I-Yang Lee

For the GRETA Steering Committee

R&D Review

November 13, 2002, DOE NP

GRETA –
Gamma Ray Energy Tracking Array

- R&D status and plan
  - Proof of principle
  - 3-cluster modules
- R&D needs
- Cost reduction and staging

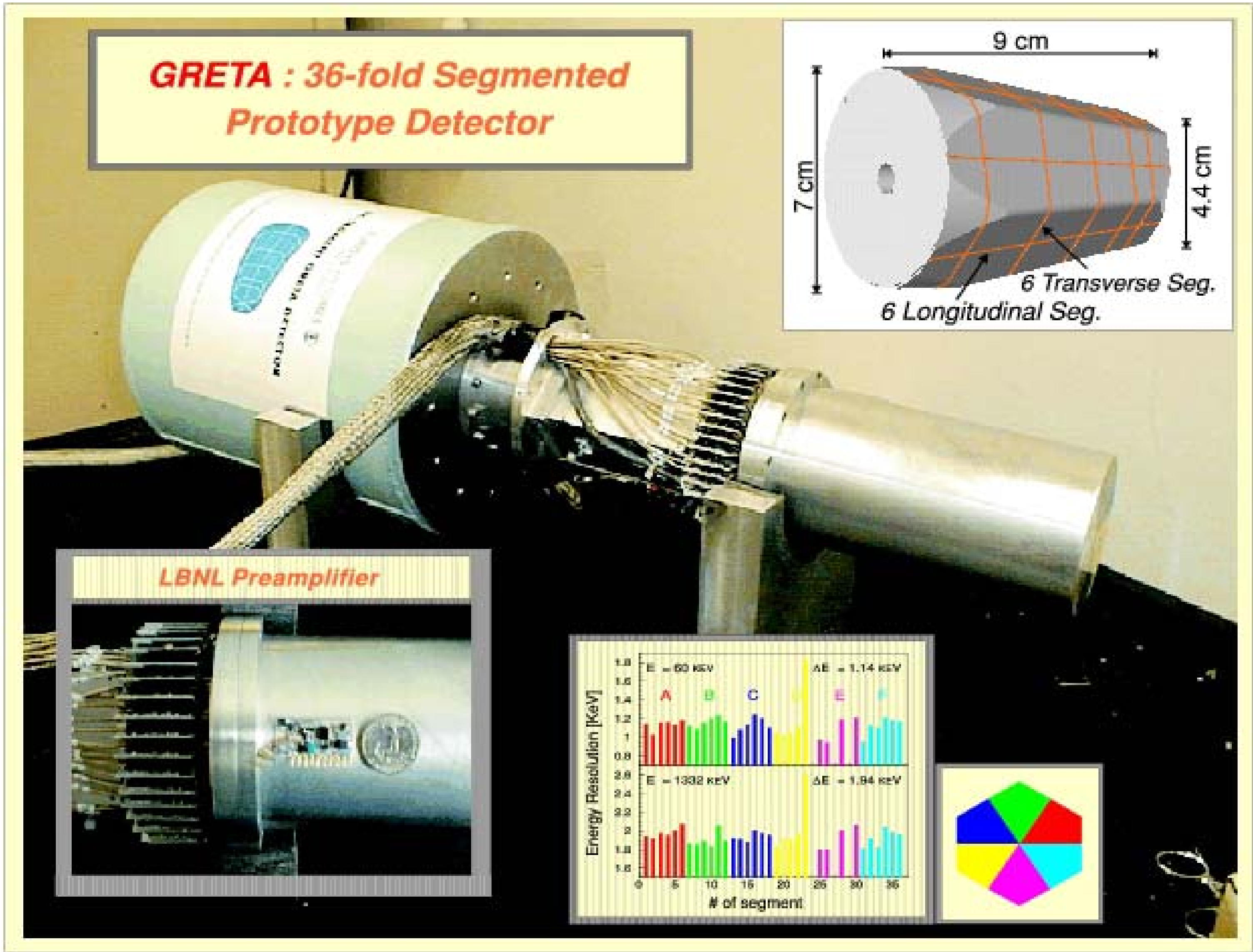
Proof of principle

No show stoppers

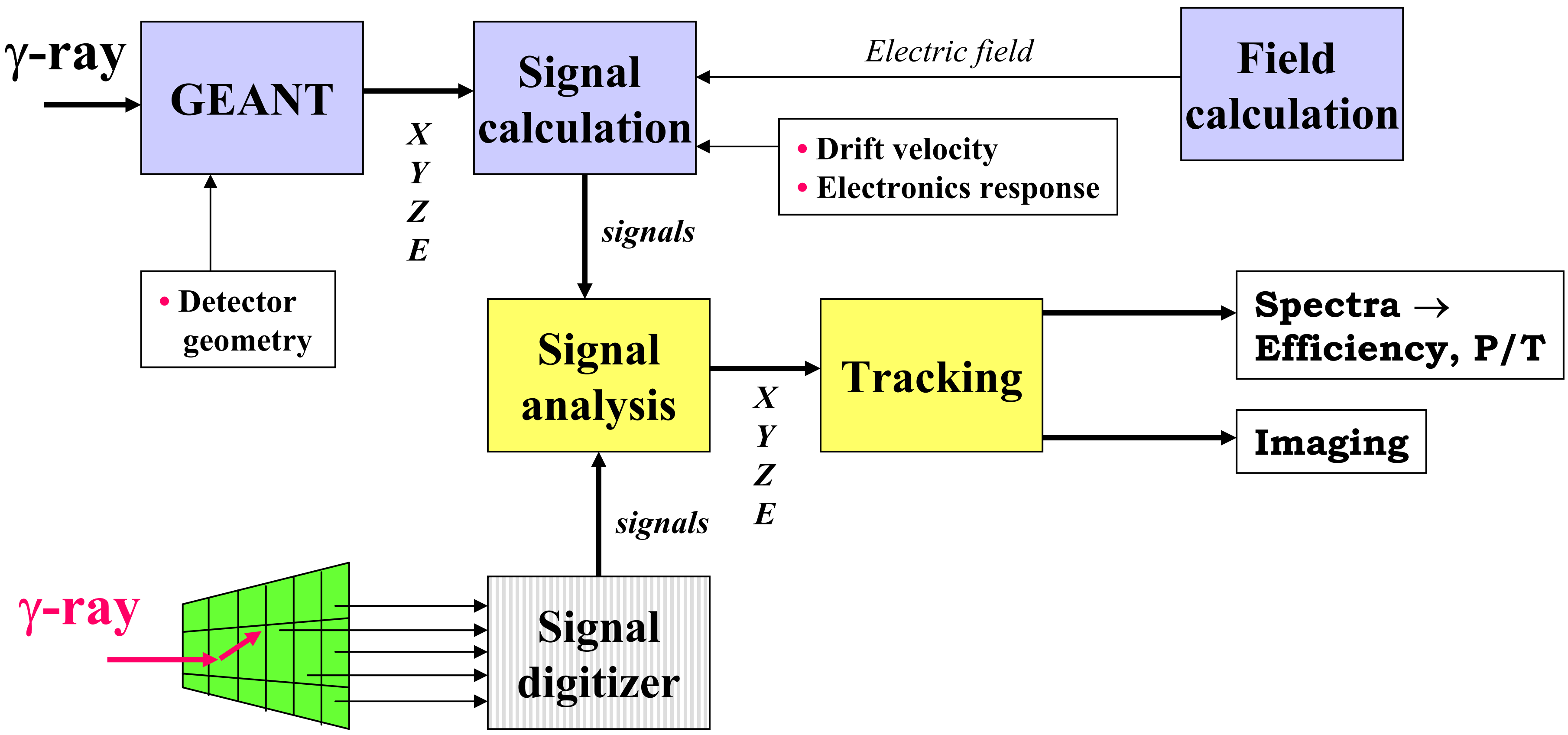
- **Segmented prototype detector**
  - Energy resolution: 1.2 keV at 60 keV and 1.9 keV at 1332 keV
  - Total integrated noise: < 5 keV (bandwidth 35 MHz)
  - 3-D position sensitivity: < 1 mm at 374 keV (single interaction)
- **Signal analysis**
  - Adaptive grid search: 1-2 mm
  - Least square: 1-2 mm
  - Genetic algorithm: 2 mm
  - Wavelet transformation: 5-6 mm
- **Tracking algorithms**
  - Compton tracking (150 keV $< E_g <$ 5 MeV) : eff = 50%, for m= 25.
  - Pair tracking ($E_g >$ 5 MeV) : eff = 50%

- M. A. Deleplanque et al., Nucl. Instrum. Methods Phys. Res. A430, 292(1999).
- G. J. Schmid et al., Nucl. Instrum. Methods Phys. Res. A430, 69 (1999).
- K. Vetter et al., Nucl. Instrum. Methods Phys. Res. A452, 105 (2000).
- K. Vetter et al., Nucl. Instrum. Methods Phys. Res. A452, 223 (2000).

Prototype detector II at LBNL



Full analysis of simulated and experimental data



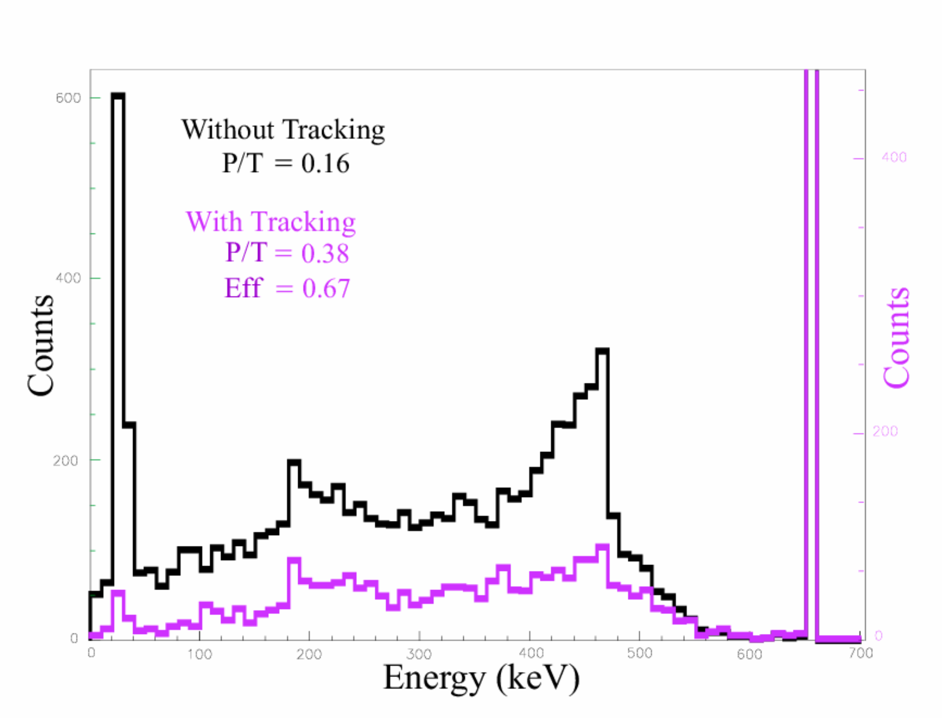
Full analysis

- E_γ=0.662 MeV, source distance= 12 cm
- Signal analysis (least square method)
  - up to 4 segments and 2 interactions per segment (98% of all events)
- For single interaction per segment
  - position resolution <1 mm, efficiency=85%
- For two interactions per segment
  - position resolution =1 mm, efficiency=70%
  - minimum separation =2 mm
- We have Studied
  - Simulation with/without tracking
  - Measurements with/without tracking
  - Compared Simulation with Data

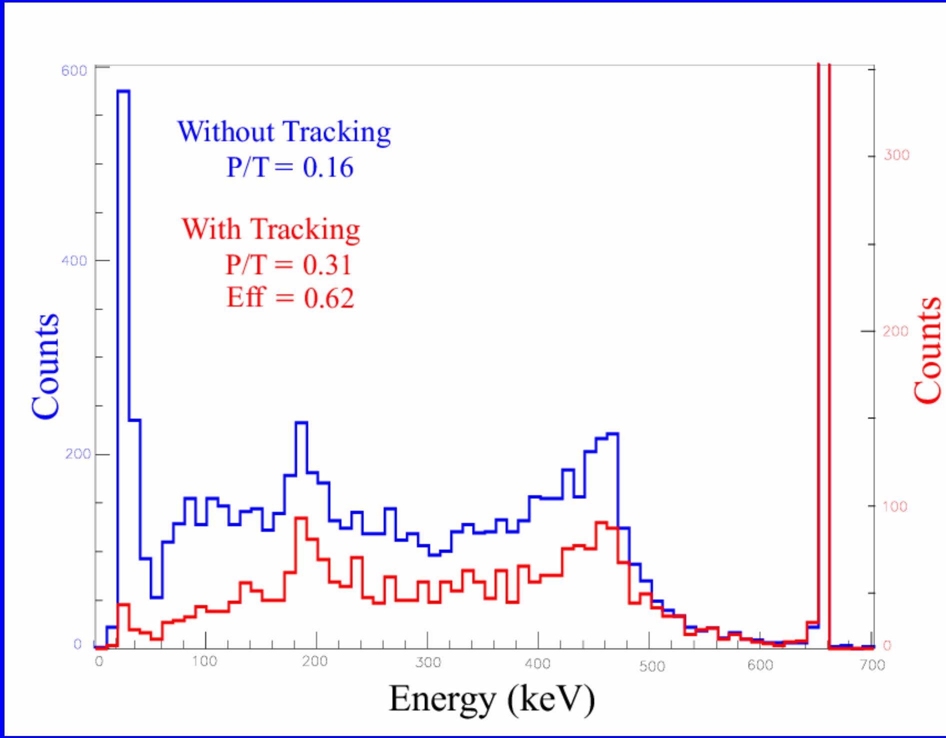
Compare simulation with measurements

E_γ=0.662 MeV

Simulation



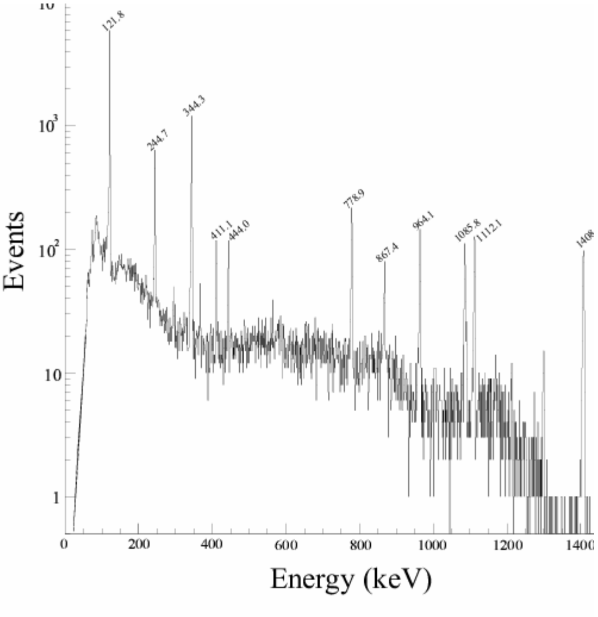
Measurements

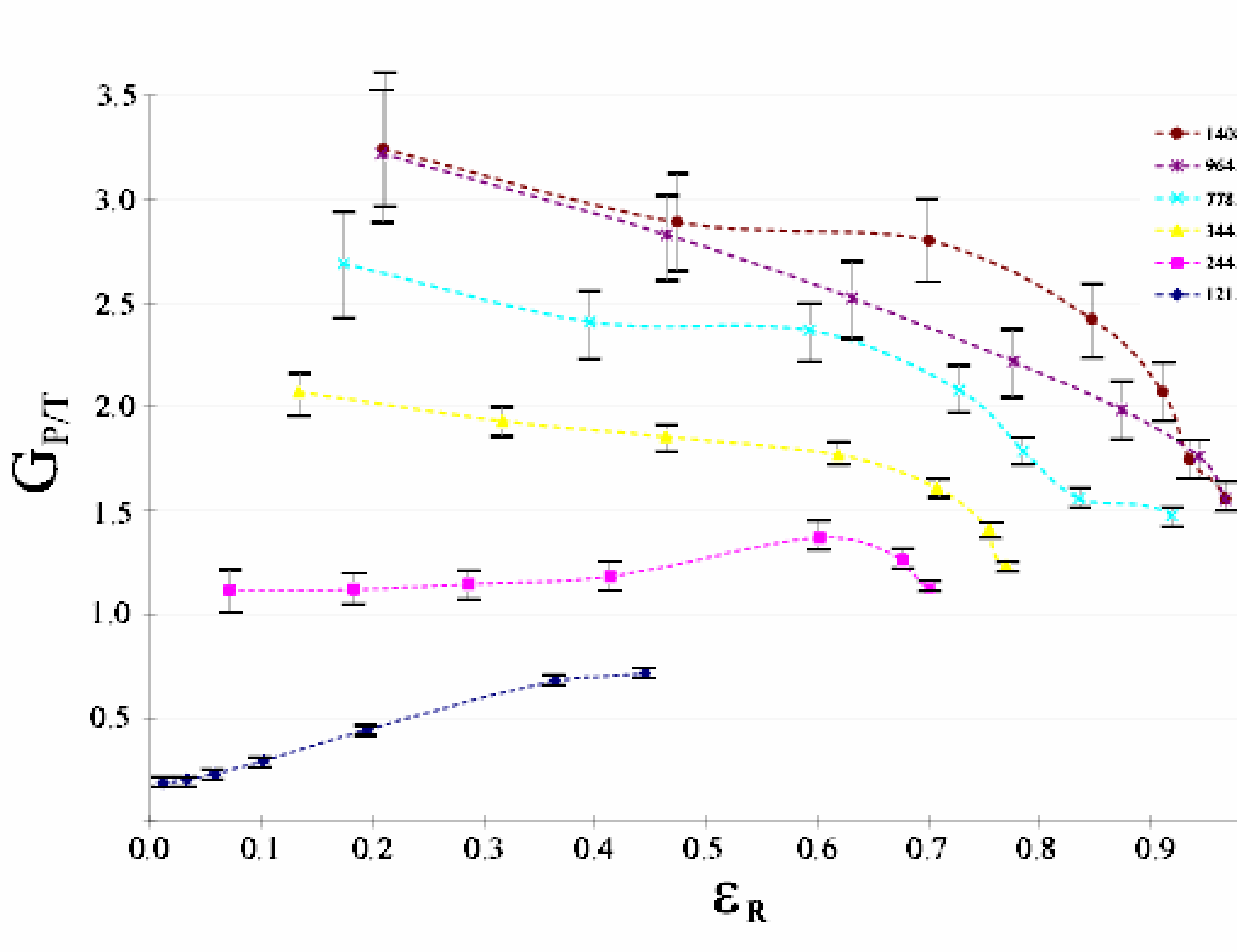


Austin Kuhn, *PhD Thesis, UC Berkeley, 2002.*

^{152}Eu full analysis

Gain in peak/total vs. efficiency





Austin Kuhn, *PhD Thesis, UC Berkeley, 2002.*

GRETA R/D plan

Goal: experiments with cluster modules

- Measurements with prototype II
- Obtain three-crystal detector modules
- Develop digital electronics
- Improve signal analysis algorithm
- Improve tracking algorithm

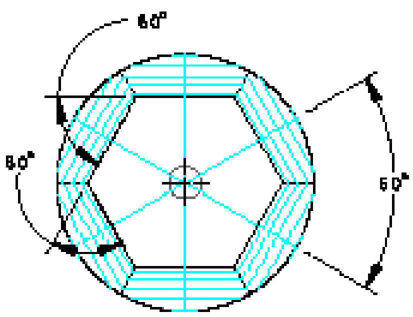
3-crystal modules

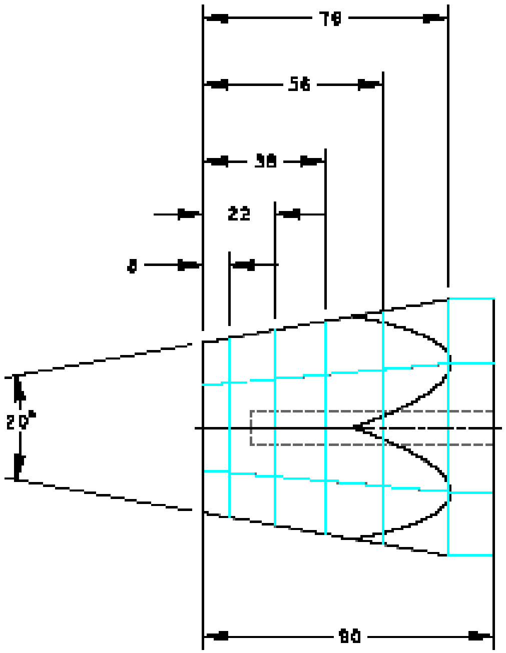
- Cold FET for the 1st module
- Test 1st module
- Test setup, mechanical support
- Design 2nd & 3rd module
- Purchase 2nd & 3rd module
- Test 2nd & 3rd module

R&D efforts

Three-crystal detector module

- Tapered regular hexagon shape.
- Dia= 8 cm, L=9 cm, 36 segments.
- Close packing of crystals with gap = 3.5 mm.
- On order.
- Expected delivery in one year.



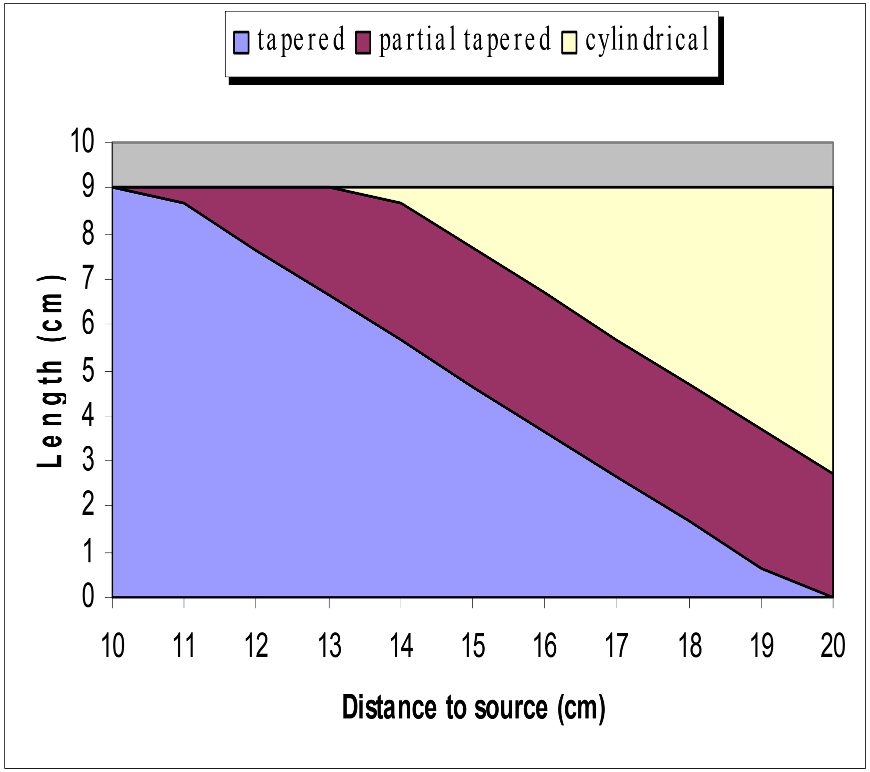


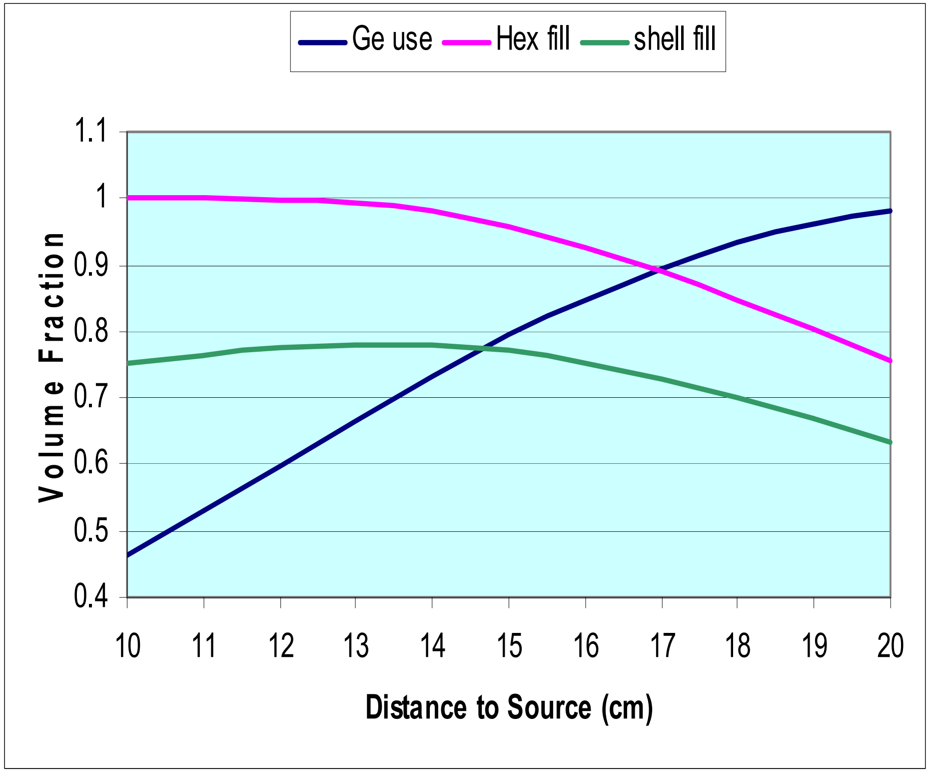
Prototype Detector III

Shape of tapered crystals

Diameter = 8 cm
Length = 9 cm
Flat taper angle = 10°

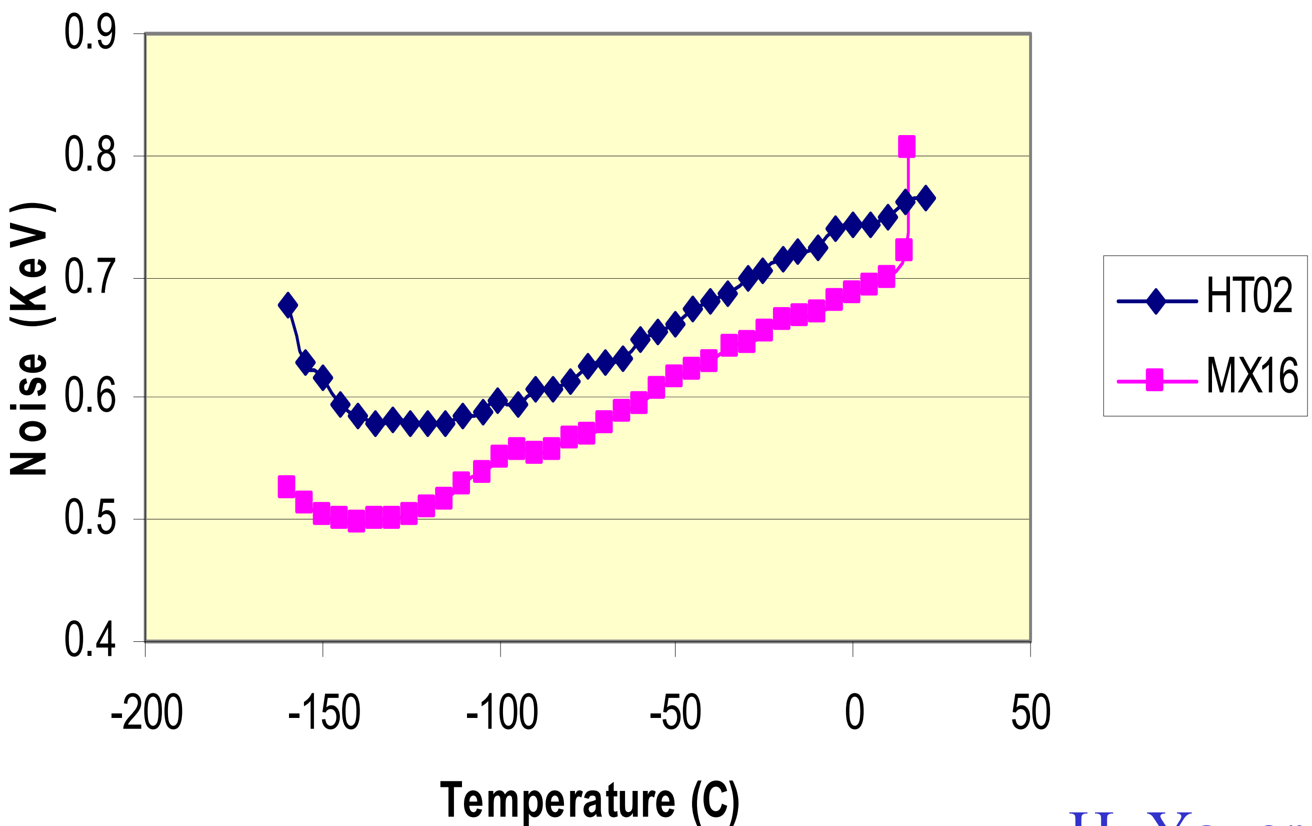
Crystal/can = 3
Small gap = 0.35 cm
Large gap = 1.0 cm





Cold FET

- At –120° C, noise is reduced to 0.7 of that at room temp.
- In collaboration with AGATA,
  the cost is now \$27k, reduced from \$80k.

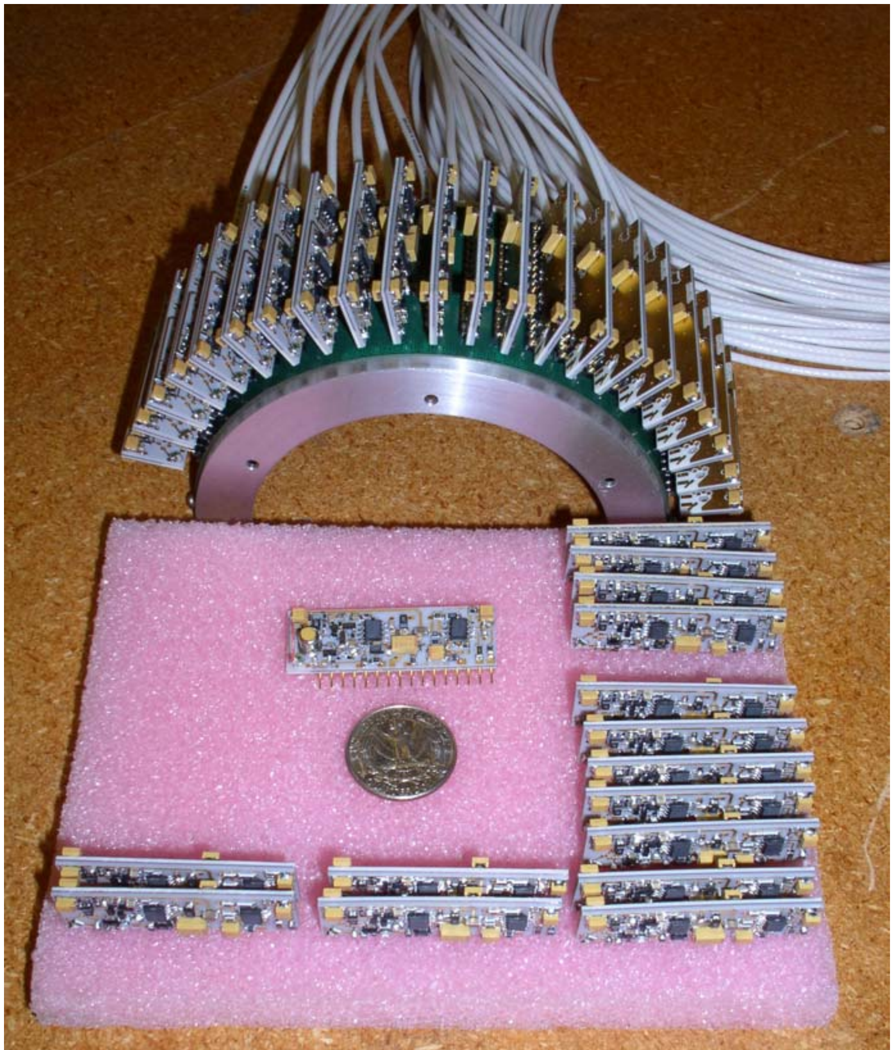


H. Yaver

Electronics & Data Acquisition

- Preamplifier
  - Design
  - Fabrication
- Signal digitizer
  - 8-ch module, test debug
  - 8-ch module, production
  - 40-channel module, design
- Data acquisition system – VME based

Preamplifiers for 3-cluster modules



Miniature

1.85” x 0.6” x 0.3”

Low noise, high band width

0.40 keV at 4 μs

0.47 keV at 0.5μs

Preamps designed by
Harold Yaver (LBNL)

Signal Digitizer

Prototype Specifications determined at ANL workshop

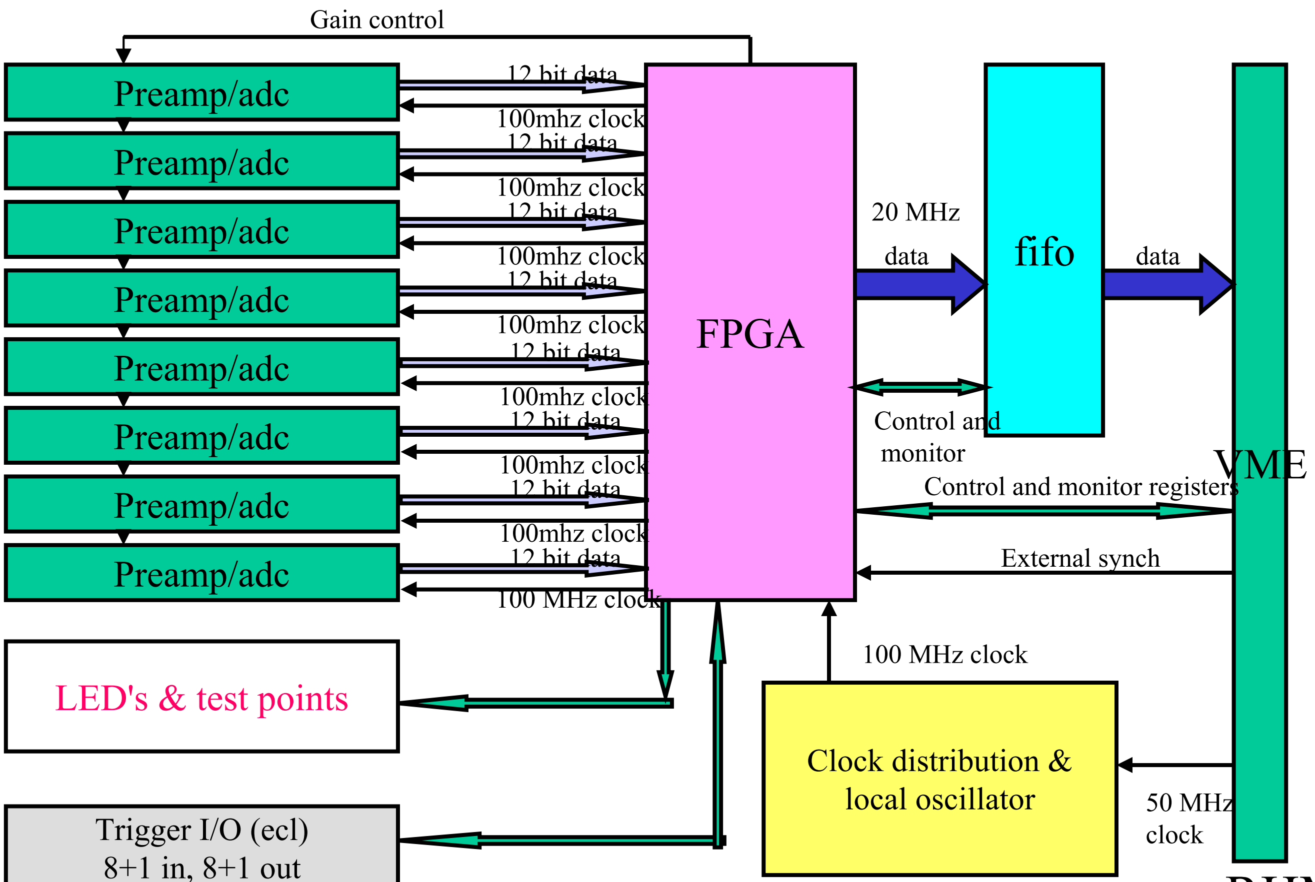
Electronic working group chaired by Dave Radford

- **Variable gain control**
- **Digitization at 100MHz, 12 bits**
- **Complex triggering (internal, external, validation)**
- **Data processing**
  - **Digital Leading Edge discriminator with programmable parameters**
  - **Digital Constant Fraction with programmable parameters**
  - **Digital Trapezoidal Shaping with programmable parameters**
  - **Raw data sample storage of charge collection**
- **VME readout**

Signal Digitizer

Schematic diagram

- 8 channel 6U VME board
- Prototype being tested (Nov. 2002)



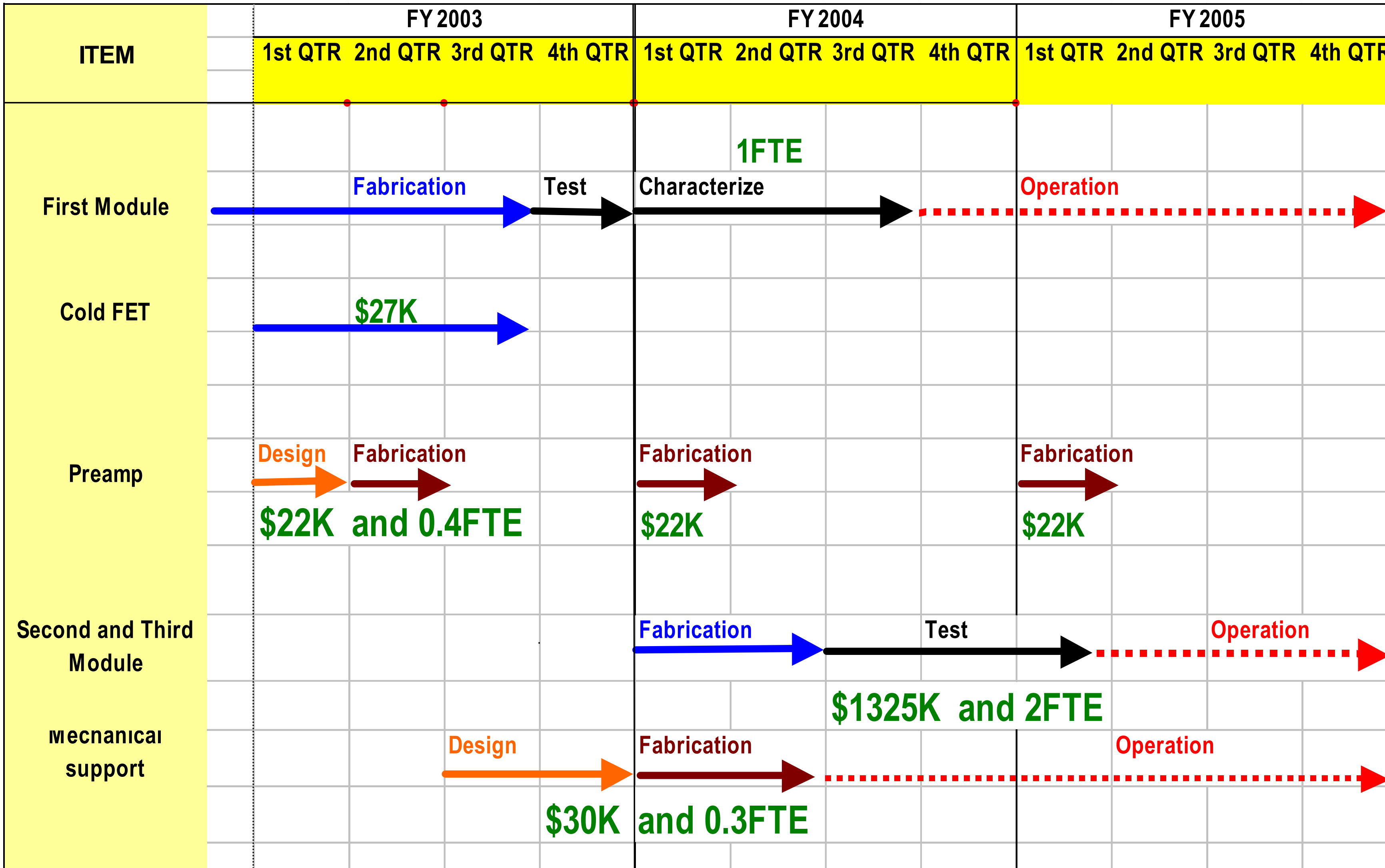
RHM 3/20/02

Software developments

- Prototype II, data analysis
  - In-beam measurements
  - Imaging
- Signal analysis, minimization
- Signal shape parameterization
- Tracking

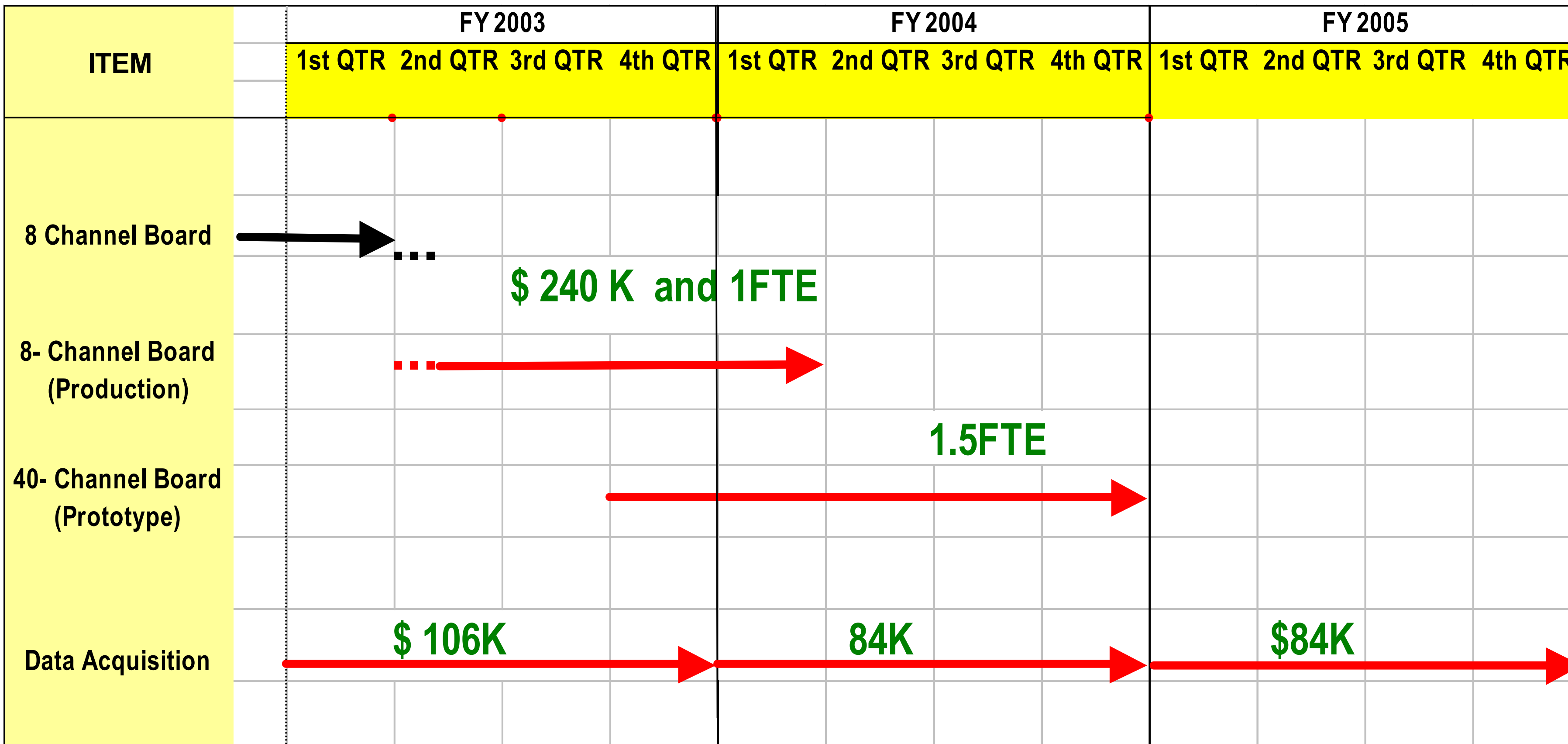
3-crystal modules

R&D timeline



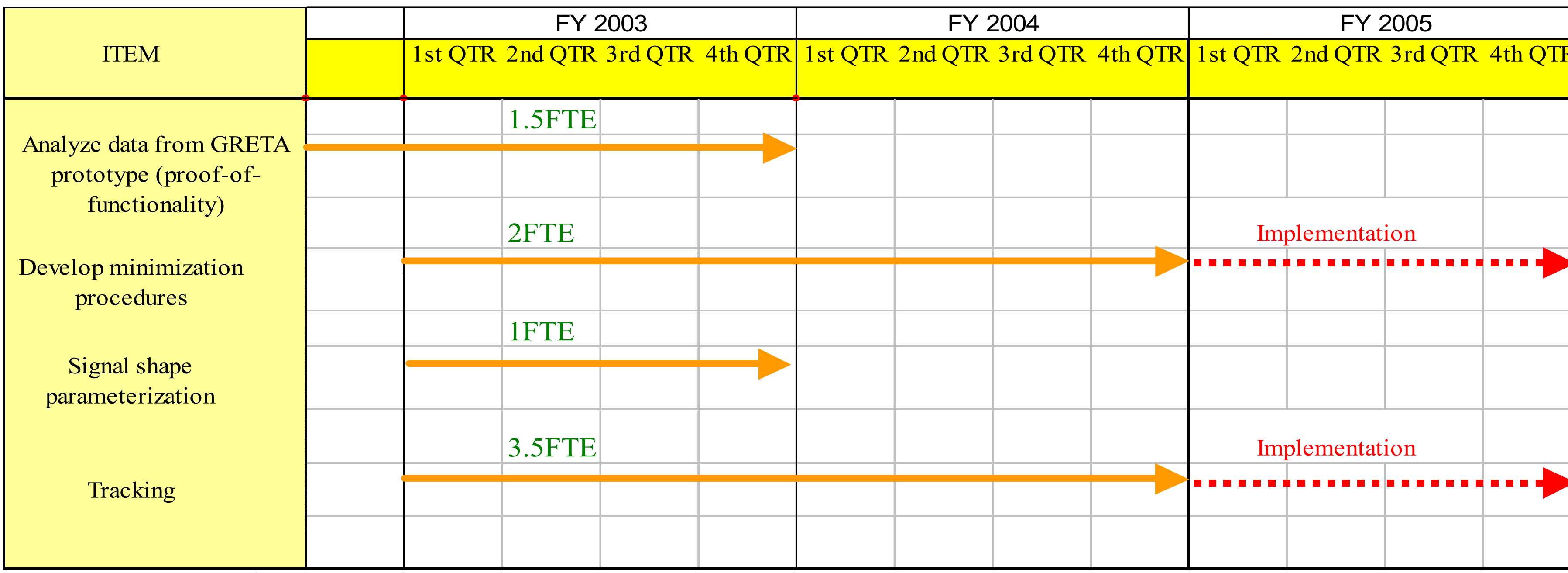
Electronics & Data Acquisition

R&D timeline



Software developments

R&D timeline



GRETA R&D costs (FY03-05)

Item	**Purchase** *($k)*	**Manpower** *(FTE-yr)*
Three 3-crystal modules	1382	3.3
Electronics	306	2.9
Data acquisition	274	
Software		12.0
Total	**1962**	18.2
	(@200k/FTE-yr)=3640	
Grand Total	**$5602k**	

GRETA R&D cost profile

	Purchase *($k)*	Manpower *(FTE-yr)*
FY03	265	7.7
FY04	981	5.0
FY05	716	5.5

Manpower for FY03

6.2 FTE available *vs.* 7.7 FTE needed

LBNL – In-beam test, design irregular detector module, **4.0 FTE**
Test 8-ch digitizer module, design preamp, software development.

Martina Descovich | I-Yang Lee | Augusto Macchivaelli
Paul Fallon | Mario Cromaz
Harold Yaver (funded by LDRD) | Vicent Riot (funded by LDRD)

ANL – Software development **0.5 FTE**

Kim Lister | Mike Carpenter

ORNL – Programming FPGA in signal digitizer **0.5 FTE**

Dave Radford | Steve Pauly (funded by STTR)

Yale – Software development **0.2 FTE**

Con Beausang | Postdoc (funded by NNSA)

MSU – Software development **1.0 FTE**

Thomas Glasmacher | Krzysztof Starosta | Will Mueller

GRETA Cost Reduction Analysis

- **Reduce the cost of Ge detector** **-$5.5 M**
- **Future cost reduction of computers** **- $0.7M**
- **Subcontract design and construction** **- $0.9M**
- **Redirect efforts** **- $4.8M**

Total Cost = $35M

Includes overhead, escalation (17%), and contingency (20%)

Price of Segmented Ge Detectors

$5.5 M savings

Type	Shape	Dia. (cm)	No. Seg	Xtal/ cryostat	Unit Produced	Year	Price $k/Xtal
Gammasphere	Cylinder	7	2	1	65	1995	**55**
MSU	Cylinder	7	32	1	18	2001	**75**
Exogam	square	5	4	4	12	2001	**38**
Clover	square	5	2	4	30	2002	**25**
Miniball	Tap.Hex.	7	12	3	6	2002	**75**
GRETA II	Tap.Hex.	7	36	1	1	1998	**175**
GRETA cluster	Tapered hexagon	8	36	3	1	2002	**250**

Manufacture estimated production price = $150k /Xtal

We think it could be obtained at price = $100k/Xtal

Cost Reduction of Computers

$0.7M savings

- Computer cost reduces by about a factor of 2 every 2 years. Our original estimate has not taken this factor into consideration. Assuming an average purchasing time period of 4 years, we could reduce the computer cost by a factor of 4,

Subcontract design and construction

$0.9M savings

- Assuming that the university will design and construct the mechanical structure, target chamber and the liquid-nitrogen system, we could save on the lower overhead rate on 9 FTE-year, for a total saving of $0.9M.

Redirect efforts

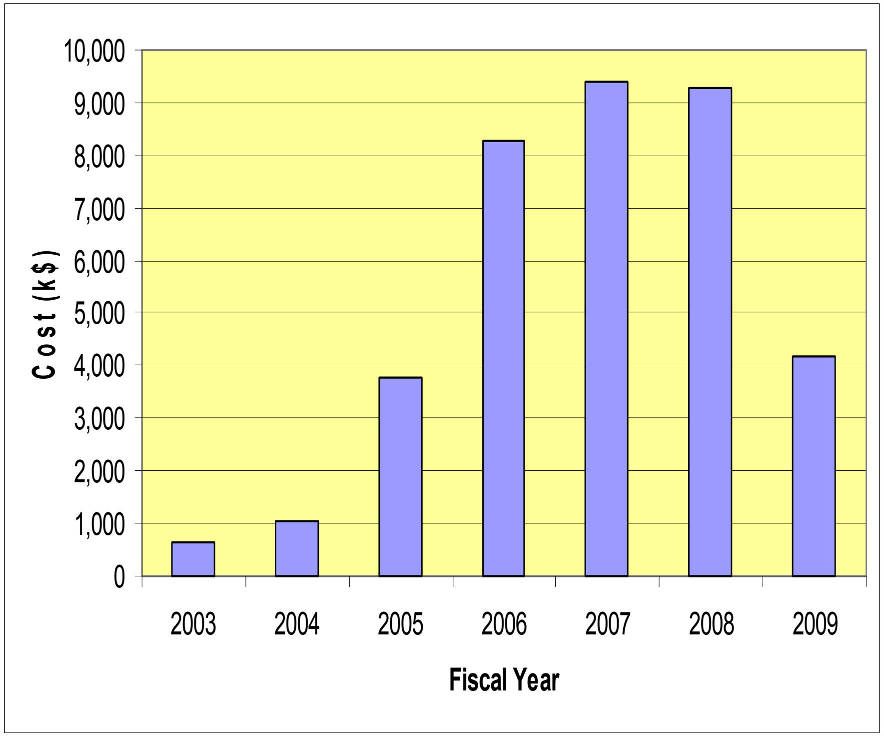
$4.8M savings

- This assumes that the efforts for project management (18 FTE-year), and half of the effort for computer software (6 FTE-year) could be redirected from existing efforts. This will save $4.8M

GRETA Total Cost and Cost Profile

FY02 Dollar, with overhead, no contingency, no escalation

Item	Purchase	Effort	
	(M$)	(FTE-yr)	
• Mechanical	0.9	5	
• LN	0.5	4	
• Detector	18.0	7	
• Electronics	3.4	10	
• Computer	1.1	13	
• Installation	0.0	6	
• Management	0.0	15	
• Safety	0.0	3	
		63	
TOTAL (M$)	**23.9**	**12.6**	**36.5**



Cost Comparison

Items	*Cost ($M)*	
	Old	*New*
Purchasing	24	18
Manpower	13	7
Escalation @17%	6	4
Contingency @20%	9	6
Total	**52**	**35**

GRETA Staged cost

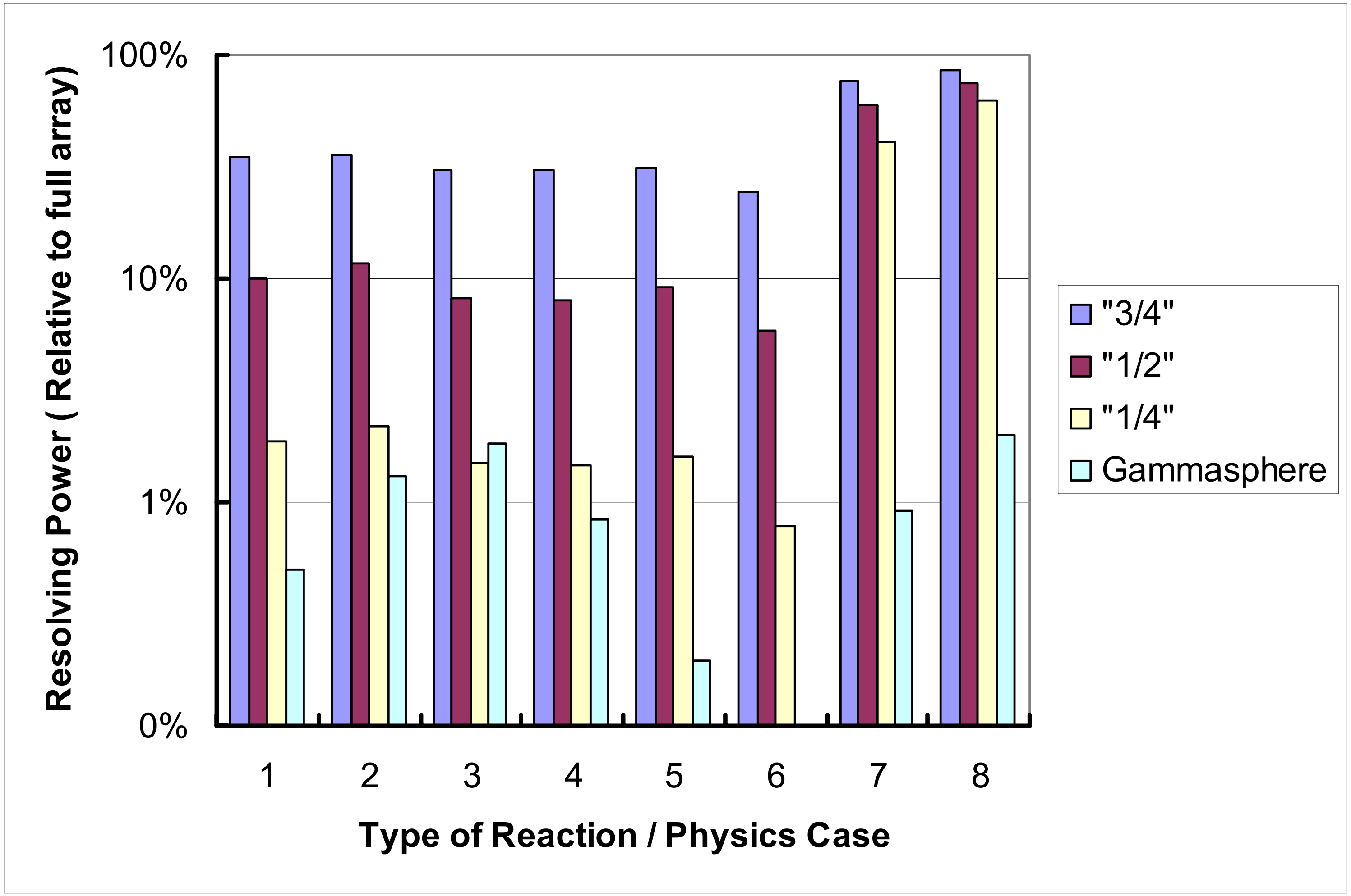
total cost $35M

Solid angle	Angular range	Cost
¼	0° - 60°	$13.54M
½	0° - 90°	+$ 7.11M
¾	0° - 120°	+$ 7.29M
Full	0° - 180°	+$ 7.41M

GRETA Staged Performance

Type of Reaction	<E_γ> (MeV)	v/c	M_γ	Resolving Power	Staging Relative Factor (Relative to Gammasphere)		
				$\Delta x = 2$ mm Ω=80%	1/4	1/2	3/4
1) Stopped	5.0	0.0	4	2.1×10^7	.02 4	.10 20	.35 70
2)	1.5	0.0	4	4.4×10^7	.02 1.5	.11 9	.34 28
3) High-spin Normal Kinematics	1.0	0.04	20	2.4×10^6	.015 0.8	.08 4.5	.31 17
4) High-spin Inverse Kinematics	1.0	0.07	20	2.2×10^6	015 1.8	.08 10	.30 36
5) Coulex/transfer	1.5	0.1	15	3.7×10^6	.015 8	.09 47	.31 160
6) Fragmentation	1.5	0.5	6	5.9×10^6	.008 100	.06 730	.25 3080
7) In beam Coulex	5.0	0.5	2	$2.7 \text{ X } 10^3$	.41 45	.60 66	.77 85
8)	1.5	0.5	2	4.1×10^3	.62 30	.75 38	.85 43

GRETA Staged Performance

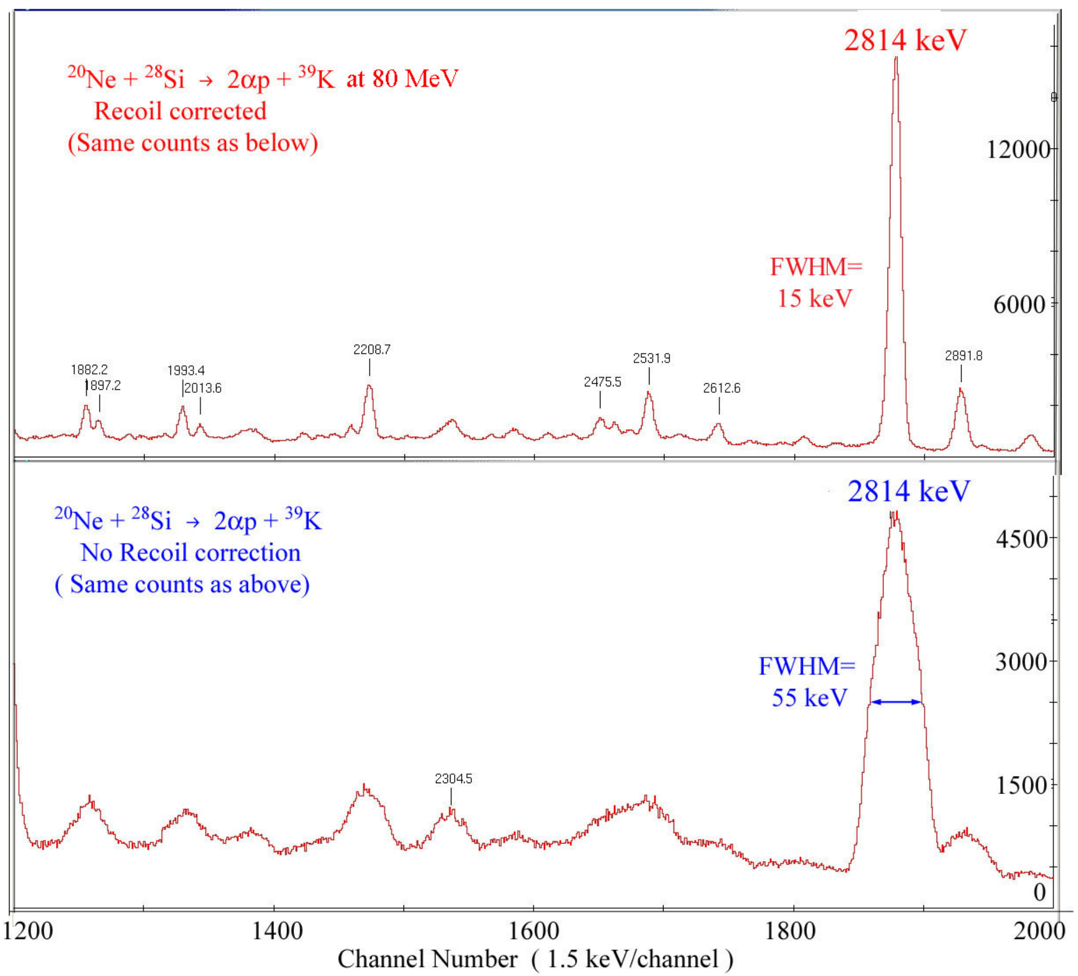


Important Performance parameters of GRETA early stage operation

- Better position Resolution – 2 mm vs. 20 mm
  - High recoil velocity experiments
- Higher efficiency for high energy gamma rays- 0.2 vs. 0.05 at 15 MeV
  - Giant resonances studies
- Compactness – ¼ GRETA is comparable or better than Gammasphere
  - Use with auxiliary detectors, BGS, new CHICO, etc.

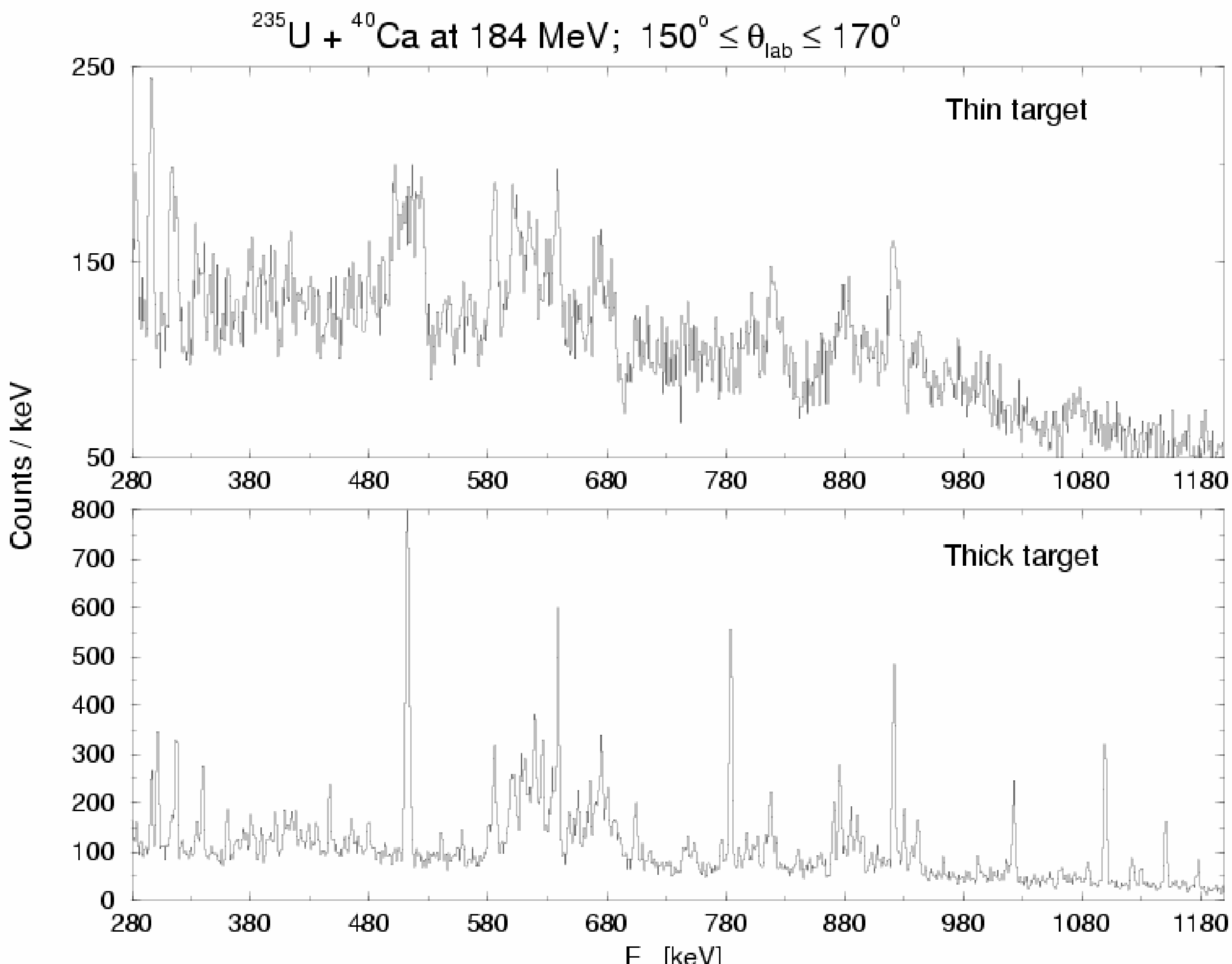
Nuclear Structure Studies

•Energy resolution in GS before and after recoil correction with the μBall.



- The remaining resolution of FWHM=15 keV is mainly due to the finite size of the GS Ge detectors.
- With the increased granularity of GRETA, for SD bands in ^{40}Ca this will be reduced to ~ 5 keV at 2933 keV (thin target contribution remains).
- More detailed spectroscopy and accurate lifetimes can be obtained on the SD Bands in nuclei like ^{36}Ar and ^{40}Ca and SD band termination can be observed.

Coulomb Excitation



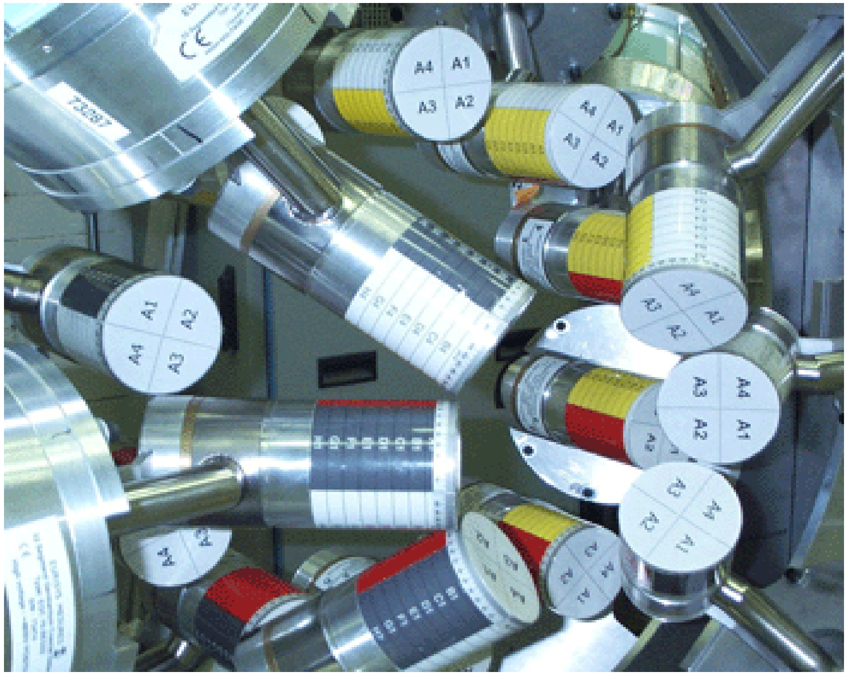
Nuclear structure studies with fast beams

- Address two of the three “crucial questions” in the chapter “Atomic Nuclei: Structure and Stability” of the 2002 Long-Range Plan for Nuclear Science.
  - “How do weak binding and extreme proton-to-neutron asymmetries affect nuclear properties? …”
  - “How do the properties of nuclei evolve with changes in proton and neutron number, excitation energy and angular momentum? …”
- Fast beams and thick secondary targets extend the scientific reach of any facility by factor of 100-1000
- Build on an emerging field less than 10 years old
- Allow high-precision measurements (1 in 10^6) : keV resolution/ GeV beam energy
- Stages of GRETA are very efficient due to forward focusing of γ-ray flux

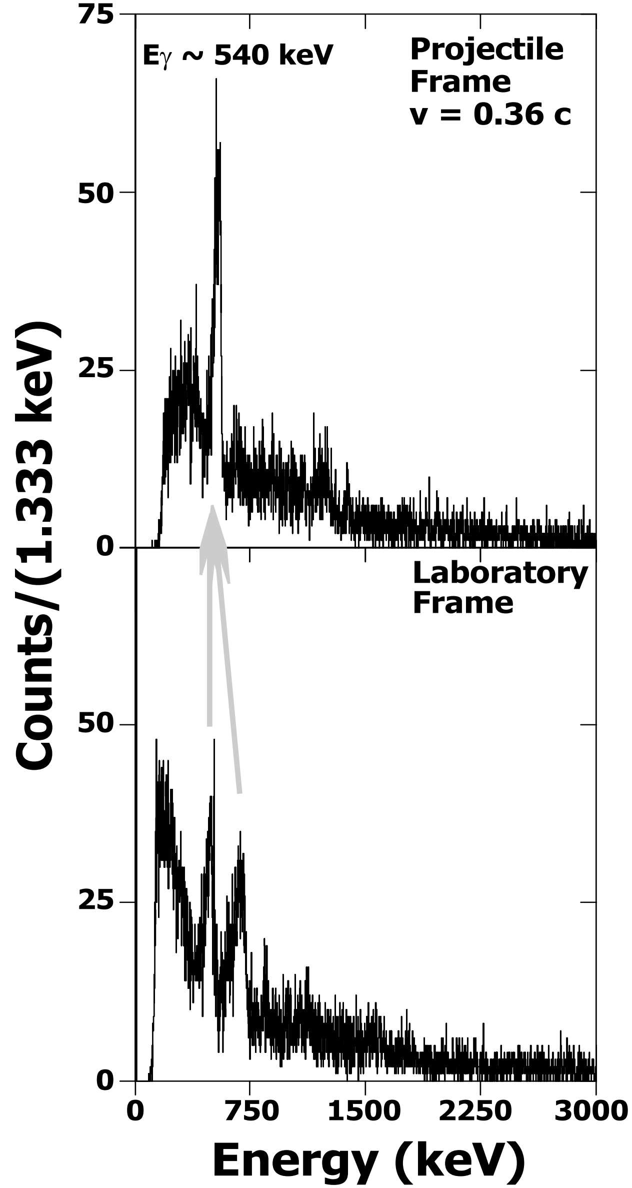
Nuclear structure studies with fast exotic beams

GRETA	Fraction of γ-rays detected at 100 MeV/A (NSCL)	Fraction of γ-rays detected at 250 MeV/A (RIA)
Stage 1 1/4	46%	59%
Stage 2 1/2	72%	81%
Stage 3 3/4	89%	93%
Stage 4 full	100%	100%

1n knockout with SeGA $^{46}Ar(Be,^{45}Ar\gamma)$

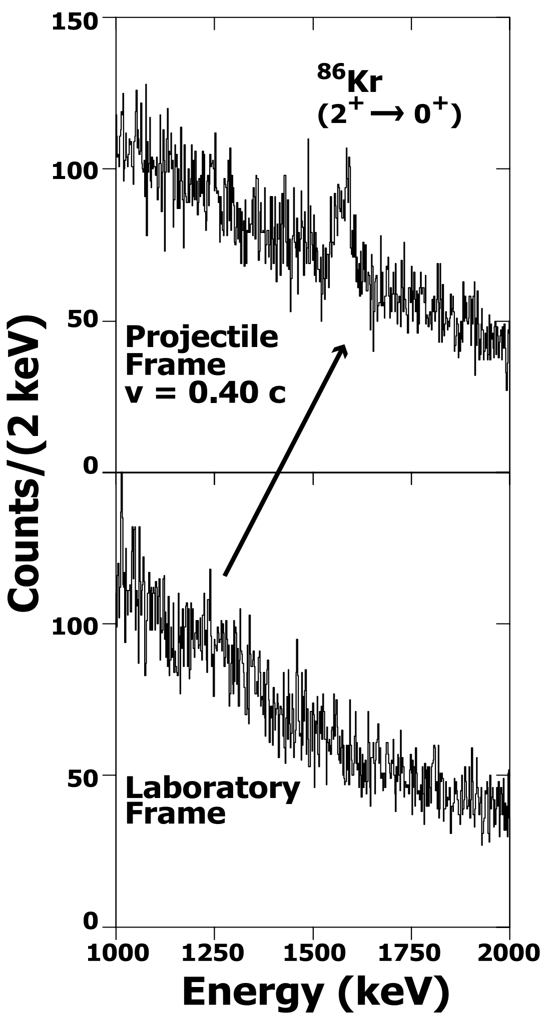


140 MeV/nucleon ^{40}Ar from CCF →
90 MeV/nucleon ^{46}Ar

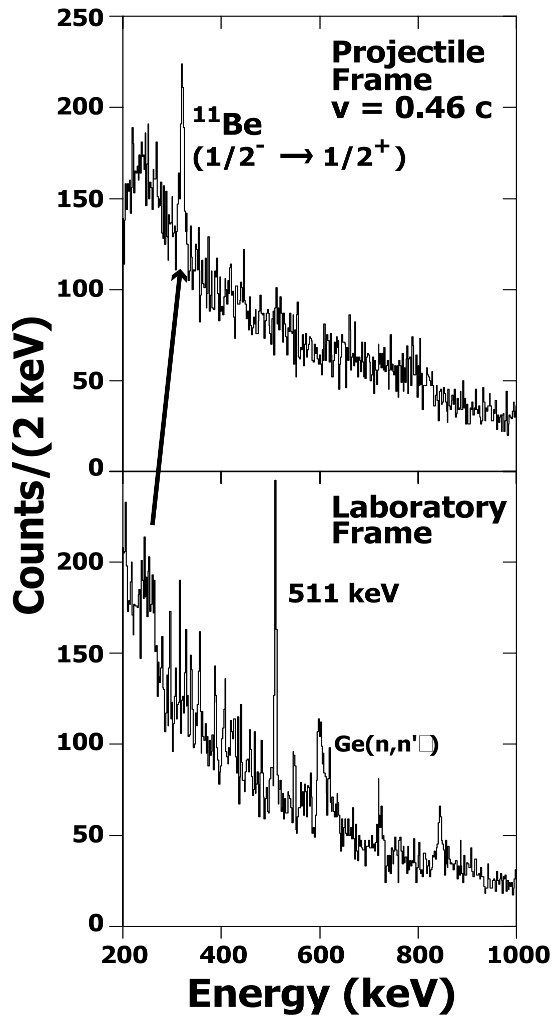


Detecting g-rays emitted from GeV beams with keV resolution: first tests

^{86}Kr+^{197}Au at 85 MeV/nucleon



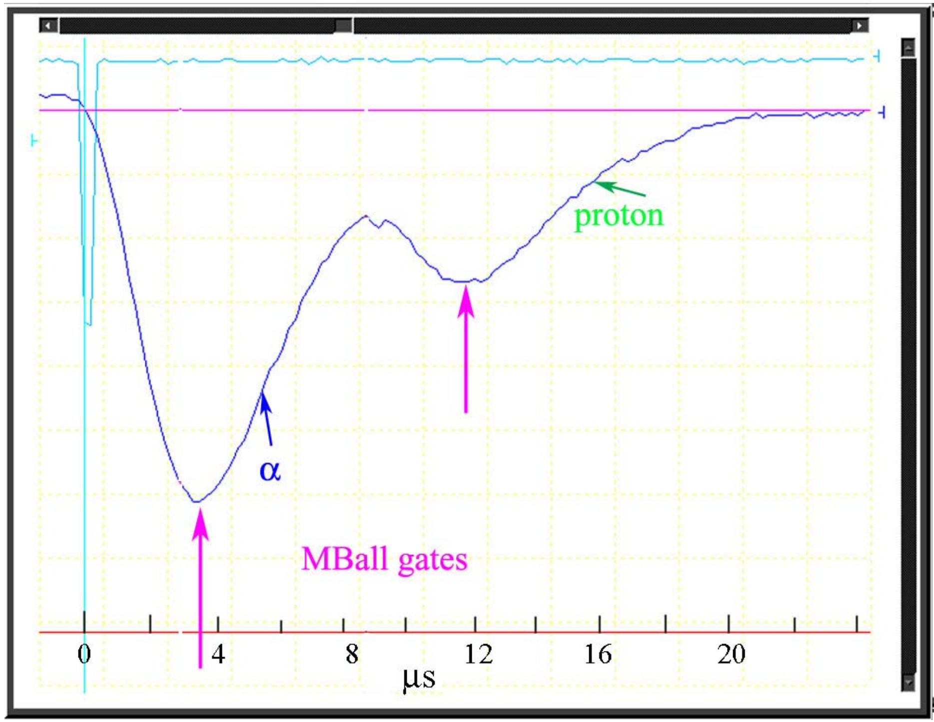
^{11}Be+^{197}Au at 109 MeV/A, $\Delta E_\gamma/E_\gamma$= 3%



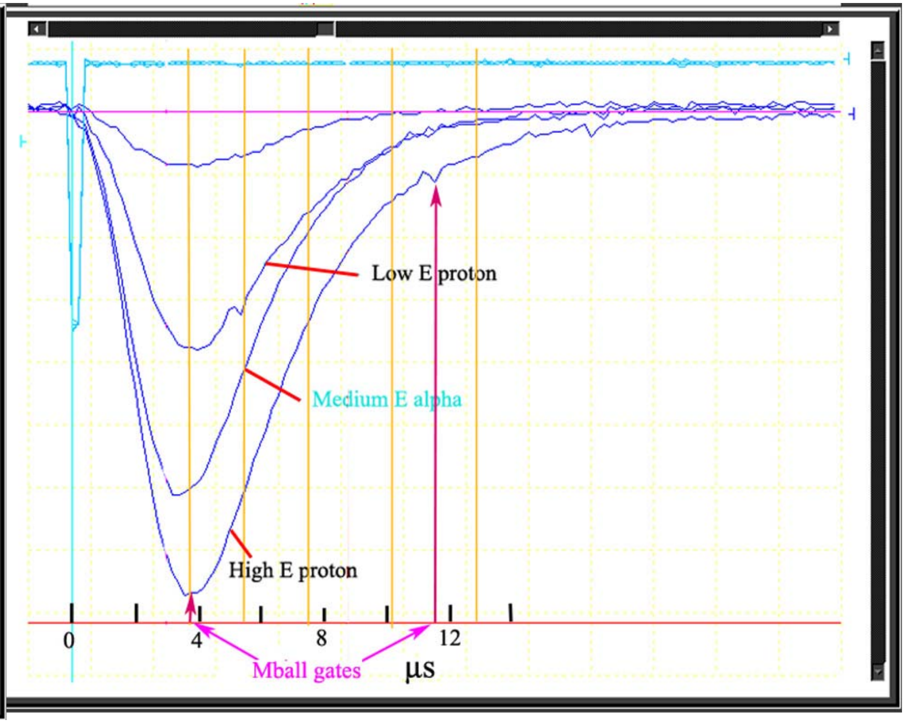
Microball improvements

- Digital signal processing
- Increase granularity

Unresolved pileup pulses in the Microball (CsI)



5-time point digital sampling to recover the pileup or increase rate by ~ 2



Conclusions

- **Proof of principle is achieved**
- **3-Cluster modules is the important next step**
- **Cost saving possibilities are being discussed**
- **Staged approached has a science base**