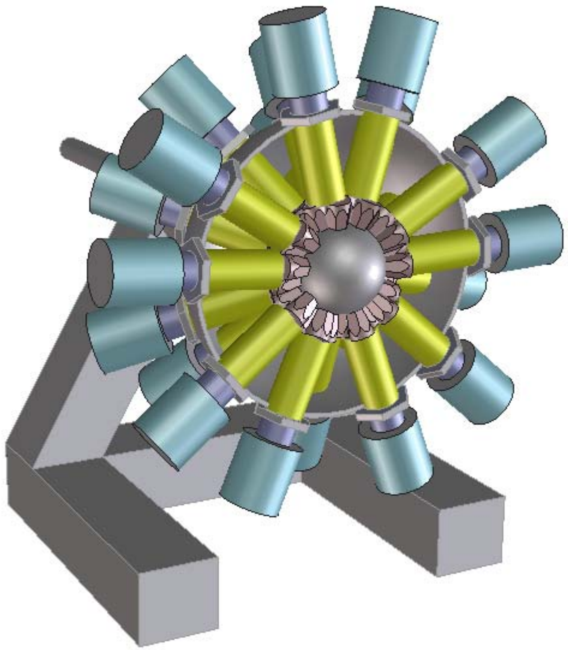
GRETA



I-Yang Lee

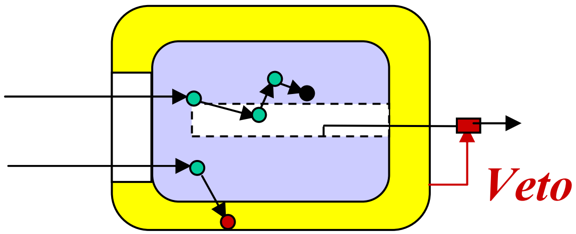
For the GRETA Steering Committee

Workshop on the Experimental Equipment for RIA

March 18-22, 2003, Oak Ridge, Tennessee

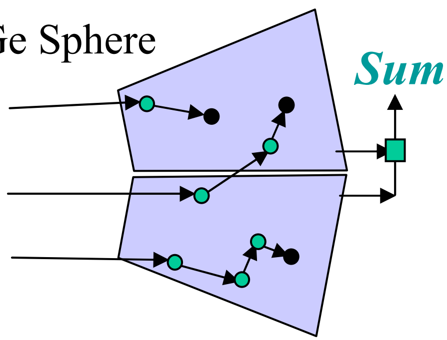
Gamma-ray Tracking Concepts

- Compton Suppressed Ge



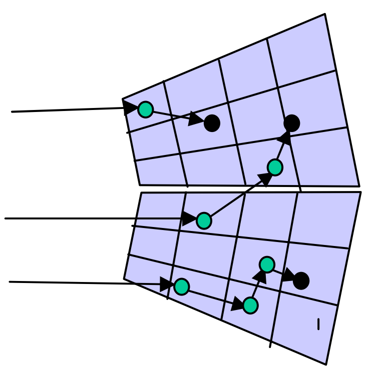
$N_{det} = 100$
Peak efficiency = 0.1
Efficiency limited

- Ge Sphere



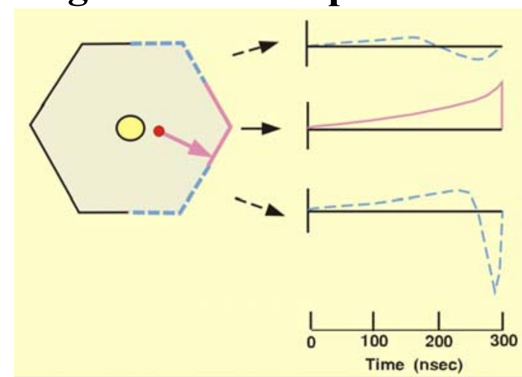
$N_{det} = 1000$ (summing)
Peak efficiency = 0.6
Too many detectors

- Gamma Ray Tracking

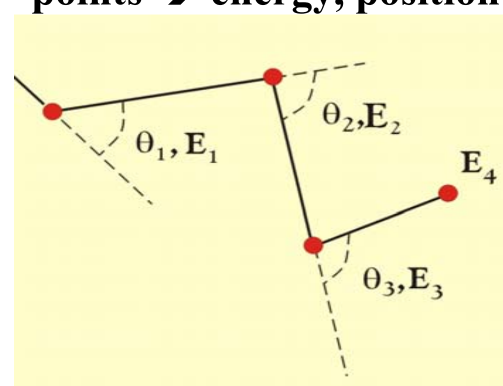


$N_{det} = 100$
Peak efficiency = 0.6
Segmentation

Pulse shape analysis in segments ➔ 3D position



Tracking of photon interaction points ➔ energy, position



Development of the U.S. gamma-ray tracking effort

- **1994 Conceptual design study**
- **1995 Duke Town meeting (1996 LRP) first discussion**
- **1997 First prototype received and tested**
- **1998 Workshop on GRETA physics (LBNL)**
- **1998 Workshop on experimental equipment for RIA (LBNL)**
- **1999 GRETA advisory committee formed**
- **1999 Second prototype received and tested**
- **2000 Workshop on GRETA physics (MSU)**
- **2000 Proposal for a GRETA module cluster submitted and reviewed, funded 2002**
- **2001 National Steering Committee formed**
- **2001 Santa Fe meeting (2002 LRP) presentation and discussion**
- **2001 Workshop on Digital Electronics in Nuclear Physics (ANL)**
- **2001 Workshop on Gamma-ray tracking detectors (Lowell)**
- **2002 Gamma Ray Tracking Coordination Committee review -*National plan for development of Gamma-ray tracking detectors in nuclear science***

GRETA Steering Committee

Development and construction of a national Gamma-Ray Energy Tracking Array for nuclear science

- Con Beausang, *Yale University*
- Doug Cline, *University of Rochester*
- Thomas Glasmacher, *Michigan State University*
- I-Yang Lee, *Lawrence Berkeley National Lab.*
- C. Kim Lister, *Argonne National Laboratory*
- David Radford, *Oak Ridge National Laboratory*
- Mark Riley, *Florida State University*
- Demetrios Sarantites, *Washington University*

Recent NSAC Review

Report of NSAC facilities review subcommittee 3/3/03 (C. Glashausser, chair), ranked GRETA :

- **Science**

  category 1 : *Absolutely central*

- **Readiness**

  category 1 : *Ready to initiate construction*

R&D Accomplishments

Proof of principle: No show stoppers

- **Segmented detectors**
  - 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_γ < 5 MeV) : eff = 50%, for m= 25.
  - Pair tracking (E_γ> 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).

GRETA Resolving Power

Realistic : Ω=0.8, Δx=2 mm

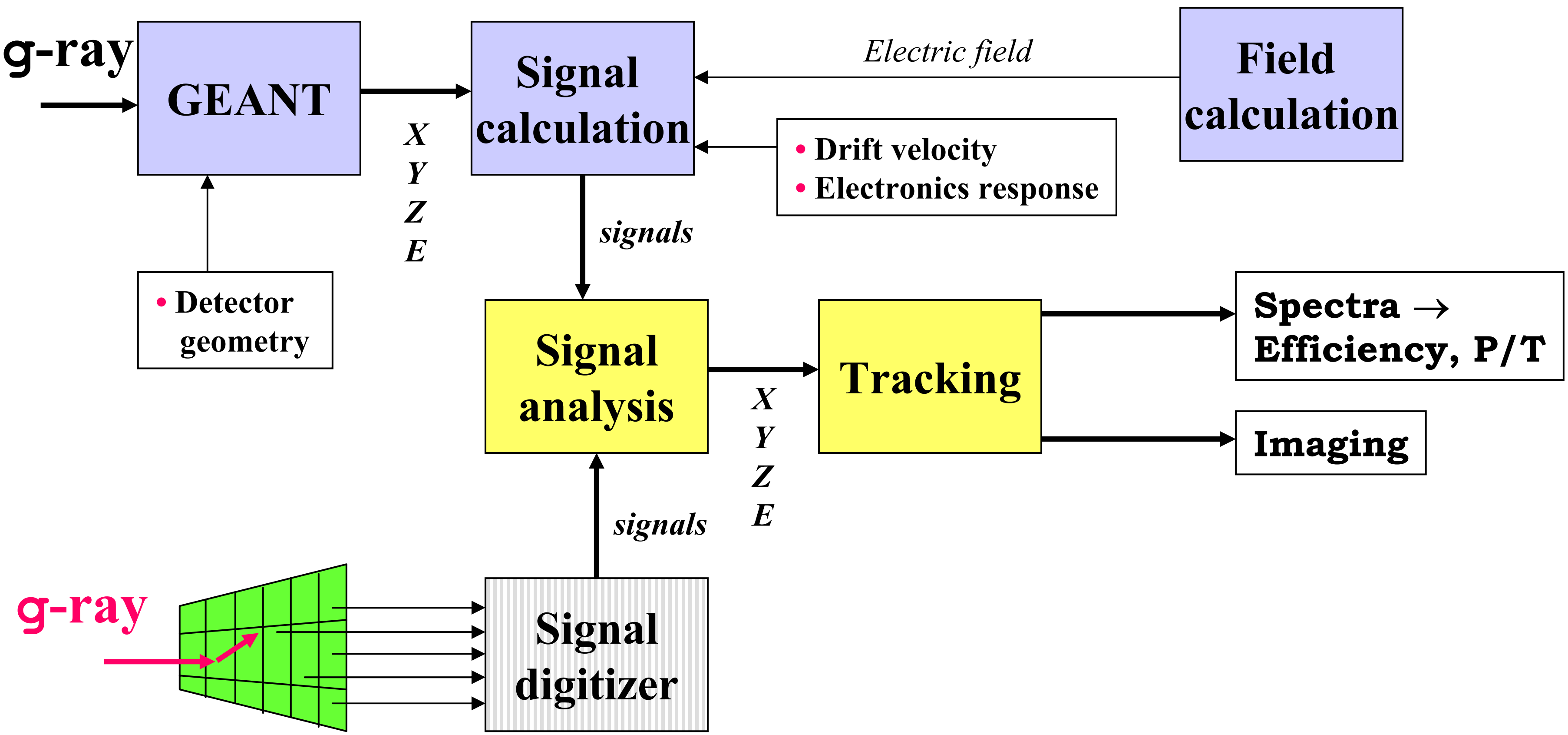
Reaction	<Eγ> (MeV)	β	Mγ	Resolving Power	× Gammasphere
Stopped	5.0	0.0	4	2.1×10^7	270
High spin					
normal kine.	1.0	0.04	20	3.3×10^6	100
inverse kine.	1.0	0.07	20	3.0×10^6	230
Coulex/transfer	1.5	0.1	15	4.5×10^6	1000
Fragmentation					
in beam	1.5	0.5	6	6.3×10^6	29000
Coulex	5.0	0.5	2	2.7×10^3	213

Recent Developments and future plans

- Full analysis of source measurements
- Design detector configuration
- Order three-crystal detector modules
- Design preamplifier
- Develop digital electronics
- Studied staged construction approach
- In-beam measurements
- Improve signal analysis algorithm
- Improve tracking algorithm

Full analysis of simulated and experimental data

Detector Prototype II



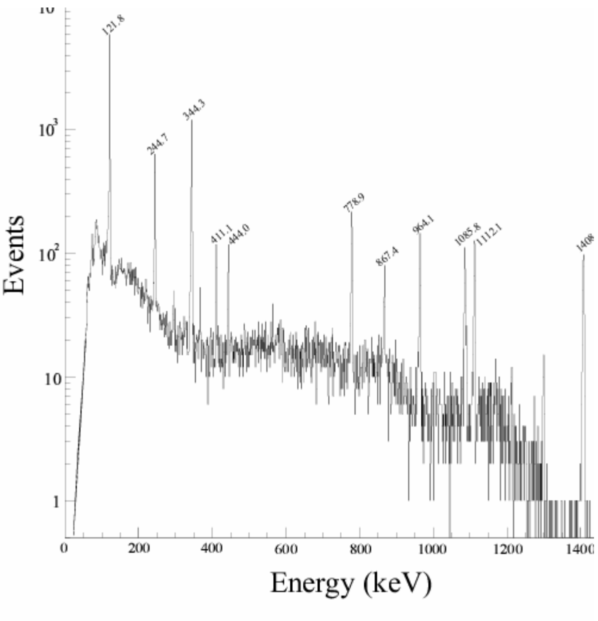
Austin Kuhn, *PhD Thesis, UC Berkeley, 2002.*

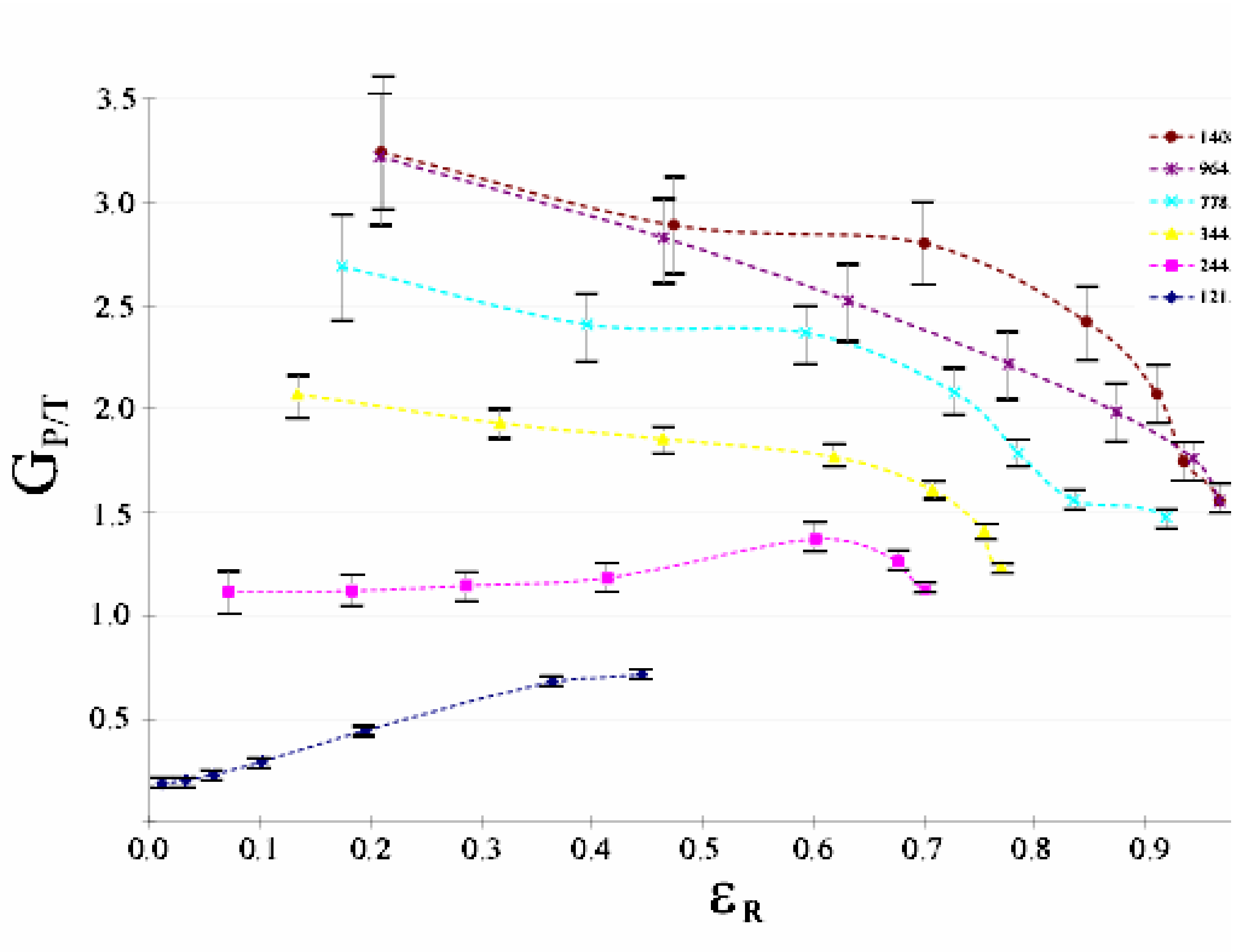
Full analysis

- ^{137}Cs, ^{60}Co and ^{152}Eu, 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, success rate=85%
- For two interactions per segment
  • position resolution =1 mm, success rate=70%
  • minimum separation =2 mm
- Compared Simulation with Data

^{152}*Eu full analysis*

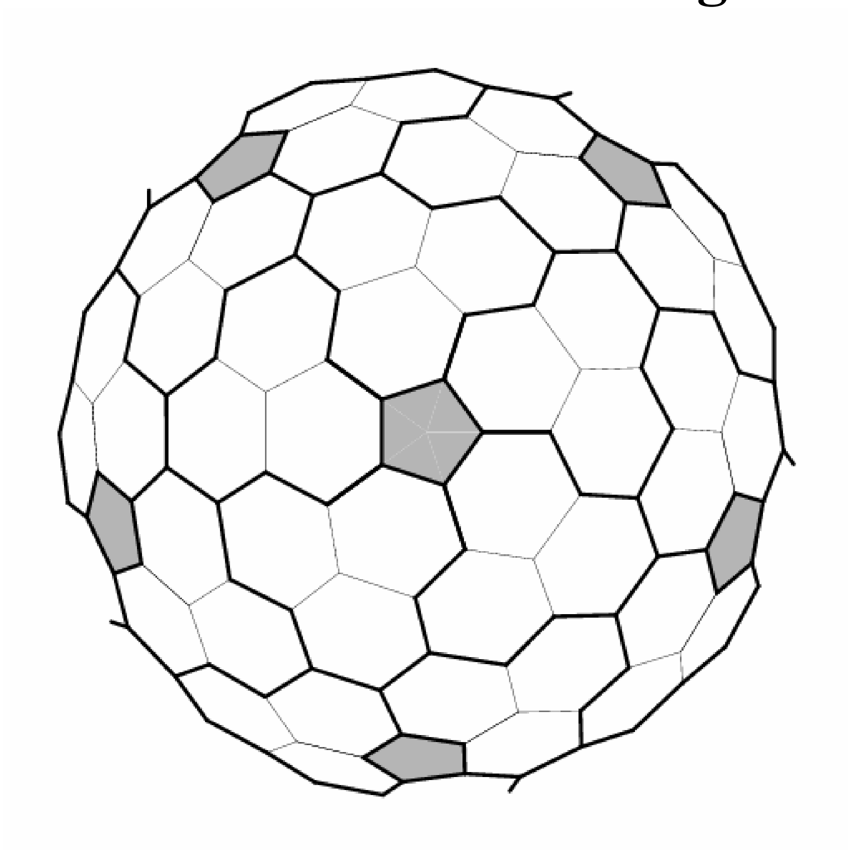
Gain in peak/total vs. efficiency

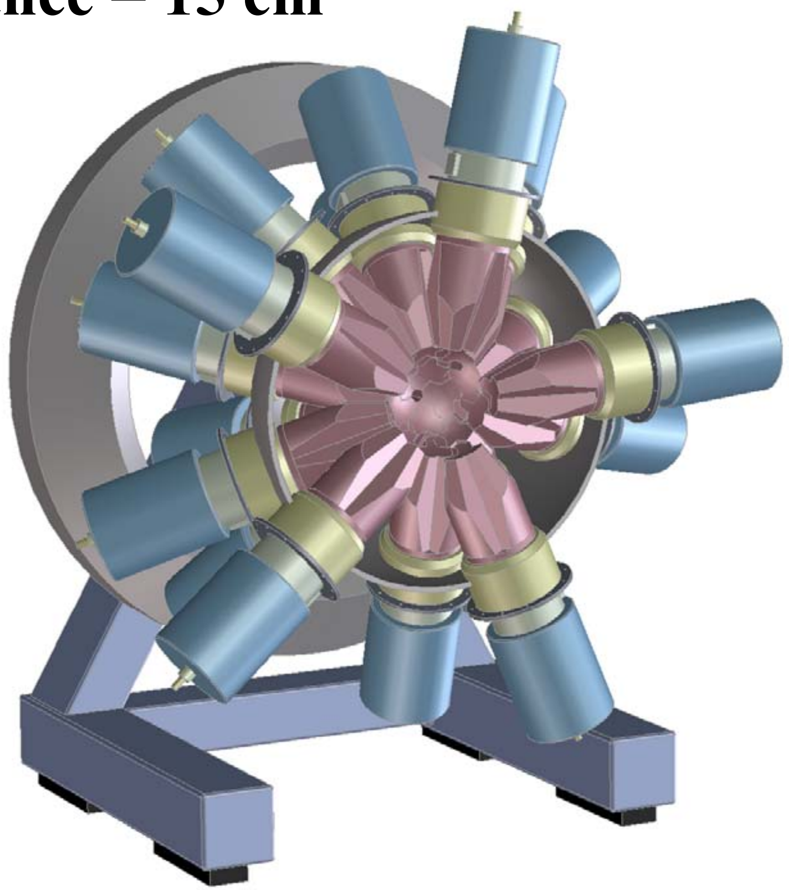




GRETA Detector Configuration

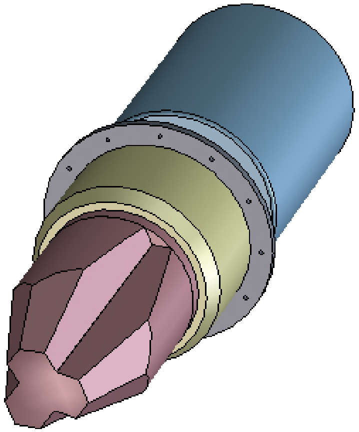
- **Two types of irregular hexagon, 60 each**
- **Pack three crystals per cryostat → 40 modules**
- **Detector – target distance = 15 cm**



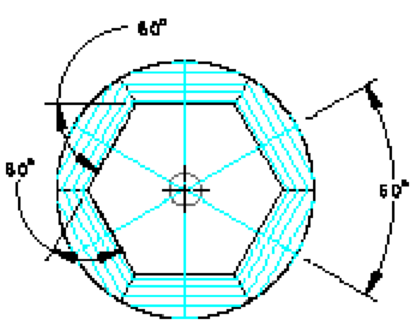


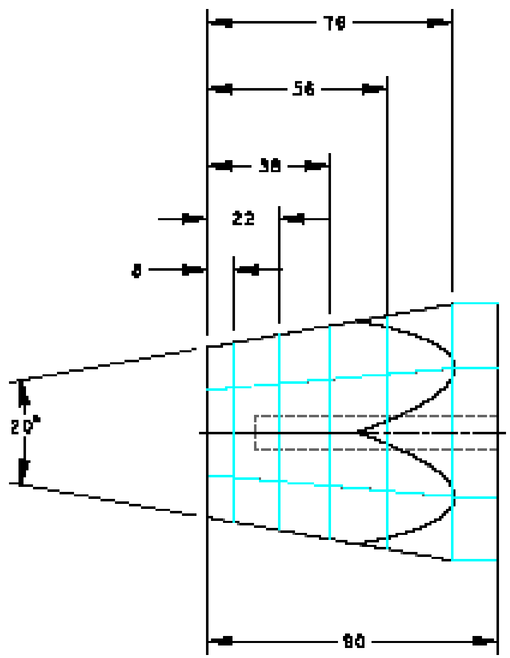
Three-crystal detector module

Building Block of GRETA



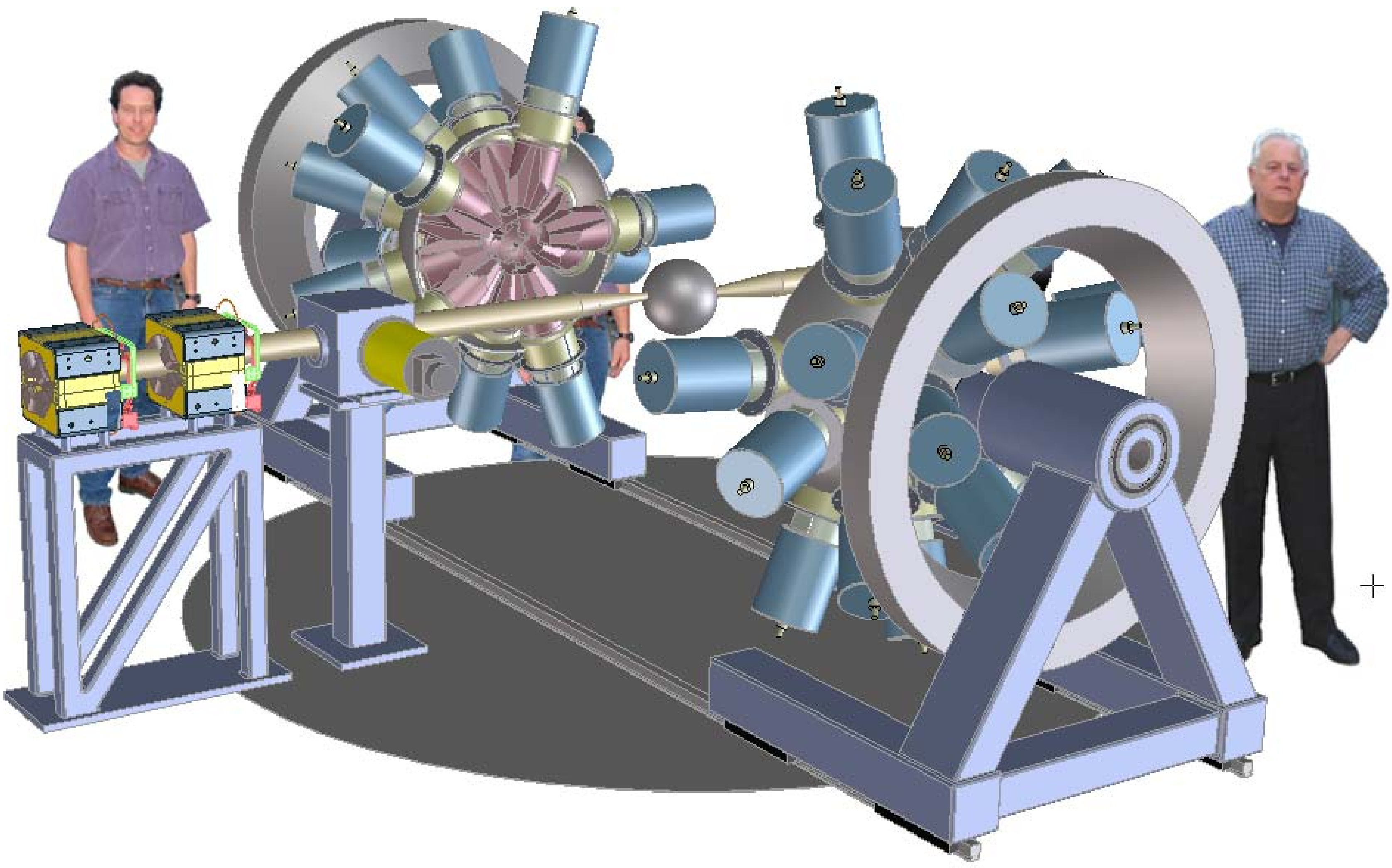
- Tapered regular hexagon shape.
- DIA= 8 cm, L= 9 cm, 36 segments.
- Close packing of crystals with gap= 3.5 mm.
- On order and expecting delivery in Oct. 2003.
- Cost = $750 k ($450k for 40 units)





GRETA Structure

Jim Comins and Robin Lafever



Electronics Production

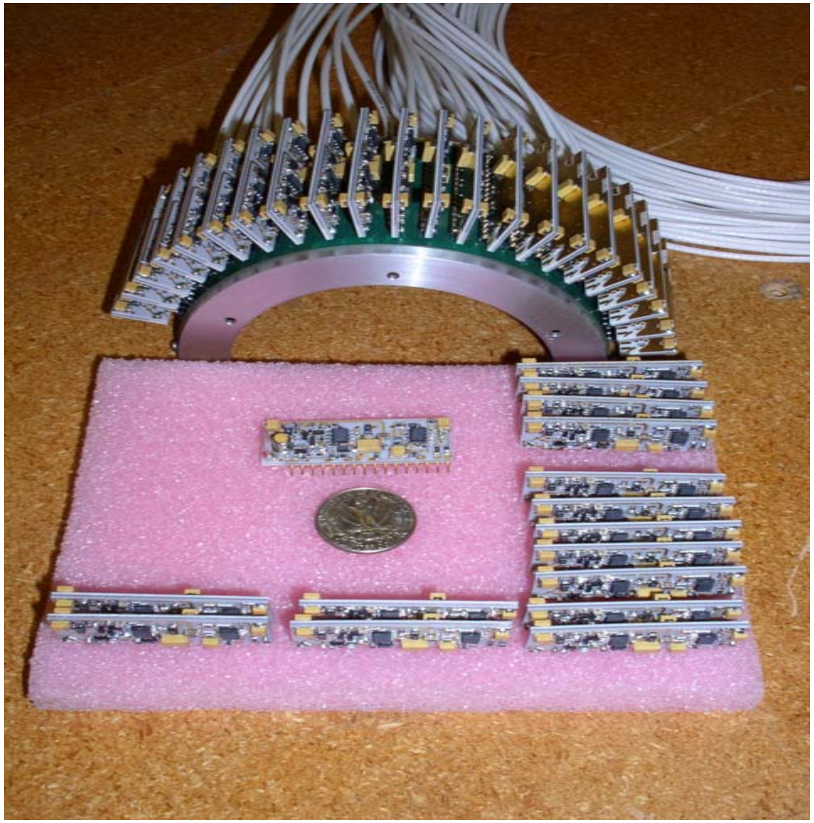
Vincent Riot, Harold Yaver and Bob Minor

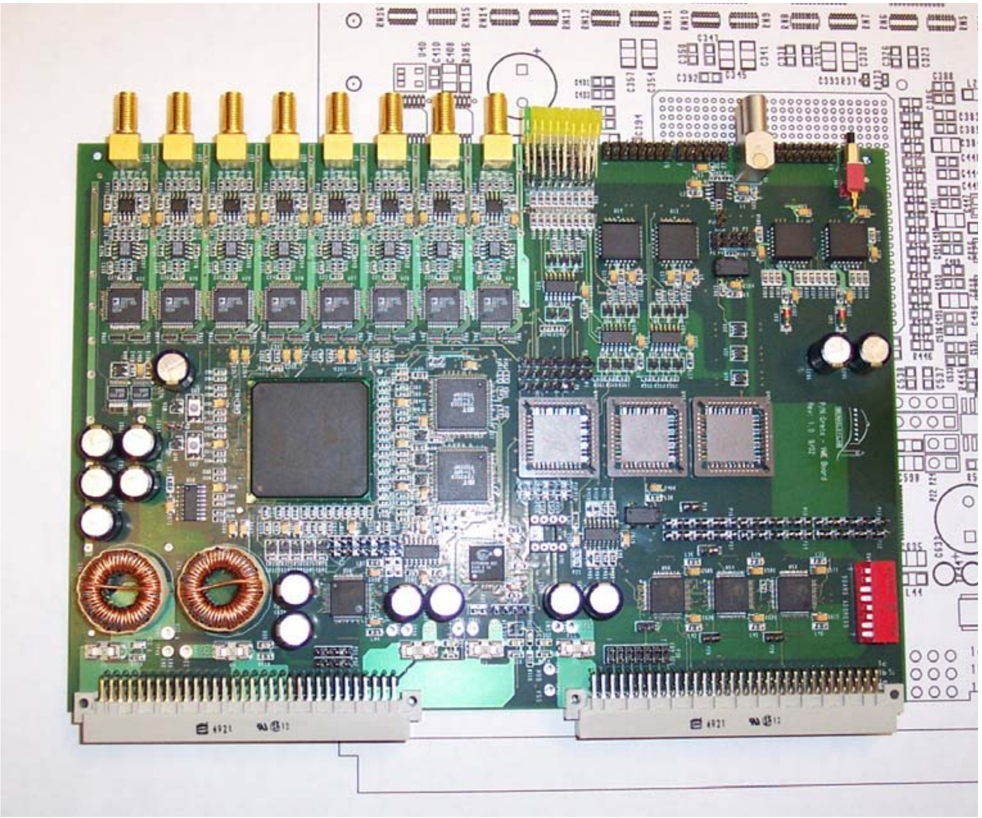
Preamplifier

- Low noise
- high band width
- $100/channel

Signal Digitizer

- Sampling rate = 100 MHz
- Resolution =12 bits
- $500/channel





Signal Digitizer

Prototype specifications determined at ANL workshop

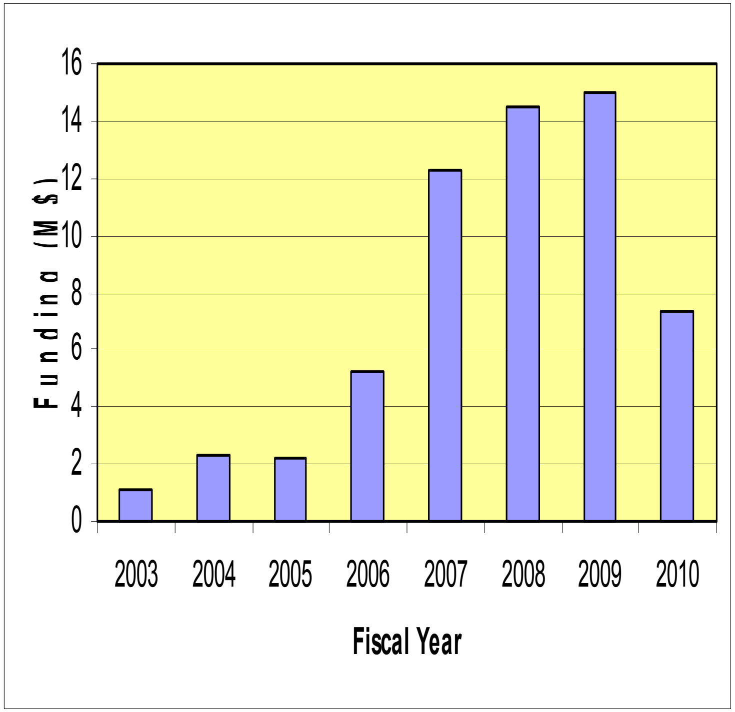
- **Variable gain control**
- **Digitization at 100MHz, 12 bits**
- **Flexible triggering (internal, external, validation)**
- **Data processing**
  - **Digital Leading Edge discriminator with programmable parameters**
  - **Digital Constant Fraction with programmable parameters**
  - **Digital Trapezoidal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

GRETA Total Cost and Cost Profile

FY02 Dollar, with overhead

Item	Purchase (M$)	Effort (FTE-yr)	
• Mechanical	0.9	5	
• LN	0.5	4	
• Detector	18.0	7	
• Electronics	3.4	10	
• Computer	1.1	13	
• Installation	0.0	6	
• Management	0.0	15	
• Safety	0.0	3	
		63	
TOTAL (M$)	**23.9**	**12.6**	**36.5**
+ escalation			**42.9**
+ contingency (27%)			**54.5 (TEC)**
+ R/D, pre-operation etc.			**60.1 (TPC)**

By: Jay Marx, Bill Edwards, Bob Minor et al.



Staged approach of GRETA

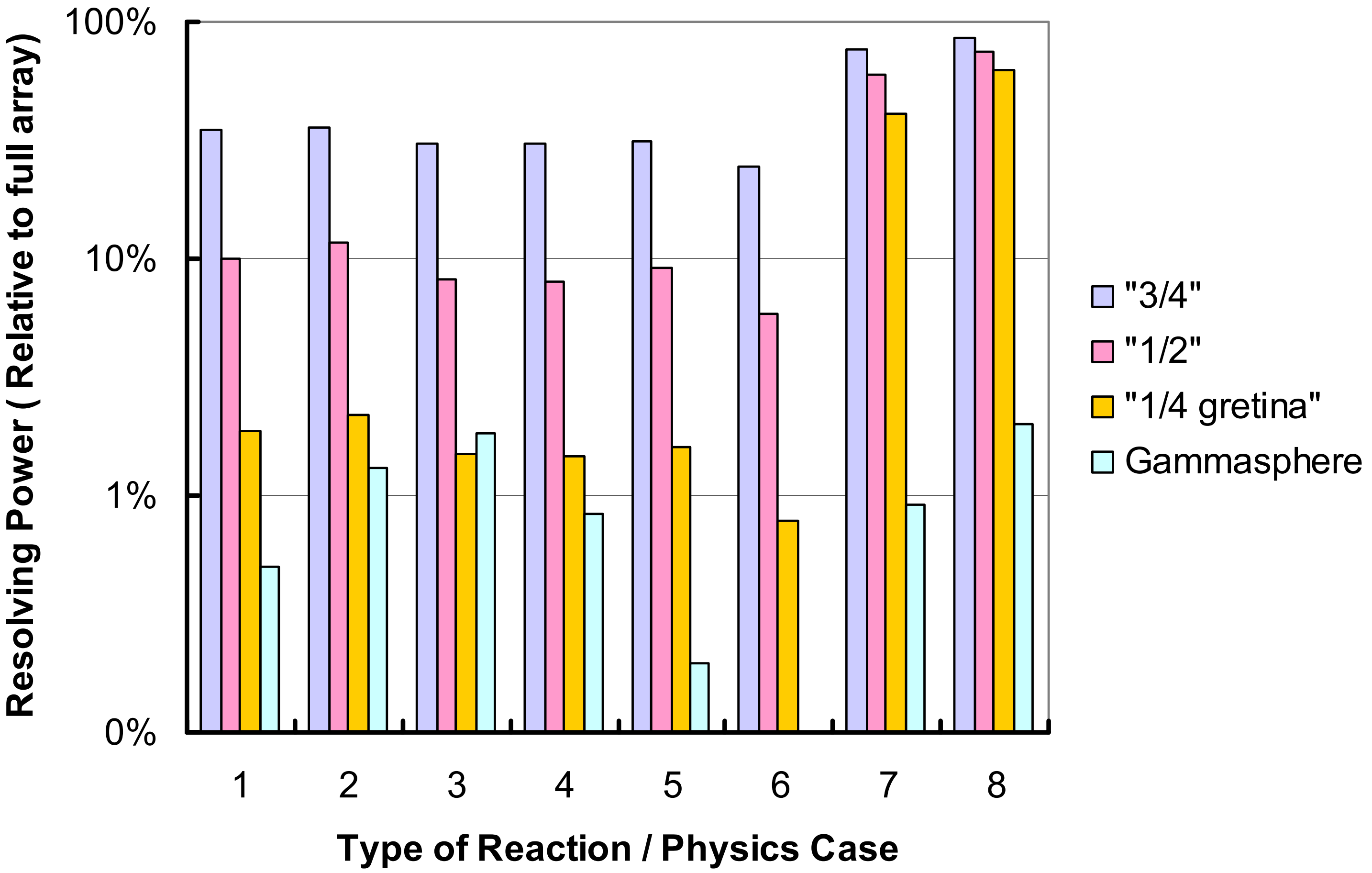
In 4 stages, each with increment of ¼ of the detector

- First stage: GRETINA = ¼ of GRETA
  - 30 crystals (10 modules)
  - Complete computer software development
- Cost of $16.7 M
- Construction period from 2004 – 2007
- Proposal is being developed

GRETA Staged Performance

Type of Reaction	$\langle E_\gamma \rangle$ (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 features of GRETINA

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

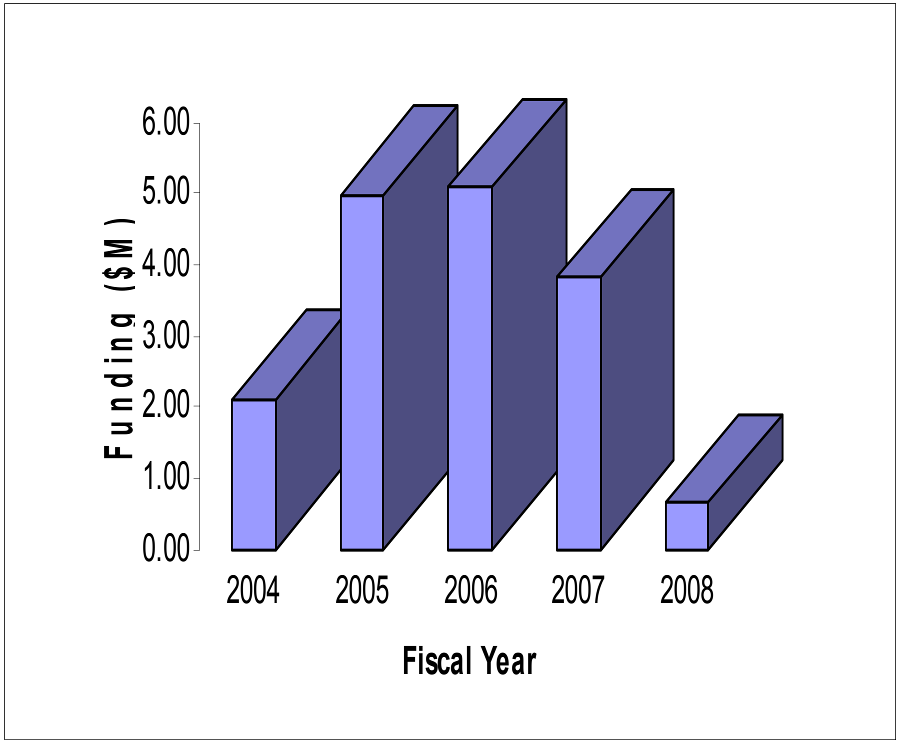
Nuclear structure studies with fast exotic beams

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%**

GRETINA Total Cost and Cost Profile

FY02 Dollar, with overhead, contingency and escalation

Item	Cost (M$)
• Mechanical	1.56
• LN	0.62
• Detector	6.39
• Electronics	2.95
• Computer	4.05
• Installation	0.26
• Management	0.52
• Safety	0.32
Total	**16.68**



Conclusion

- **R&D efforts achieved *"proof of principle"*.**
- **Engineering design started on critical items.**
- **Exciting physics case has been identified for gretina.**
- **National effort involving steering committee and working groups.**
- **gretina /GRETA ready to initiate construction**