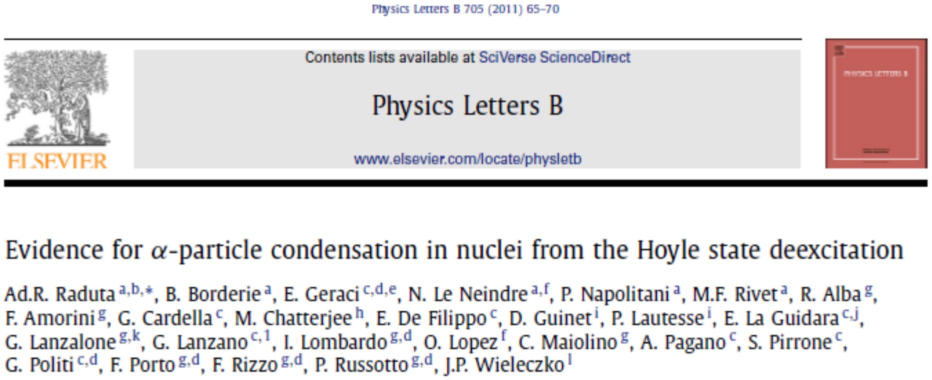
^{8}B reconstruction from ^{6}Li+p+p
IF NO missing energy



Energy "spot on" ~ 1 ppt for IAS.

The 1p decay is ALLOWED by energy but FORBIDDEN by isospin.

E. ^{12}C at 7.6 (Hoyle)
What is the % prompt 3-body?


Physics Letters B 705 (2011) 65–70

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Physics Letters B

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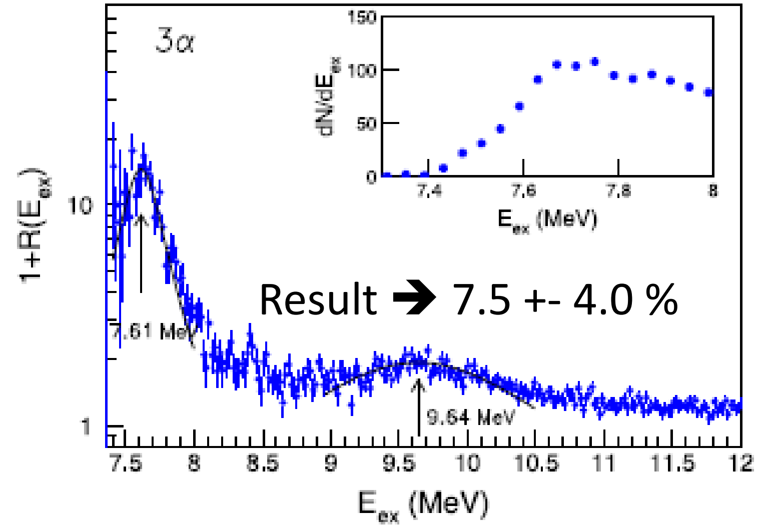
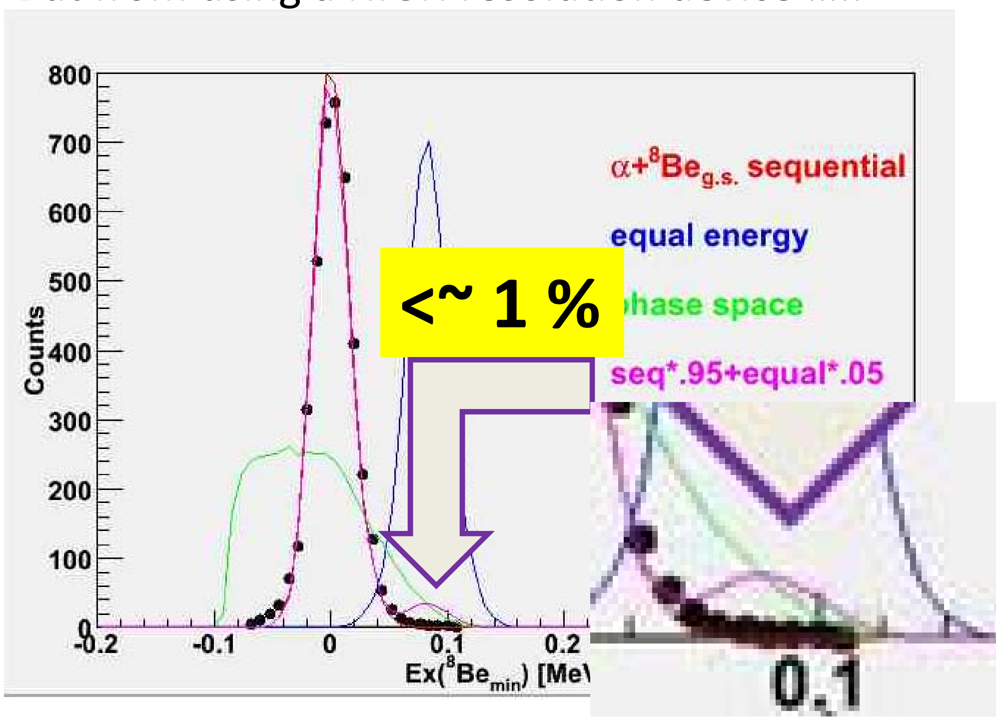
Evidence for α-particle condensation in nuclei from the Hoyle state deexcitation

Ad.R. Raduta[a,b,*], B. Borderie[a], E. Geraci[c,d,e], N. Le Neindre[a,f], P. Napolitani[a], M.F. Rivet[a], R. Alba[g], F. Amorini[g], G. Cardella[c], M. Chatterjee[h], E. De Filippo[c], D. Guinet[i], P. Lautesse[i], E. La Guidara[c,j], G. Lanzalone[g,k], G. Lanzano[c,1], I. Lombardo[g,d], O. Lopez[f], C. Maiolino[g], A. Pagano[c], S. Pirrone[c], G. Politi[c,d], F. Porto[g,d], F. Rizzo[g,d], P. Russotto[g,d], J.P. Wieleczko[l]

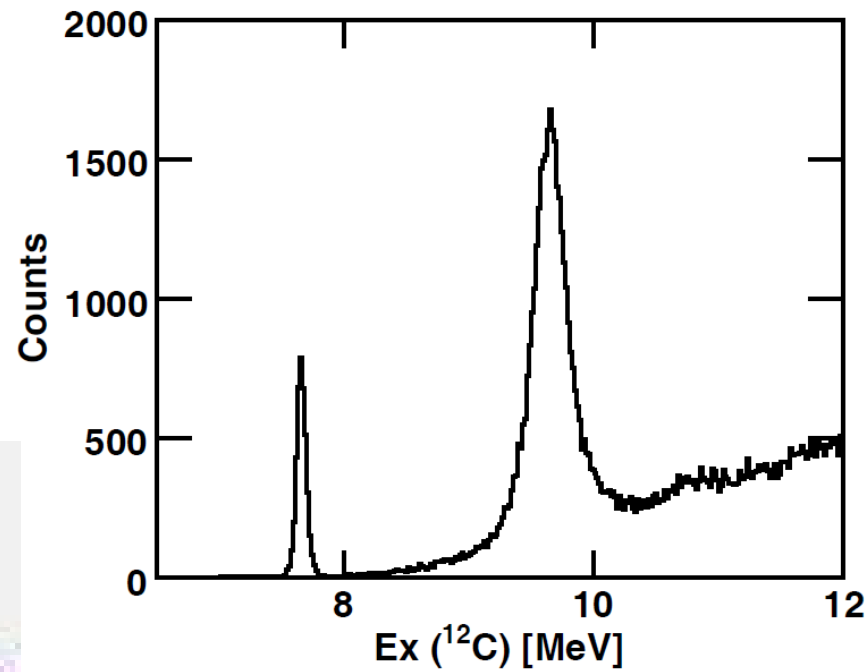


Result ➔ 7.5 +- 4.0 %

But from using a HIGH resolution device …..

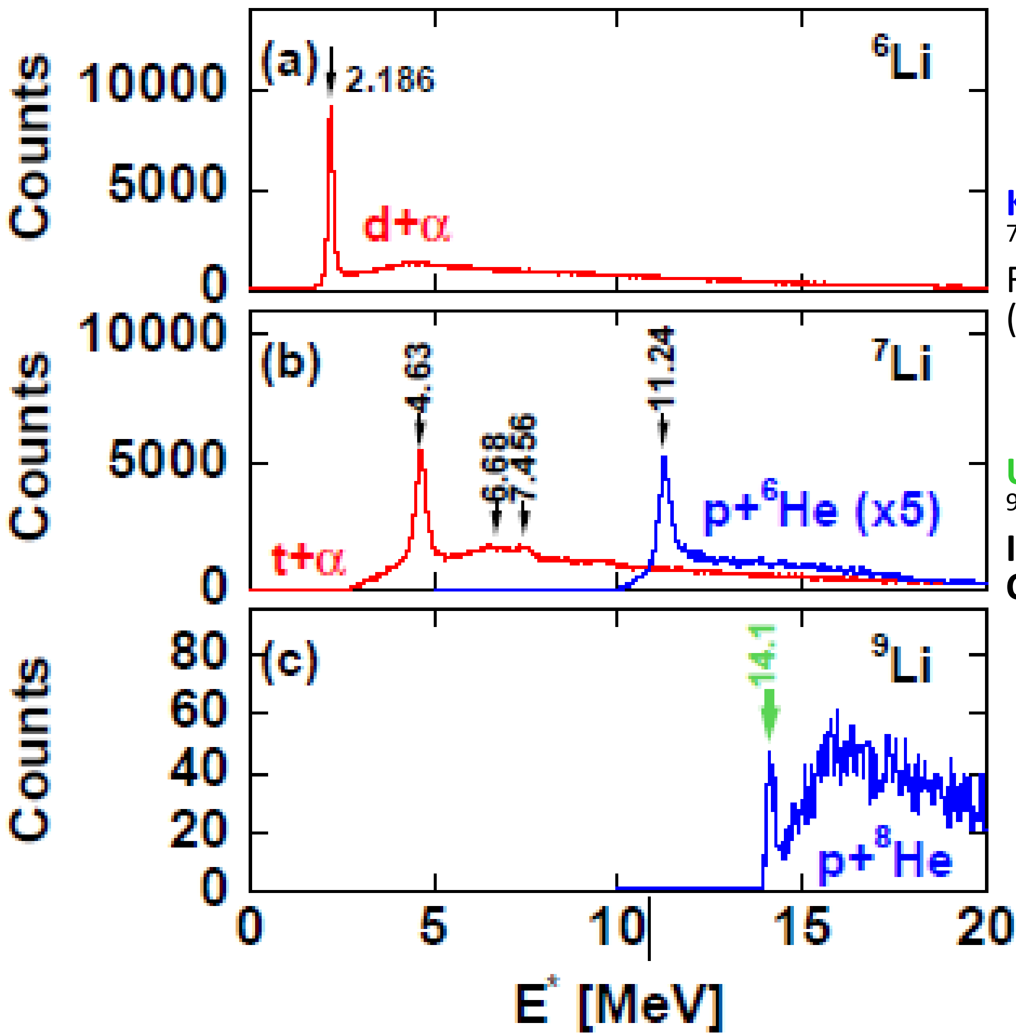


<~ 1 %



Physics ← RESOLUTION

F. A new state in ^{9}LI is it 9LiIAS (of 9He)?
Secondary beam of ^{12}Be ($t_{1/2}$ = 24 ms) ➔ Smash it up
Look in debris using particle-particle correlations



Known
^{7}He analog in ^{7}Li
Resonance ⇦⇨ Resonance
(I = 3/2-, T=3/2)

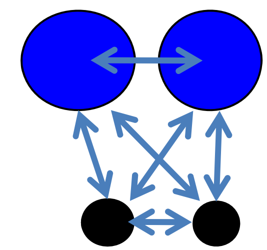
Unknown
^{9}He analog in ^{9}Li (I =1/2, T=5/2) ?
Its ~600 keV lower than "expected".
Could be Thomas-Ehrman shift
BUT
It would be a shift when the reference is unbound.
(Logic ????)

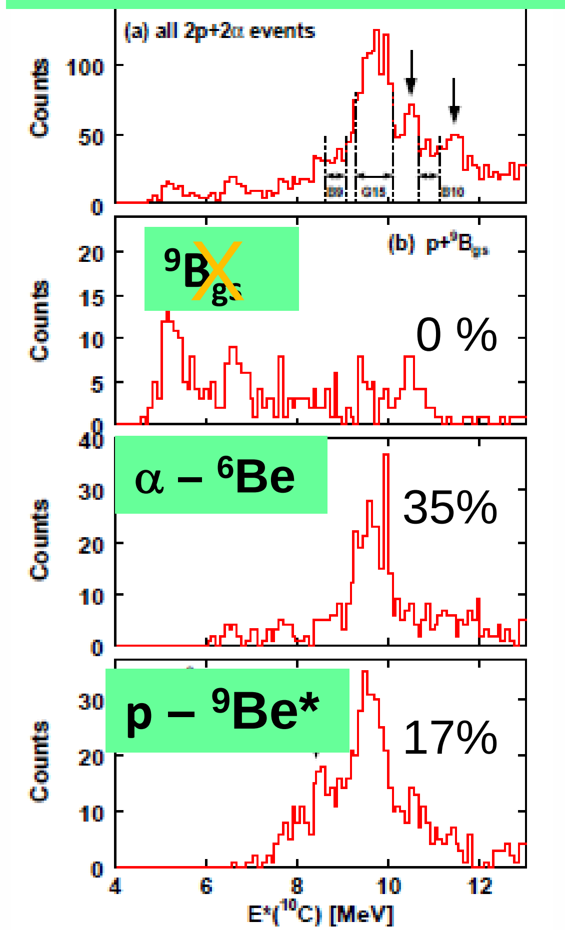
G. Another new state in $^{10}C^*$ at $E^* = 9.7$ MeV

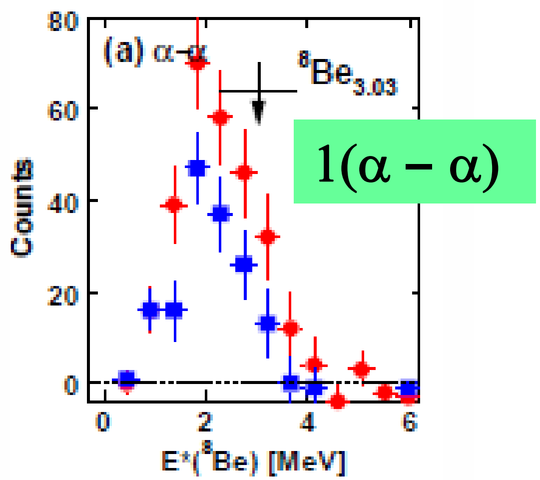
17 % + 35 % boring, but the other 50 % displays a highly unusual & highly (4-body) correlated decay

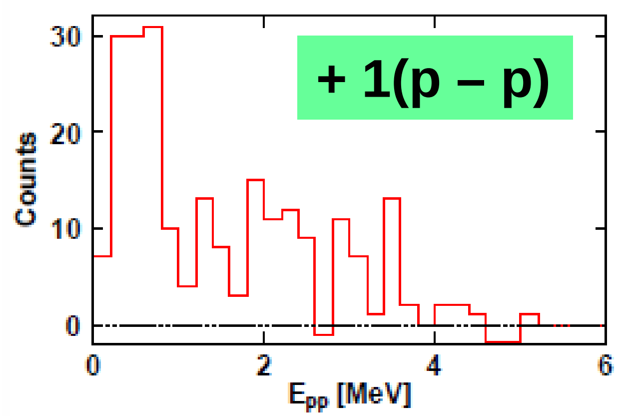
➔ $1(p\text{-}p) + 4(p\text{-}\alpha)_{5Li} + \sim 1(\alpha\text{–}\alpha)_{\sim 8Be(2+)}$

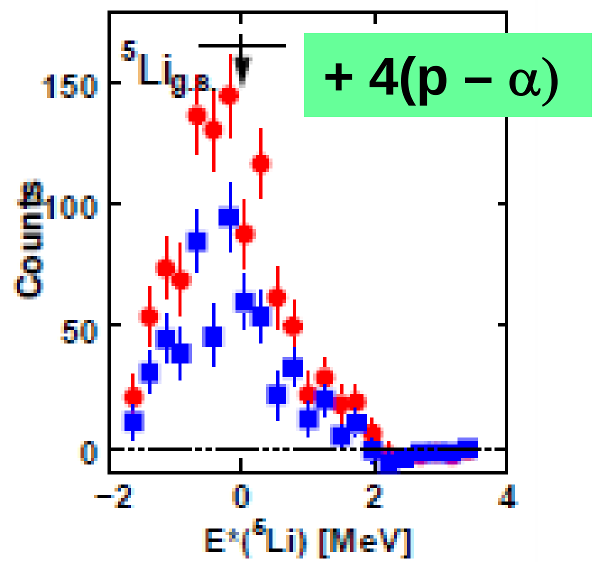
A “menage a quatre” state.









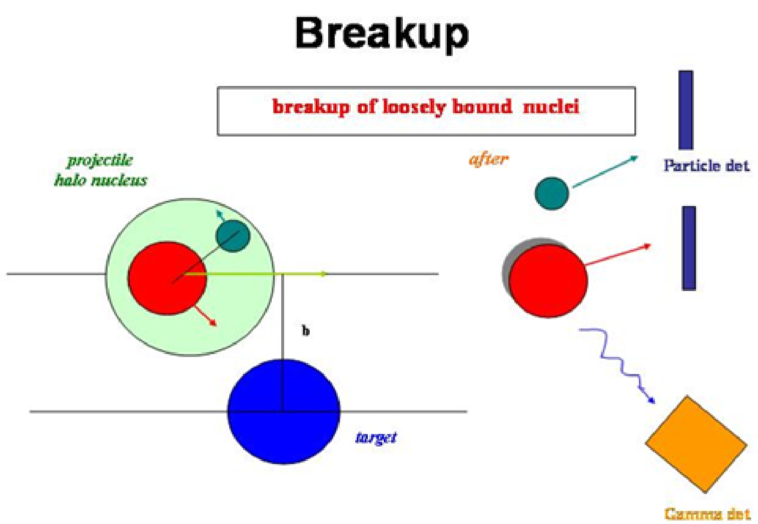


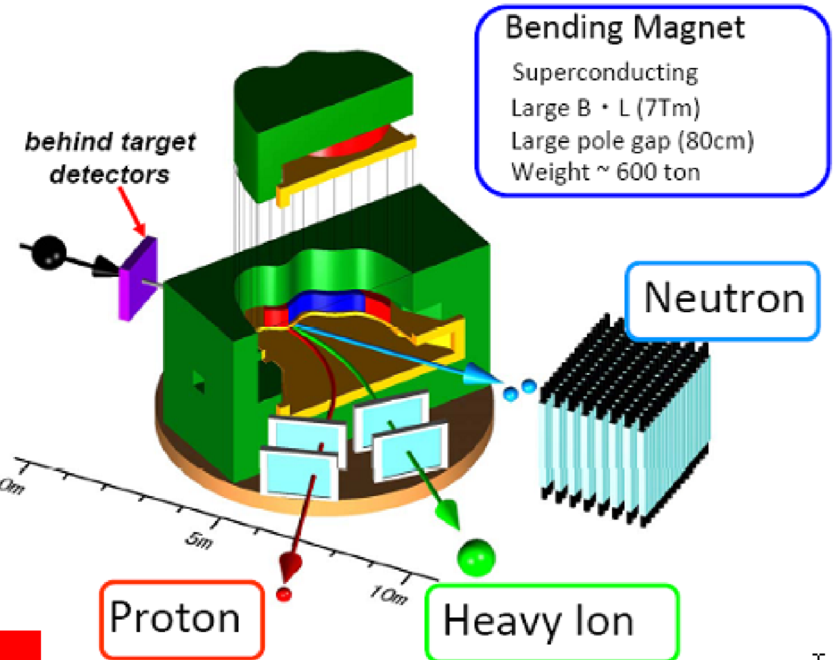
And the rest ?

Some correlations unavoidable !

LI +HI tracking
(for breakup reactions)
After target
Before SAMURAI

PRESENT PROBLEM





Before magnet need to track BOTH

HI and protons.

Tacking means (x,y) at two positions

Energy Loss in 300 um Si (69.6 mg/cm^2)

Z	Ion	100 MeV*A	200 MeV*A	400 MeV*A	[dE(Z)-dE(Z-1)]/dE(Z) At 400 MeVA (same A)
1	**p**	**0.404**	**0.250**	**0.170**	
3	^{6}Li	3.6	2.7	1.5	
6	^{12}C	14.6	9.1	6.1	29.7%
8	^{16}O	26.1	16.1	11.0	
10	^{20}Ne	40.9	25.4	17.3	19.2%
14	^{28}Si	80.5	49.9	34.0	
18	^{40}Ar	133.	82.7	56.4	10.9%
20	^{40}Ca	164.	102.	165.	
26	^{56}Fe	277.	173.	118.	7.6%
30	^{64}Zn	368.	231.	158.	
36	^{86}Kr	526.	333.	229	5.4%
40	^{90}Zr	645.	411.	284	
50	^{120}Sn	986.	641.	447.	4.0%

Papers on or using HINP chip

Technology:	G. L. Engel, et al., NIM **A 573**, 418 (2007). G. L. Engel, et al., NIM **A 612**, 161 (2009). G. L. Engel, et al., NIM **A 652,** 462 (2011).
^{6}Be:	L.V. Grigorenko, et al., Phys. Rev. C **80**, 034602 (2009). L.V. Grigorenko, et al., **Phys. Lett. B** **677**, 30 (2009).
^{8}C and ^{8}B$_{IAS}$: **+ misc**	R. J. Charity, et al., **Phys. Rev. C** **82**, 041304(r) (2010). R. J. Charity, et al., Phys. Rev C **84**, 014320 (2011).
^{10}C:	R. J. Charity, et al., Phys. Rev. C **75**, 051304(R) (2007). K. Mercurio, et al., Phys. Rev. C **78**, 031602(R) (2008). R. J. Charity, et al., Phys. Rev. C **80**, 024306 (2009).
^{12}Be:	R. J. Charity, et al., Phys. Rev. C **76**, 064313 (2007).
Misc:	R. J. Charity, et al., Phys. Rev. C **78**, 054307 (2008).
SF from (p,d):	Jenny Lee, et al., **Phys. Rev. Lett.** **104**, 112701 (2010). Jenny Lee, et al. Phys. Rev. C **83**, 014606 (2011).
rp-process:	A. M. Rogers, et al., **Phys. Rev. Lett.** **106**,252503 (2011).

Isospin symmetry breaking: R. J. Charity, et al., Phys. Rev. C. in press (2011).

Hoyle state decay:	J. Manfredi, et al., Manuscript in preparation.

This productivity has come from the CMOS chip being useful
FOR many different detectors and configurations and AT different accelerator labs.
THANK YOU

Extra’s

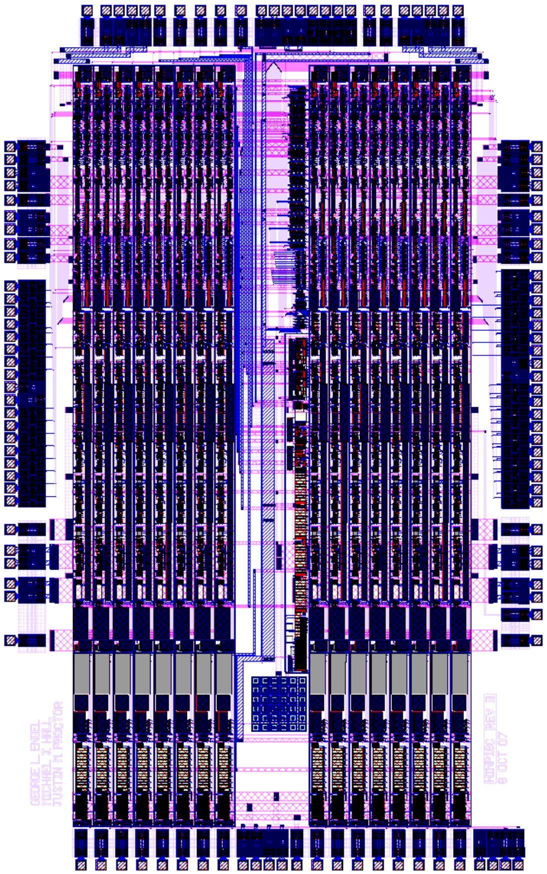
Plan for RIKEN

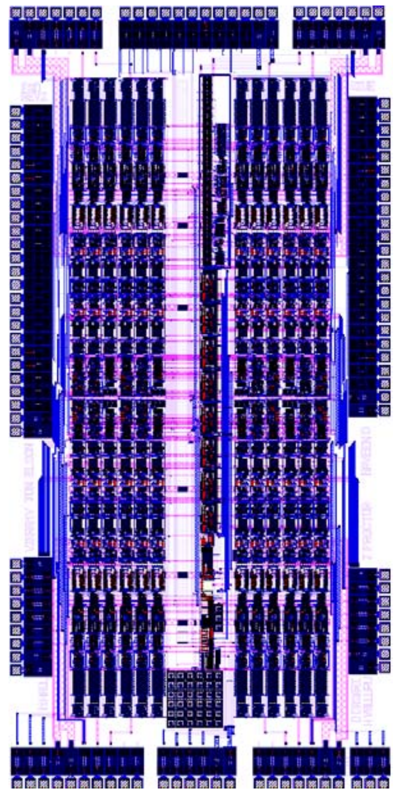
1. Proposed geometry
   a) "GLAST" Si, 384 strips, 228 um pitch ➔ 5 SSD's
   b) MICRON TTT (128 strips, 758 um pitch) ➔ 2 DSSD's + 1 SSD
2. Design/create very large dynamic range CSA (VLDR-CSA)
3. Design/create sqrt compressional amp.
4. HINP (upgrade REV-IV)
   a) Fix logical error and make time output independent of temp.
   b) Extended range option with Knee
   c) Change selectable gain ranges to 50/175 MeV, 150/400 MeV (linear/knee)
   d) Move ADC onto CB. (This reduces readout time and eliminates need for VME QDC.)

WU – SIUE ASIC development effort

HINP-16c and **PSD-8c**

For Si-strip detectors for scintillators

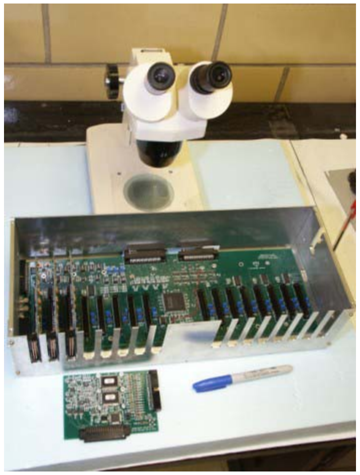


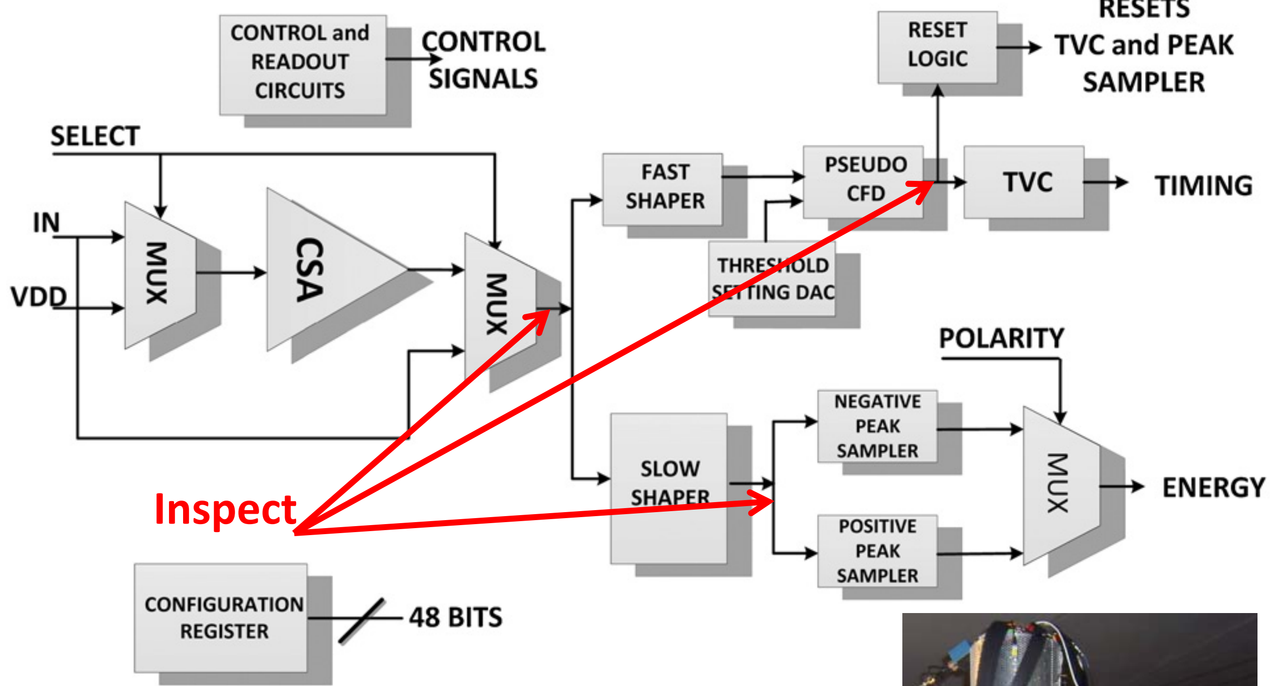


(Both configured for 32-channel operation, but only implemented 16(8) to save $'s.)

HINP-16C

G.L. Engel, M. Sadasivam, M. Nethi, J.M. Elson, L.G. Sobotka, R.J. Charity
A Multi-Channel Integrated Circuit for Use in Low-and Intermediate-Energy Nuclear Physics - HINP16C, *Nucl. Instru. Meth. A, 573, 418-426 (2007).*

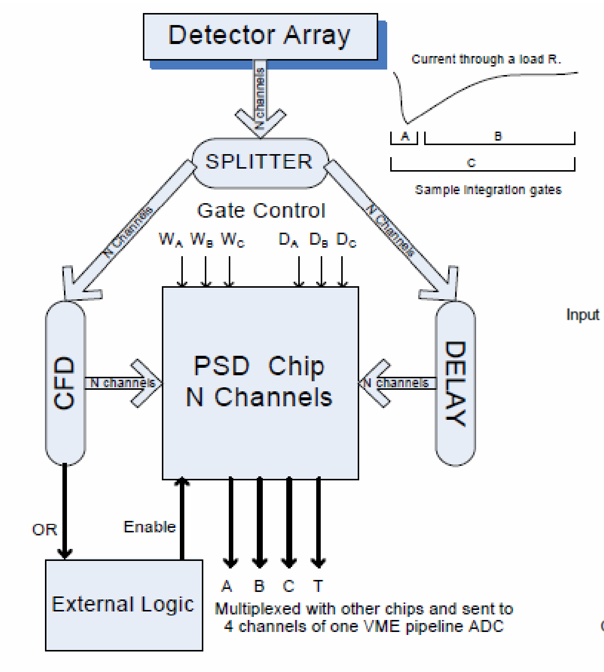


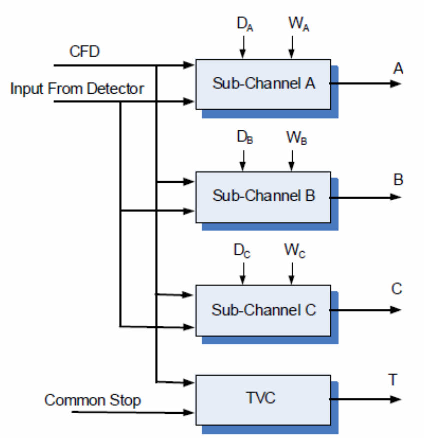


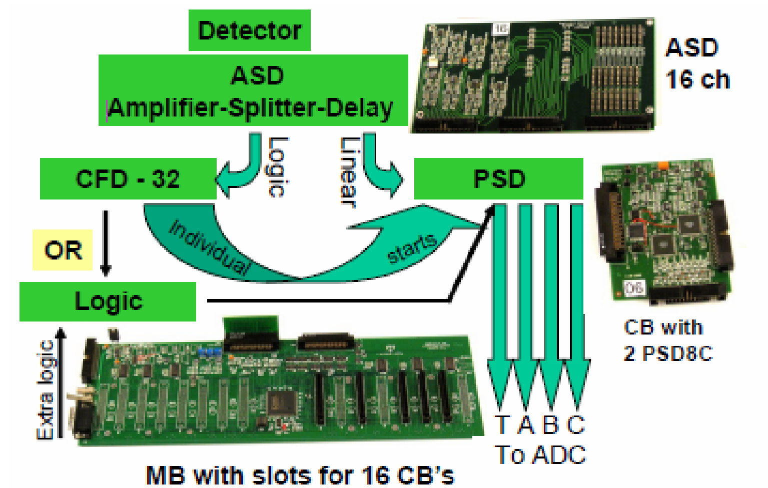
1. Two internal CSA's (80 and 300 MeV ranges)
2. External CSA option
3. TCV
4. 32 ch/Chip Board/ 512 ch/Mother board
5. All pipelined into ADC
6. As of 8/2011 there are 12 (science) + 2 (technical) papers in print using or about HINP.
7. Used by (or will shortly be used by): WU, MSU, IU, ORNL, TAMU, LSU, FSU, RIKEN, ND

PSD-8C

G.L. Engel, M.J. Hall, J.M. Proctor, J.M. Elson, L.G. Sobotka, R. Shane, R.J. Charity, Design and Performance of a Multi- Channel, Multi-Sampling, PSD-Enabling Integrated Circuit, *Nucl. Instru. Meth. A, 612, 161-170 (2009)*





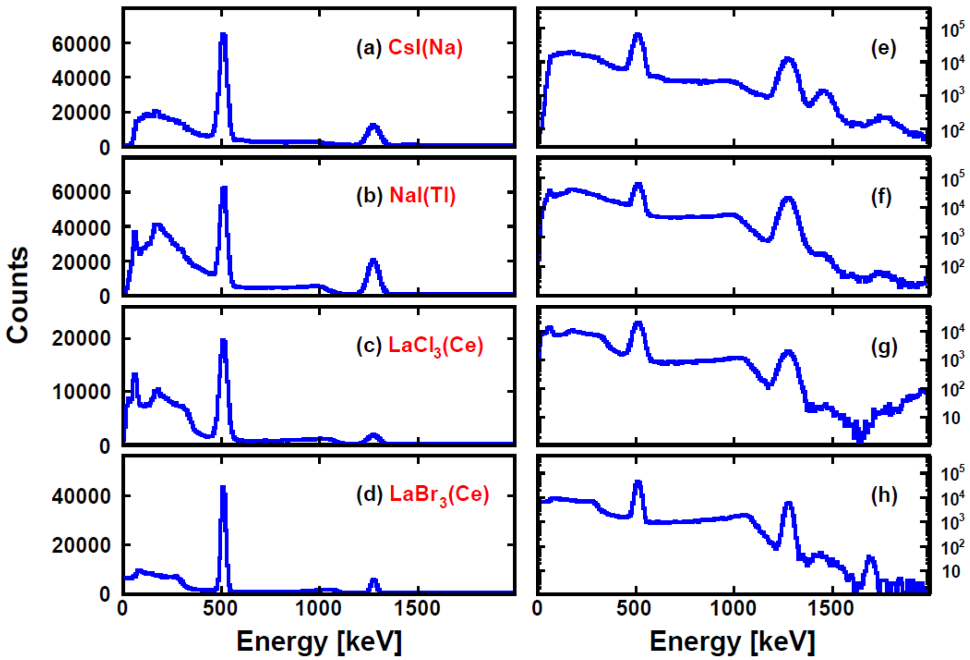


1. External CFD (32C CFD designed at WU – CAMAC)
2. Three integration regions (A,B, abd C) start and width user controlled
3. TVC circuit
4. A, B, C and T, piped to On CB ADC's.
5. VME only needs XLM-XXV

PSD -8C performance

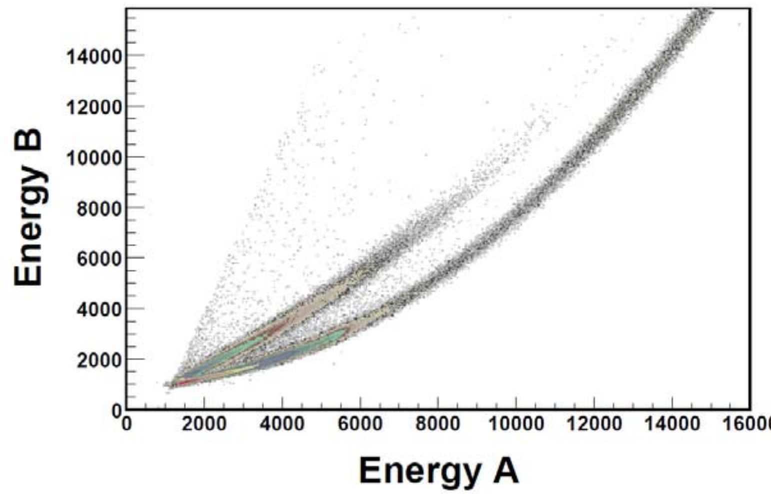
Single gate on various scintillators

^{22}Na



BC-501

^{252}Cf



Two tech. papers + two projects in the works.

One of these is a DTRA (LANL) project using **CLYC**

HINP PSD

HINP

1. Fix only major existing problem (auto reset)
2. Extended-range CSA (see below)
3. Move ADC('s) to CB [like ➔ PSD]
4. Companion external CSA (Bipolar, 380 nm)
5. Satisfy all the users.

New chip submission expected early 2012.
In the meantime make a few more 1000 chs
Using existing chip.

PSD

1. Work with LANL to make directional n/γ hand-held monitor.
   LANL has already submitted a paper using PSD-8C
2. Work with Sarantites for forward Position-sensitive phoswich.