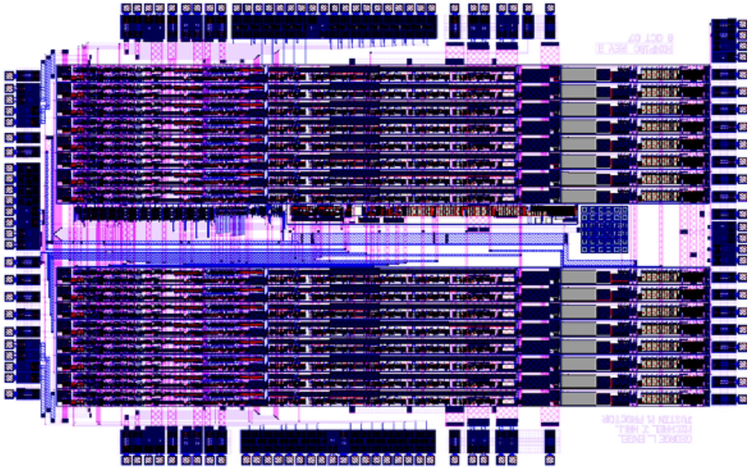
ASIC tool bag:
What have we got, what will we have
and how these tools impact NEUTRON DETECTION

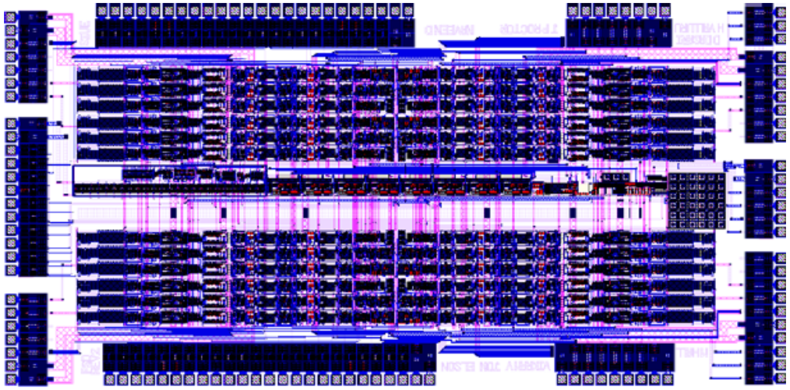
HINP-16ch

For Si-strip detectors



PSD-8ch

scintillators



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

Testing of new PSD to start soon, submit 16-ch CFD chip in July, new HINP 2019.

May 2018

Present usage

Institution	Device	~ # of channels
HINP		
MSU-WU-WMU	HiRA Array	> 2000
ORNL-RUTGERS	S-ORUBBA	~ 2000
LSU-FSU	ANASEN	~ 1000 (lost track)
TAMU	FAUST	~ 512
RIKEN	HI/p tracking	~ 1000
ND	??	~ hundred

3 technical & ~ 25 science papers have been published (by us) about & using HINP-16C.

PSD		
LANL	pointer survey meter	16*
WU	Scint Wall (DGS)	256 → 512
FSU (perhaps)		

3 technical papers + few science papers .... And*

* Perhaps coming to some "first-responders" near you.

Technology and light-nuclei continuum spectroscopy papers

Technology:	G. L. Engel et al., NIM **A 573**, 418 (2007).	HINP
	M. S. Wallace et al., NIM **A 583**, 302 (2007).	HIRA
	G. L. Engel et al., NIM **A 612**, 161 (2009).	PSD improvements ported to HINP
	G. L. Engel et al., NIM **A 652,** 462 (2011).	HINP + PSD

A = 5 ➔ ^{5}H and ^{5}Be — Wuosmaa et al., Phys. Rev. C **95,** 014310 (2017); R. J. Charity et al. in preparation (2018).

^{6}Be: — L.V. Grigorenko et al., **Phys. Lett.** B **677**, 30 (2009); L.V. Grigorenko et al., Phys. Rev. C **80**, 034602 (2009).
I.A. Egorva et al., **Phys. Rev. Lett.** 109, 202502 (2012).

^{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).
K. W. Brown et al., Phys. Rev. C **90**, 027304 (2014).

AAS — *J. Okolowicz, M. Ploszajczak, R. J. Charity and L. G. Sobotka, Phys. Rev. C* ***97****,044303 (2018).*

^{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).

T = 5/2➔^{11}Li,^{11}Be,**^{11}B** — R.J. Charity et al., Phys. Rev. C **86**, 041307 (**R**) (2012).

^{12}C (Hoyle) — **J. Manfredi** et al., Phys. Rev. C **85,** 037603 (2012).
^{12}O + ^{12}N$_{IAS}$ — **M. Jager** et al., Phys. Rev. C **86**, 011304 **(R)** (2012).
^{11}O + ^{12}O — **T. Webb** et al., **close to submission** (2018).
^{12}Be: — R. J. Charity et al., Phys. Rev. C **76**, 064313 (2007).

^{13}O decay and ^{12}N (2-) — L. G. Sobotka et al., Phys. Rev. C **87**, 054329 (2013).

^{16}Ne (3-body) — **K. W. Brown** et al., **Phys. Rev. Lett. 113,** 232501 (2014), **K. W. Brown** et al., Phys. Rev. C **92,** 034329 (2015).

^{17}Na + (^{8}B,^{9}B,^{9}C,^{16}F) — **K. W. Brown** et al., Phys. Rev. C **95,** 044326 (2017).

^{17}Ne (alignment +) — R.J. Charity et al., Phys. Rev. C in press (2018).

Misc (inc. ^{9}Li*,^{10}Be*): — R. J. Charity et al., Phys. Rev. C **78**, 054307 (2008).

Isospin symmetry breaking — R. J. Charity et al., Phys. Rev. C. **84**, 051308 (**R**) (2011).

Alignment ^{6}Li, ^{7}Be: — R. J. Charity et al., Phys. Rev. C. **91**, 024610 (2015).
^{7}Li — **D.E.M. Hoff** et al., **Phys. Rev. Lett. 119**, 232501 (2017); **D.E.M Hoff** et al. Phys Rev. C in press (2018).

Overview

Have made several generations of both HINP (for Si) and PSD (for scintillators).

They work but we can do better!

➔ New **PSD** has been FABed and we expect it in house very soon.

➔ A 16-ch **CFD** has been designed and it will go out for FAB this summer.

➔ New **HINP** is being designed. Expect to be ready to submit by end of 2018.

<u>These will be the last (for my career) for these chips.</u>

1. **HINP** will have better resolution, have lower power & be easier to use.
2. **PSD + CFD** will make 1000+ch n detectors **duck soup**.

Last HINP

OBJECT: **Extend range and reduce thresholds present HINP design**

CHANGES: New Charge amp, dual (live) shapers,
New peak detectors (CDS from BNL design),
CFD has 10x added to LE,
Differential off chip, ADC's on CB (250 MHz dig ALL – high, low, time - parallel)
E_{high} (100 MeV), E_{low} , (400 MeV), T (2 or 4 us options) streams
digitized in parallel on CB ➔ XLM-XXV
Each XLM ➔ 1000 ch (2000 ch if make 32-ch chip)

Two simultaneous gain ranges: **~**100 and ~400 MeV
linear to ~ 75 % of ranges then compressive ➔ go to HIGHER than nominal range

Thresholds: ~ 250 keV

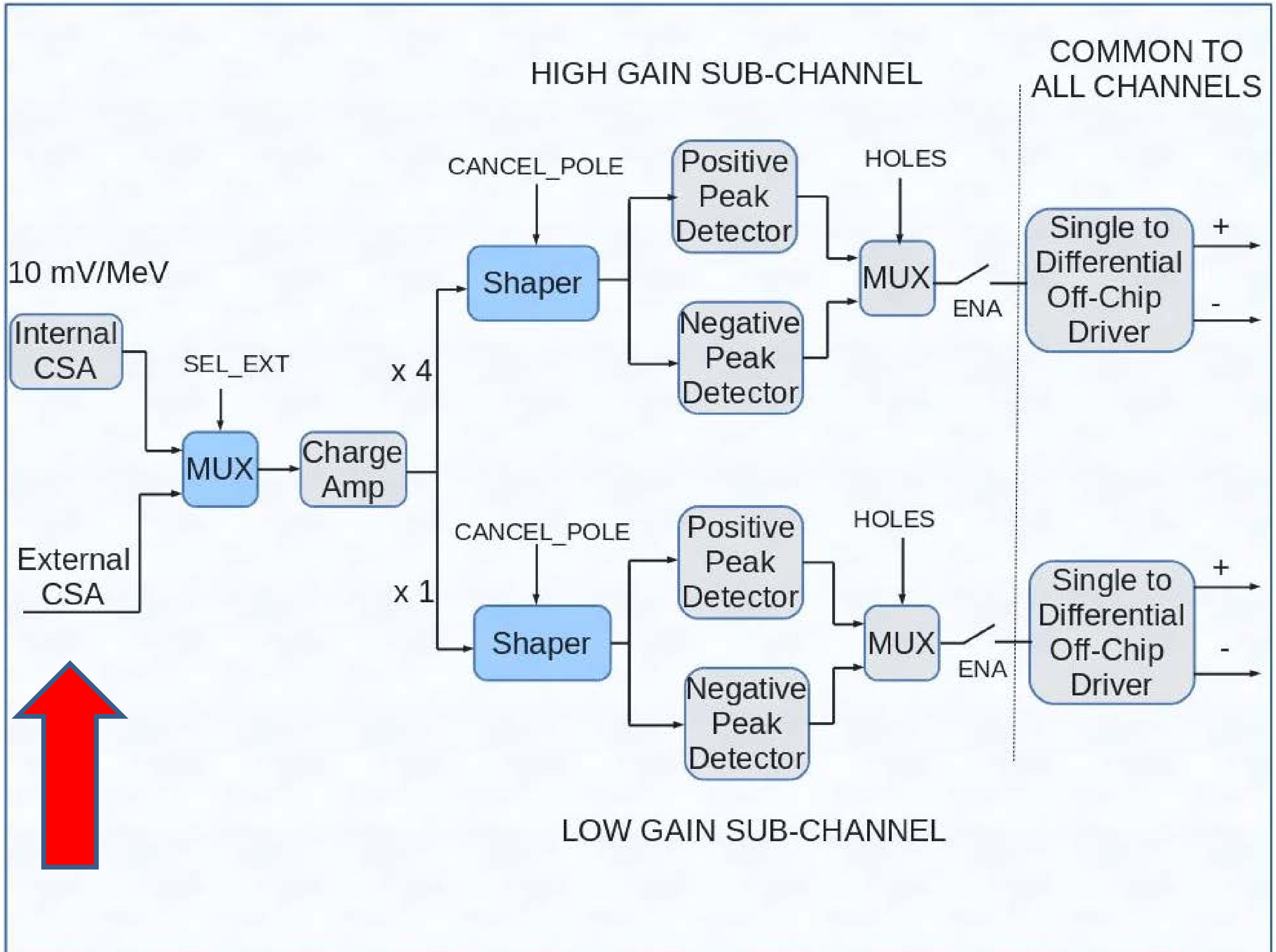
Resolution: ~ 50 keV (high gain) ~ 100 keV (low gain)

Down side: **This version does *not* allow the user to use an external CSA.**

Errors on HINP-4.

1. Logical - Required FPGA gymnastics to properly down load. (Seems to work – phuu !)
   ➔ downloading slow (will be a few s/512 ch)
   ➔ Could influence time resolution on +ve polarity
2. We think a component in the peak sensor is undersized making some channels compressive.

Next HINP (2019)



Switch process
From
AMI 5.0 V 0.5 um (C5N)

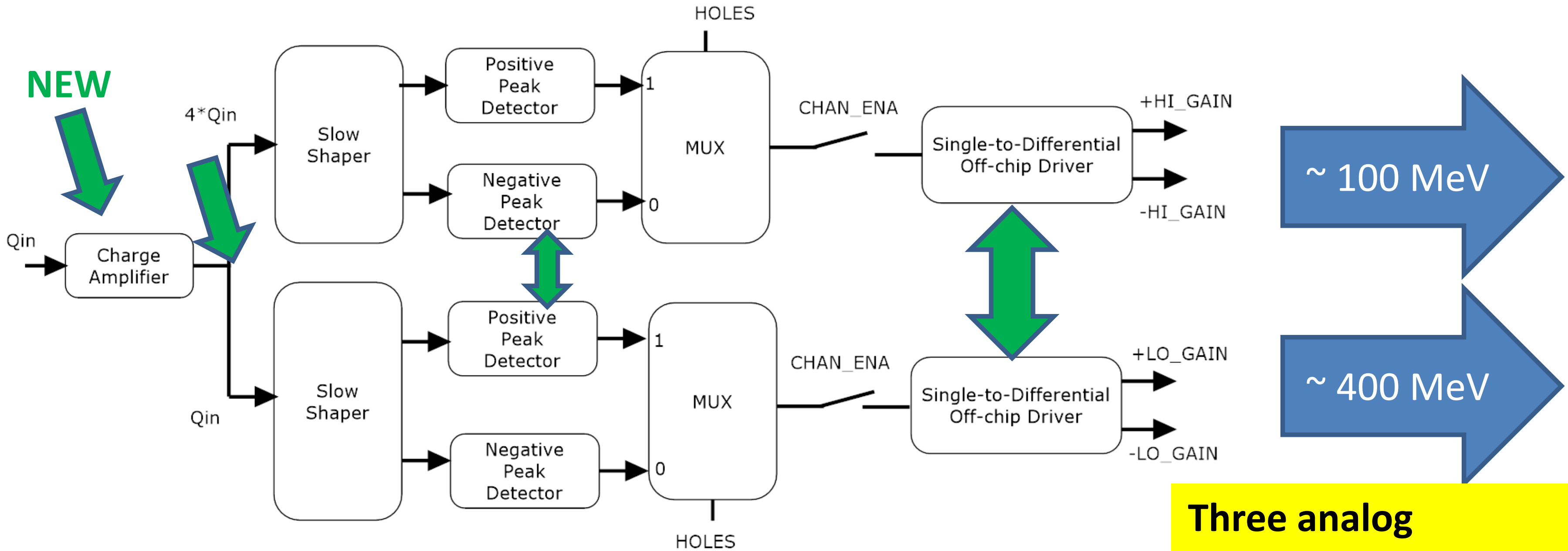
To
3.3 V AMS C35 process.

External CSA
Improved
Resolution & linearity

Change to 3.3V removes
25% of components
From CB
Slightly lower power

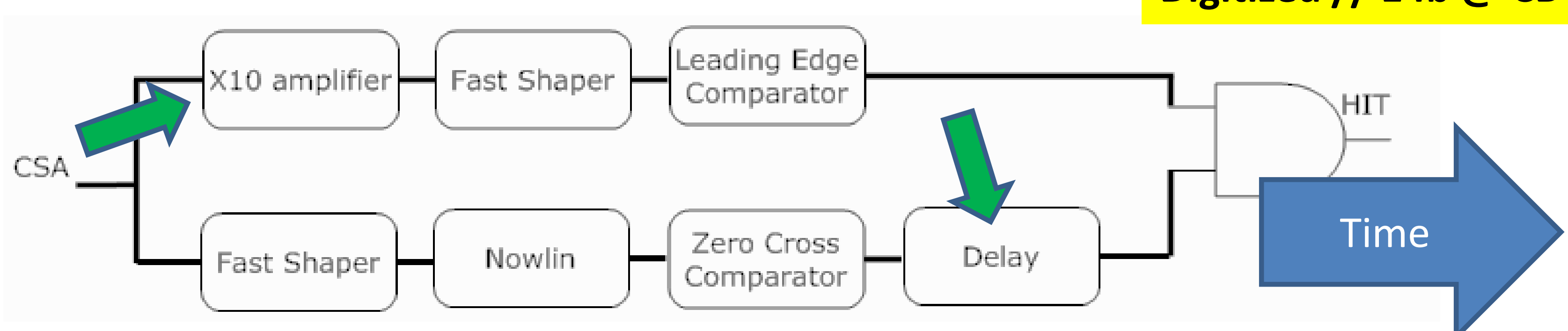
NO ERRORS

Energy Branch Block Diagram (much is new)



Three analog Streams Digitized // 14b @ CB

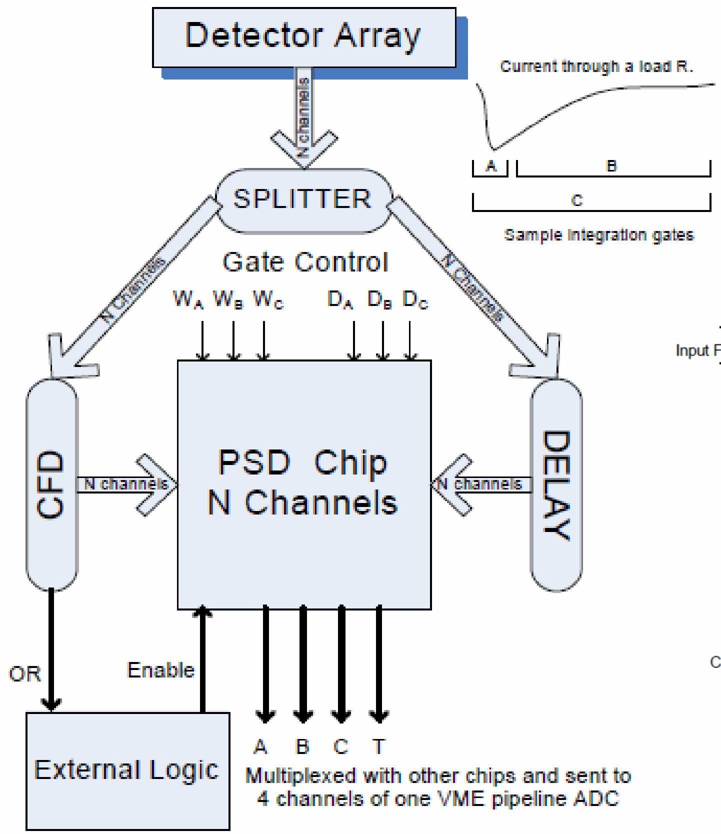
CFD Block Diagram

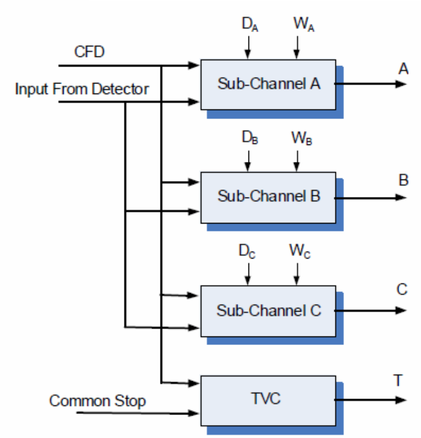


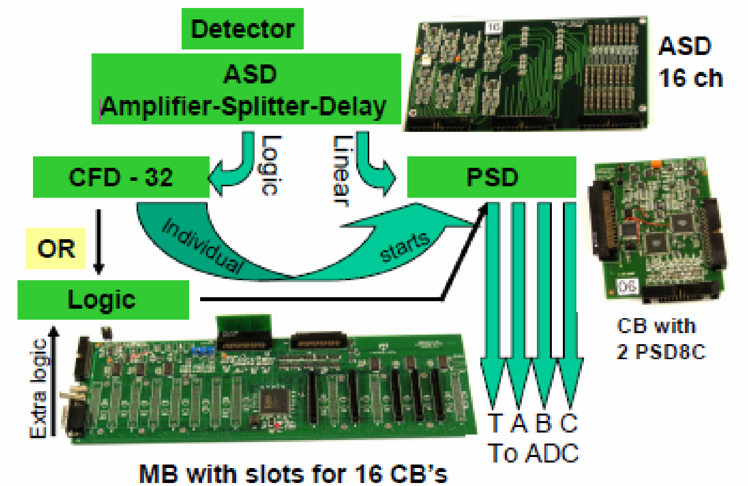
CSA signal comes from first op amp in the slow shaper of the high-gain branch.
Digital delay block in zero-cross leg compensates for delay through x10 amplifier.

In service 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)*







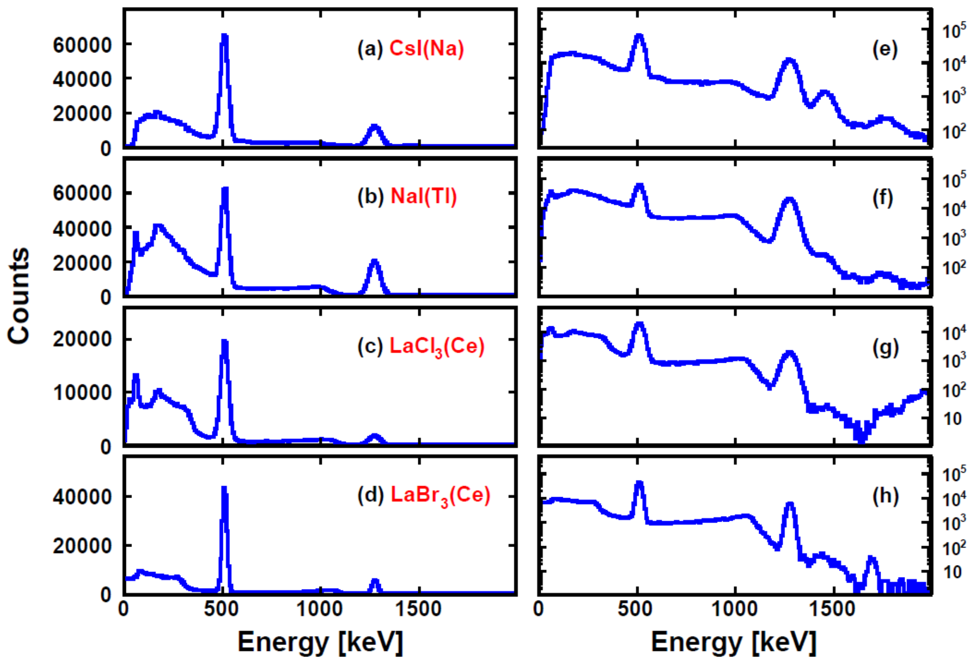
Four analog Streams Digitized // 14b @ CB

1. External CFD (32-ch CFD designed at WU – CAMAC)
2. Three integration regions (A,B, and C) start and width user controlled
3. TVC circuit
4. Analog A, B, C (integrators) and T streams piped to **On CB ADC's**.
5. One VME XLM-XXV ➔ 2 x 256 channels

PSD -8C performance

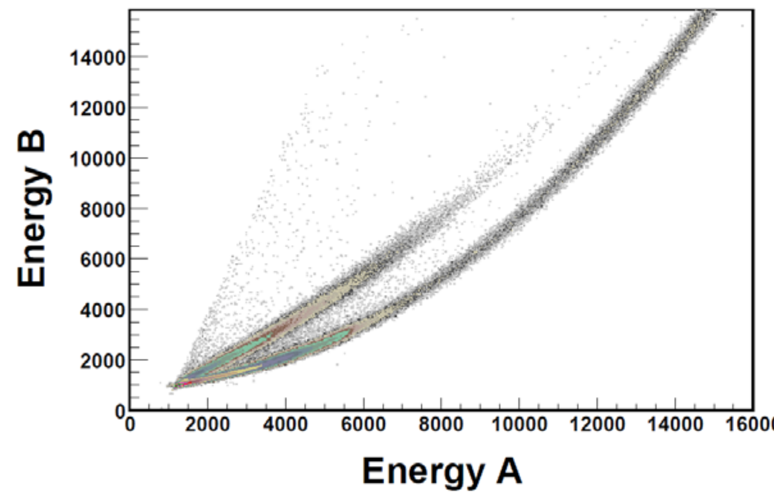
Single gate on various scintillators

^{22}Na



BC-501A

^{252}Cf

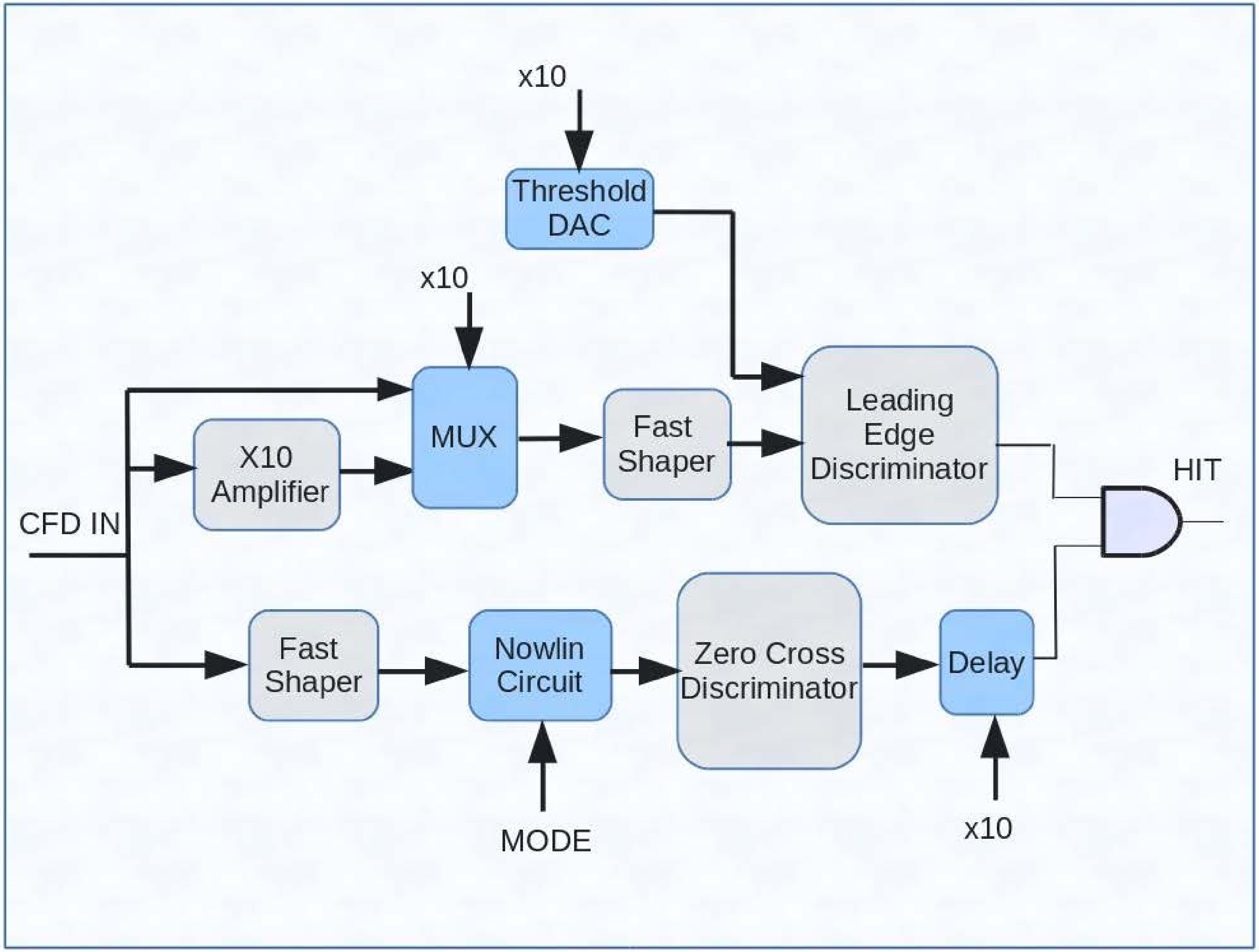


Two tech. papers + two projects in the works.
One of these is a DTRA (LANL) project using **CLYC**

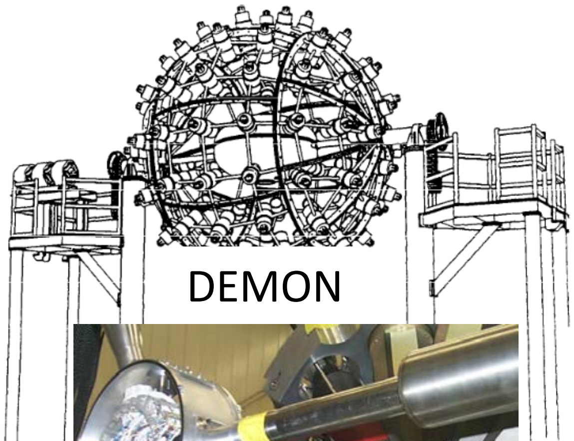
➔NEW PSD has simplified and improved time resolution, expect < 300 ps.
➔ Will be compatible with 3.3 V FPGA's (CB 75% the component count.)
➔Compatible with CFD ASIC.

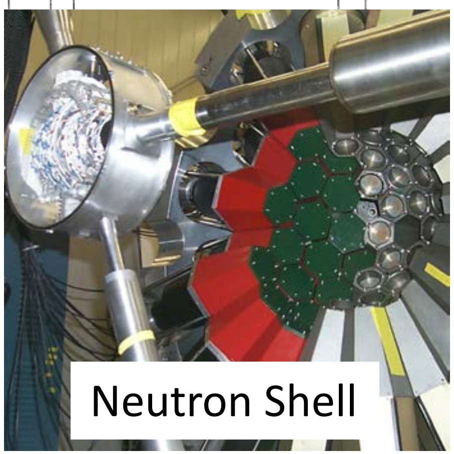
CFD-16c

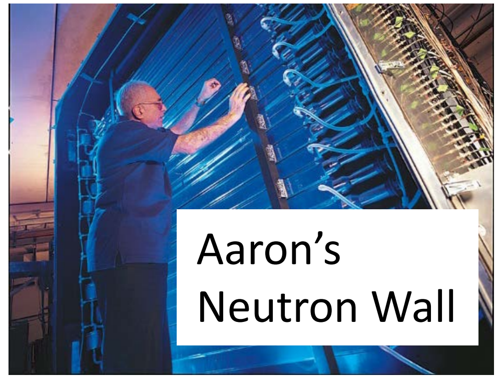
Simulated (designed for) liquid scint. to CsI(Tl)

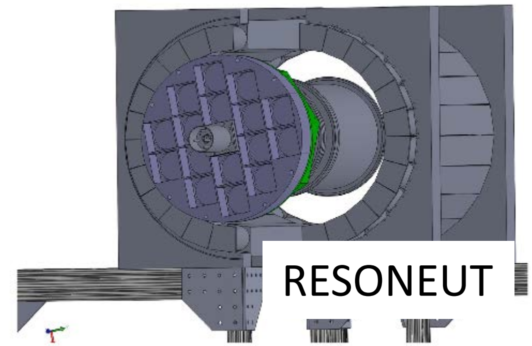


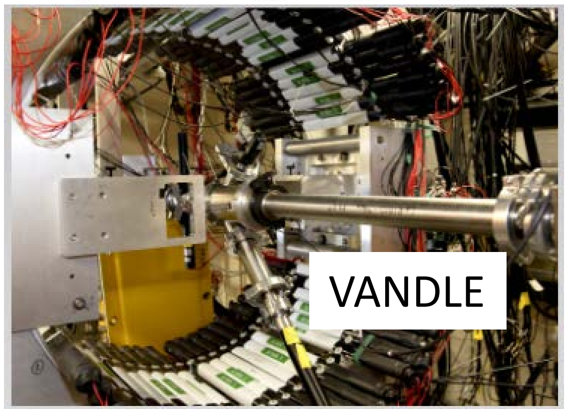
Some of the considerable n-detector array efforts

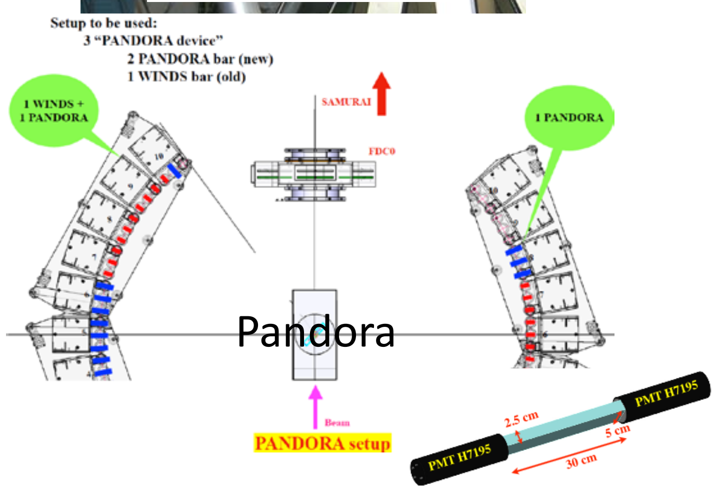


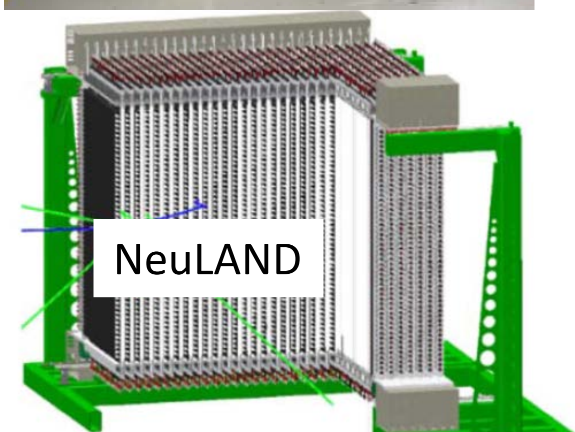












Some interesting problems
1n, 2n, np + residue invariant mass spectroscopy.

1. $^{8}Li_{IAS}$
2. Three-body photo disintegration of t
   (a two-neutron correlation experiment)
3. ^{9}Li E* = 14.1 MeV – why are there “tuned” resonances?
   This resonance is “tuned” to CP threshold BY open neutron channel.
4. ^{26}O – it is no accident that the 2-n separation energy is
   ~ ZERO
5. Correlations in $^{8,10}He^{*}$ decay. (^{5}H – likely not worth it.)
6. Decay of $^{11}Be_{IAS}$ (analog of $^{11}Li_{gs}$) – n-p correlation

Tools   Issues

Scintillators

Fast plastic
Liquid (~BC-501A)
p-terphenyl (and inorganic possibilities)
EJ-276

Light transducers

PMT's (glass or small metal)
MA-PMT's
SiPM's

1. Resolution: time and pos ➔ Size/vol. hurt
2. Efficiency: size vs layers ➔Size/volume help
3. 2n vs n-scattering differentiation
   - Contiguous hurts
   - Ability to stagger helps
   - multi-anode PMT's hurt (x-talk, fix geo.)
4. Invariant mass (w fast beams) vs neutron spectra from stopped decay

Signal Processing

	DSP	*vs*	*ASIC ("PSD+CFD")*
PSD	best		good
Timing	probably best		very good
Anal. Flexibility	can't be better		Limiting but fine if information discrete (not continuous)
Cost	likely prohibitive ch > 100 impacts transducer choices.		not an issue Ch < 1000
Size/power	not bad		suits itinerant exps

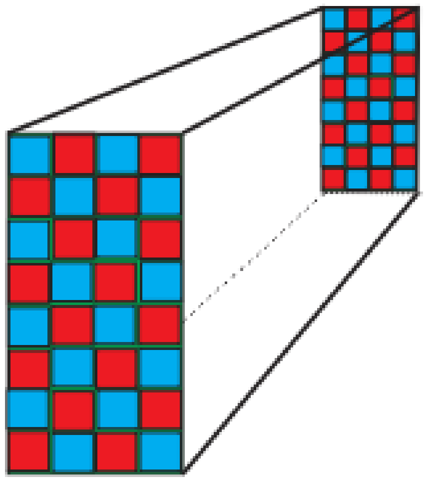
➔ Present exercise: "Poofing" (i.e. dreaming) unencumbered by ch count ➔

Four concepts to follow (A-D) …. each interesting to think through.

Concept A (modern Aaron)

ONE liquid volume optically separated into hundreds of “straws” each with square cross section

R11265U-M4



32 or 128 straws, read out on both ends

64 or 256 ch/block

Realistic expectations

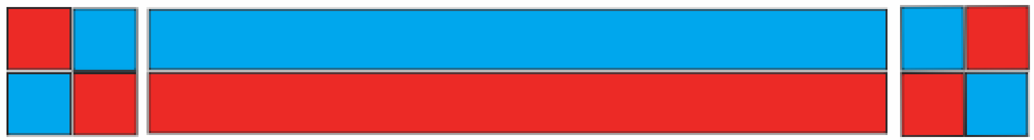
10 mm x 300 mm “staws”
10 x 10 x ~25 mm boxcells
300 ps timing

Good compromise …
Use small normal
end-on PTM on one end.

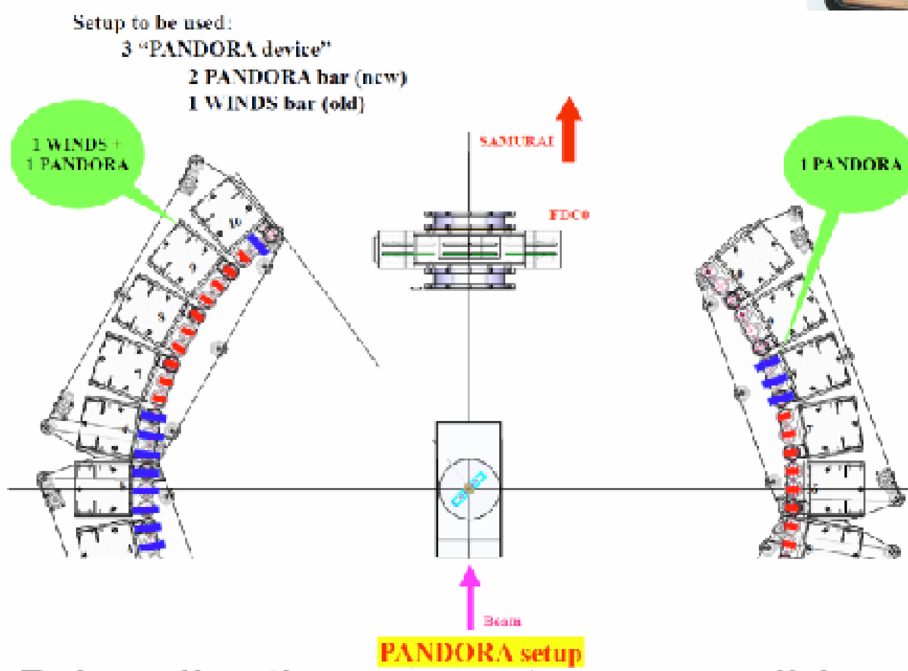
Inexpensive
(Could make many such “blocks”)
The
GOOD: timing and 2-D localization
BAD : poor third dimension, Cannot stagger

Concept B

Modular with EJ-276 square, optically separated, square “straws”
10 mm x 10 mm cross section is a good compromise.



Arrange a la
Pandora or VANDLE



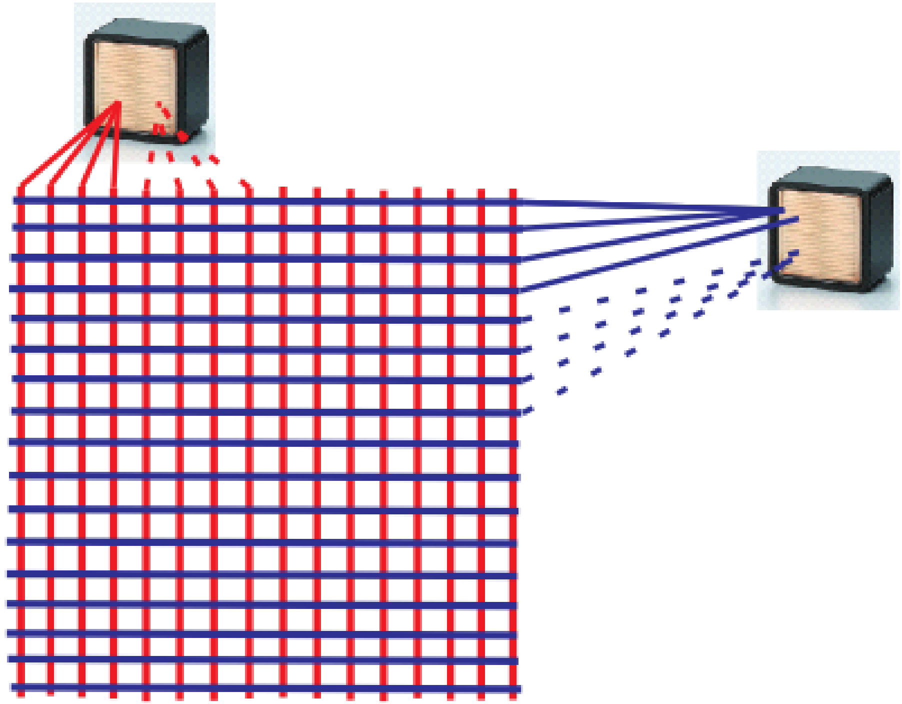
GOOD: timing and 2-D localization, can stagger, solid
BAD : poor third dimension

Idea: To promote internal reflection, surround by thin layer of PMMA (n=1.49) or water (1.33).

Concept C

"Fiber" EJ (a development project).
This is for E_n > 5 MeV (range of recoil ~ fiber width)

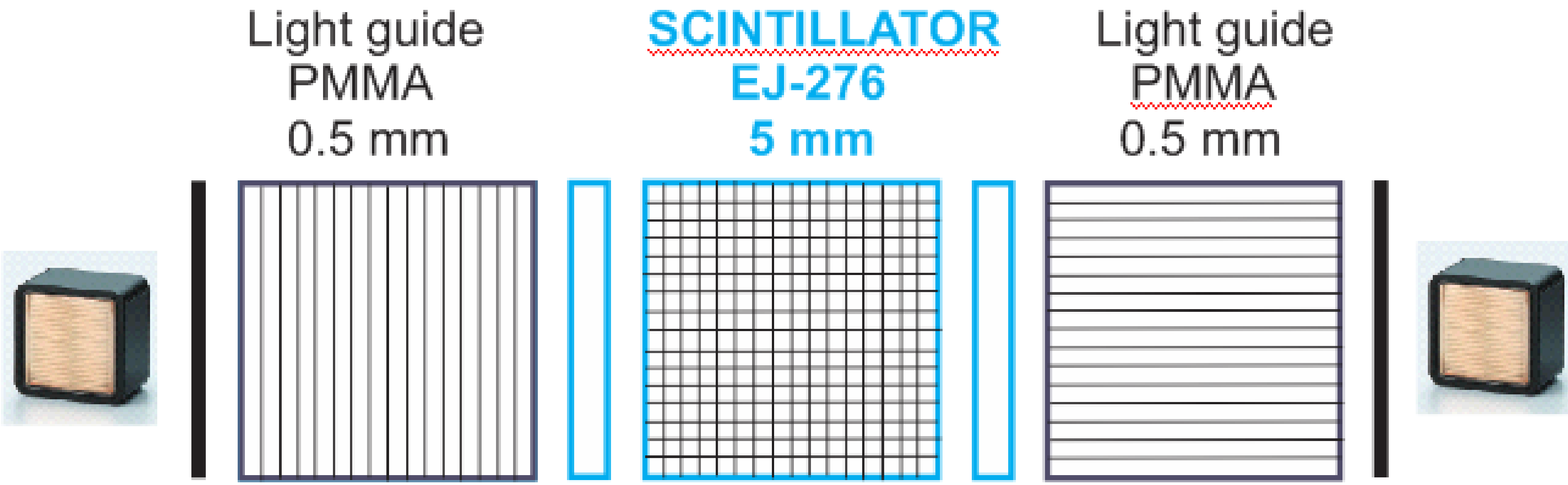
Shares some qualities with
Converting detectors.
(In fact could add Fe layers.



The GREAT: 3-D localization
The Good : timing
The UGLY : High threshold

Straw straw-man detector: feed 8x8 (64) 0.25 mm fibers into one active PMT sector (or SiPM)
X & Y by virtue of p-recoil range and delta's.
position localization 2 x 2 x 2 mm,

Concept D



Stack multiply layers PERHAPS with each X(Y) servicing two Y(X)'s.

Build up block 32 cm x 32 cm x 4 cm thick.
Each such block 256-ch make several/many such "blocks"

The GOOD: Timing, **3-D** localization, can stagger, fabrication
The BAD : Threshold likely not quite as low.

If the scint were small cubes (5x5x5 mm) of p-terphenyl, the "bad" moves to the "good"

Unfortunately….

We did NOT have the manpower to do simulations of these ideas
Hopefully within CENTAUR we can compare and contrast.

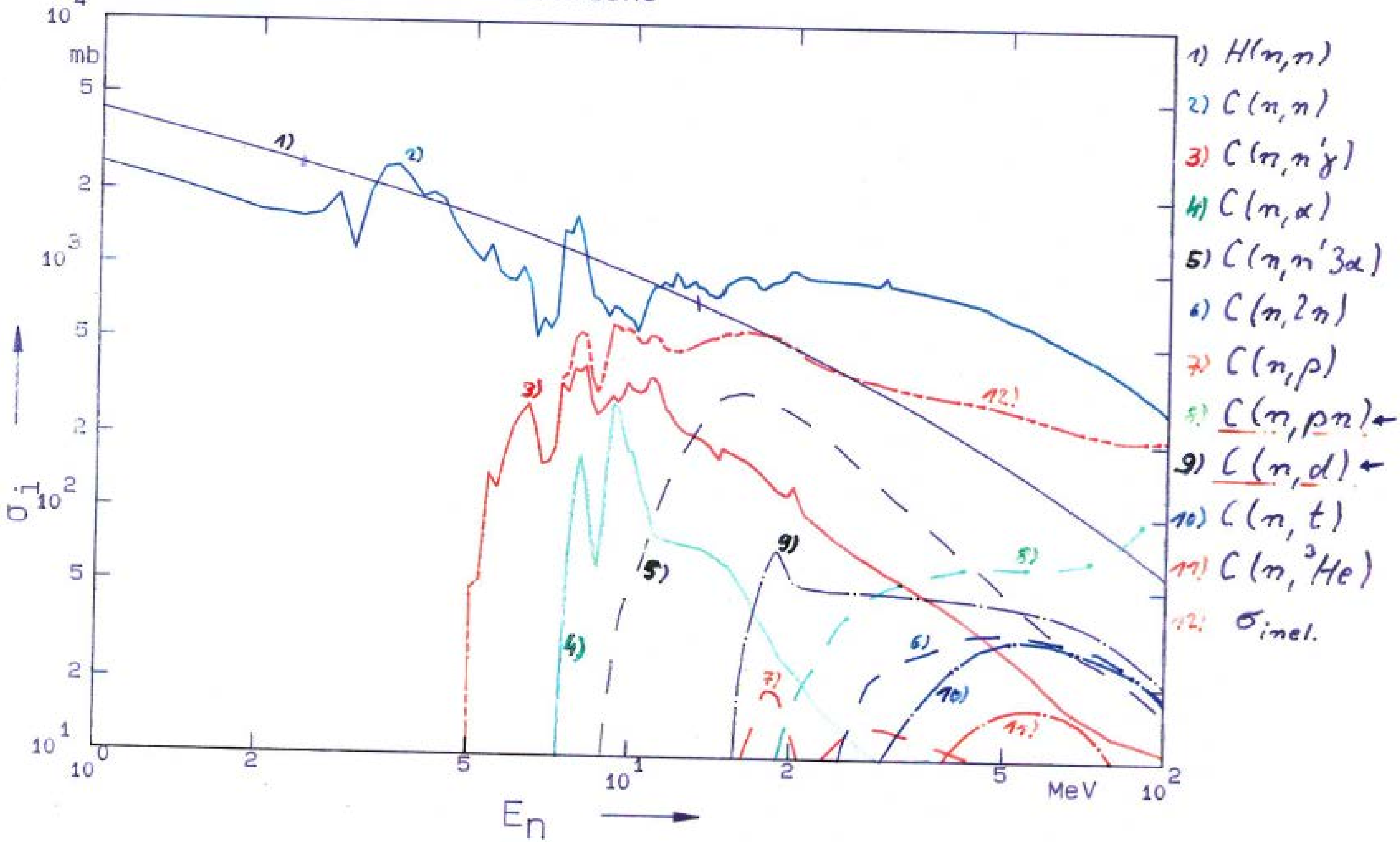
The point is: IF we imagine large ch counts,
there are possibilities not envisioned
or at least built (as far as I know).

ASIC's are NOT the answer,

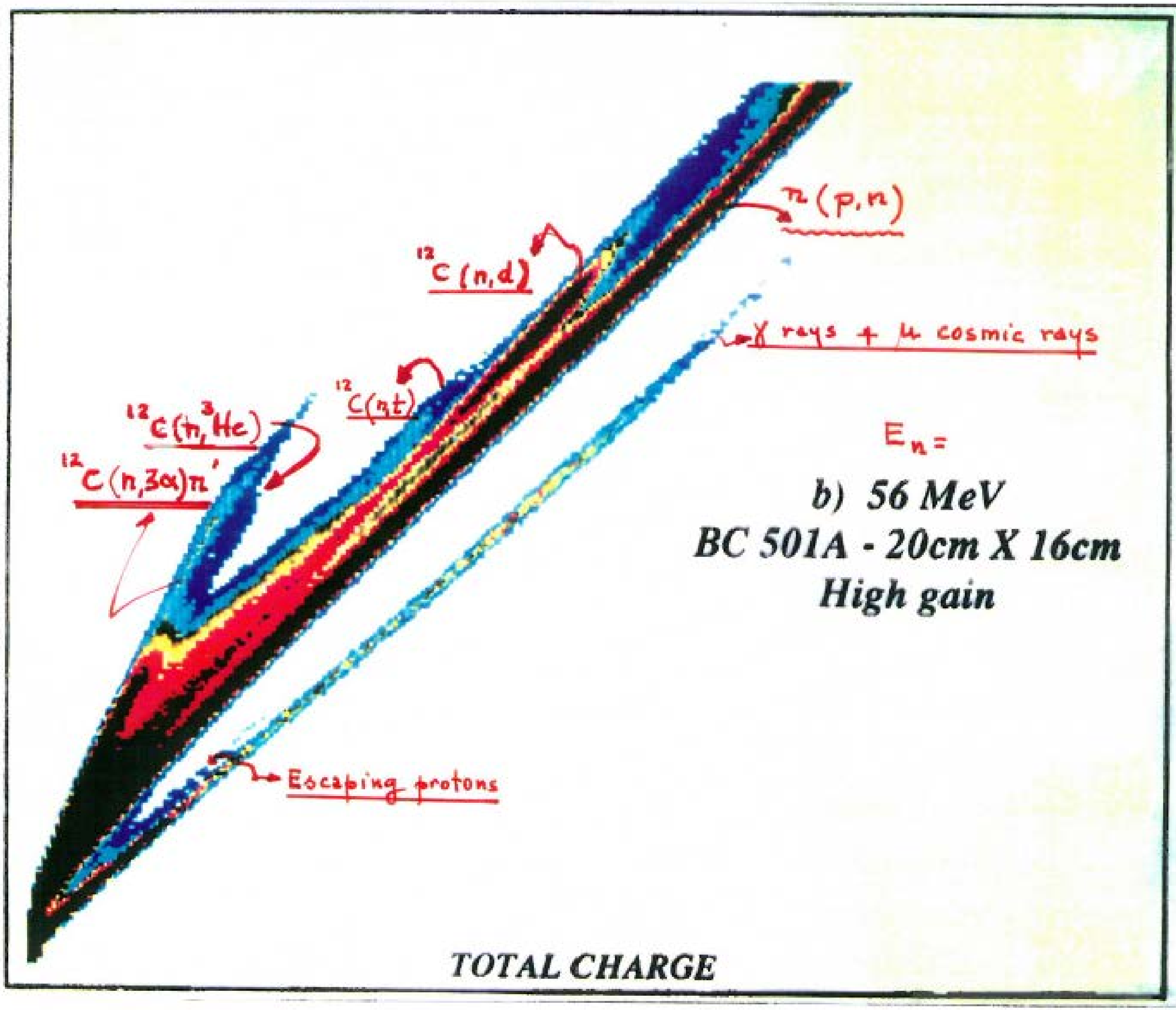
but having them allows for options that complement DSP.

Elastic scattering on protons and carbon material are the main generation of the scintillation pulse

SCINFUL partial cross-sections



SCINFUL 23: 40: 22 7-FEB-91



SLOW COMPONENT
TOTAL CHARGE
n (p,n)
^{12}C (n,d)
γ rays + μ cosmic rays
^{12}C (n,t)
^{12}C (n,^{3}He)
^{12}C (n,3α)n'
Escaping protons
E_n =
b) 56 MeV
BC 501A - 20cm X 16cm
High gain