

Implementation of the FIPS Algorithm

Michael Schlarb, E12, TU München

AGATA Week

Legnaro, January 20th 2010

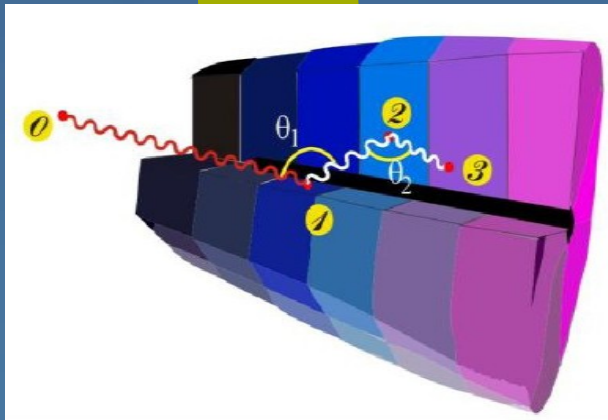


- Introduction
- Pulse Shape Analysis
- Application to simulated experiment
- Summary & Outlook



AGATA Real Time DAQ

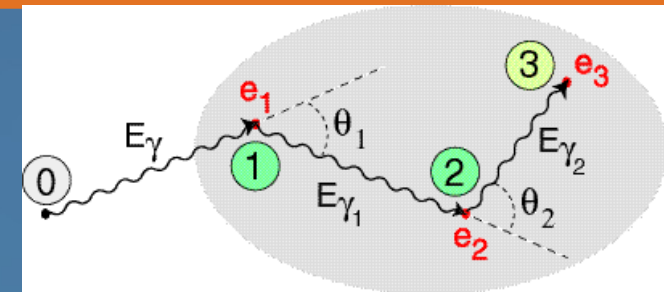
Segmented
HPGe Detector



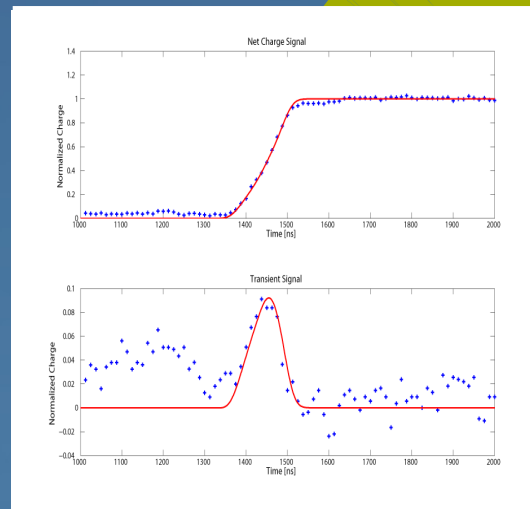
Identified
locations

$(x,y,z,E,t)_i$

Reconstruction of scattering
Path via tracking



Reconstruction of location
with PSA

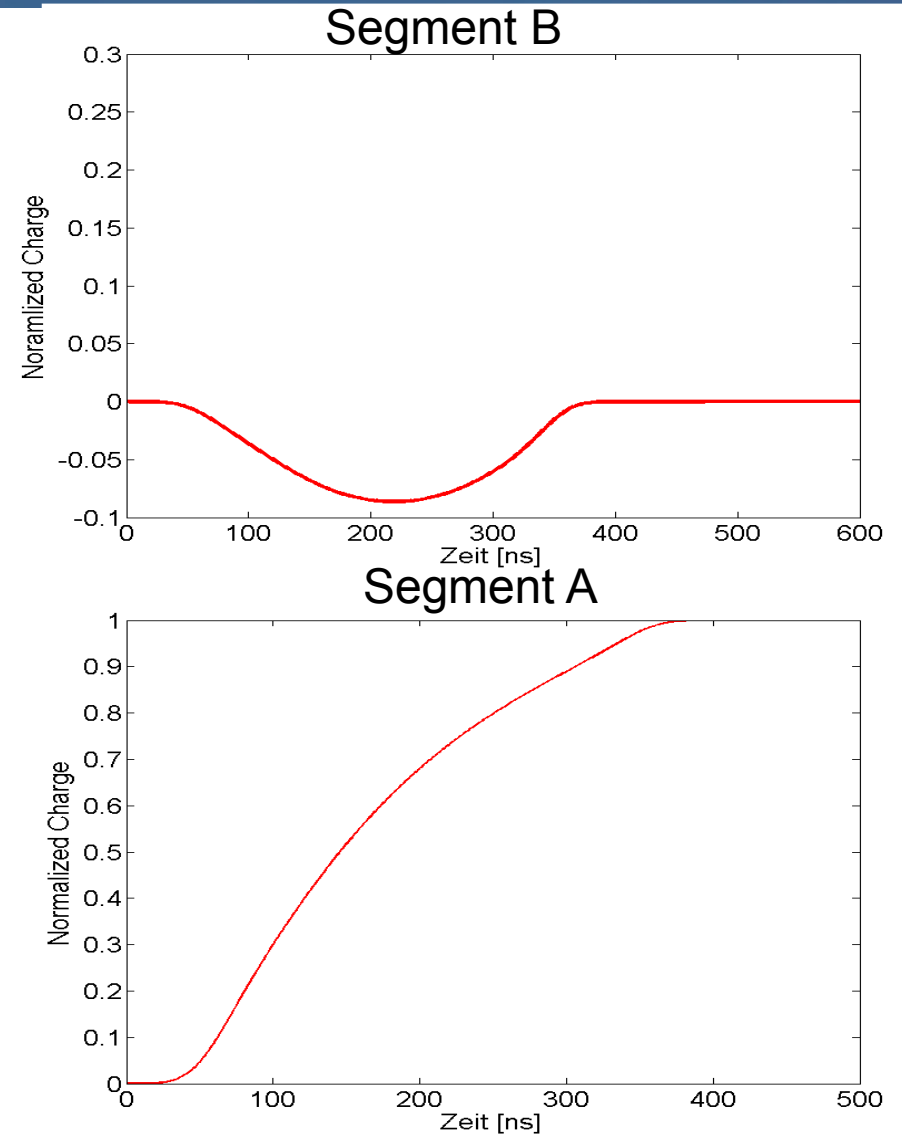
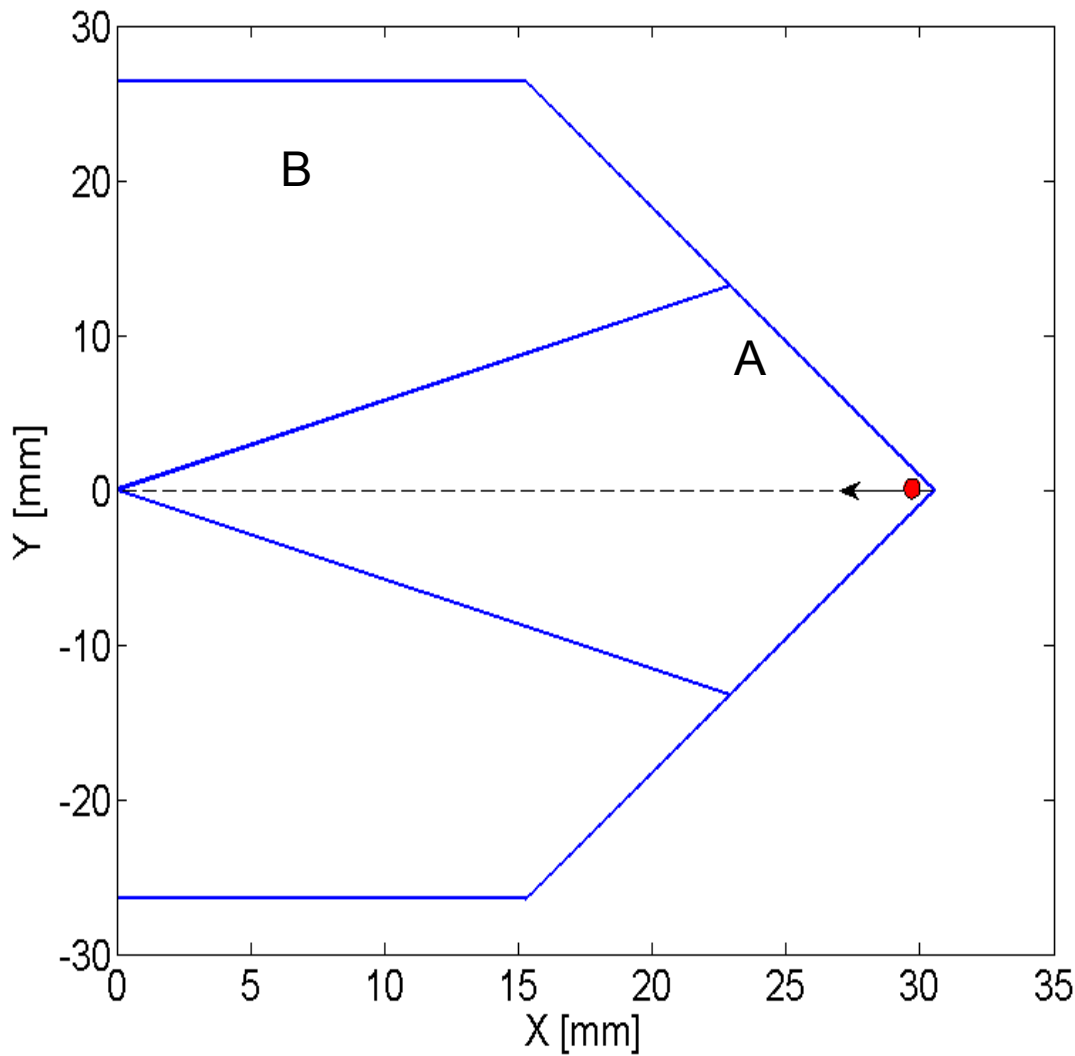


Digital Electronic

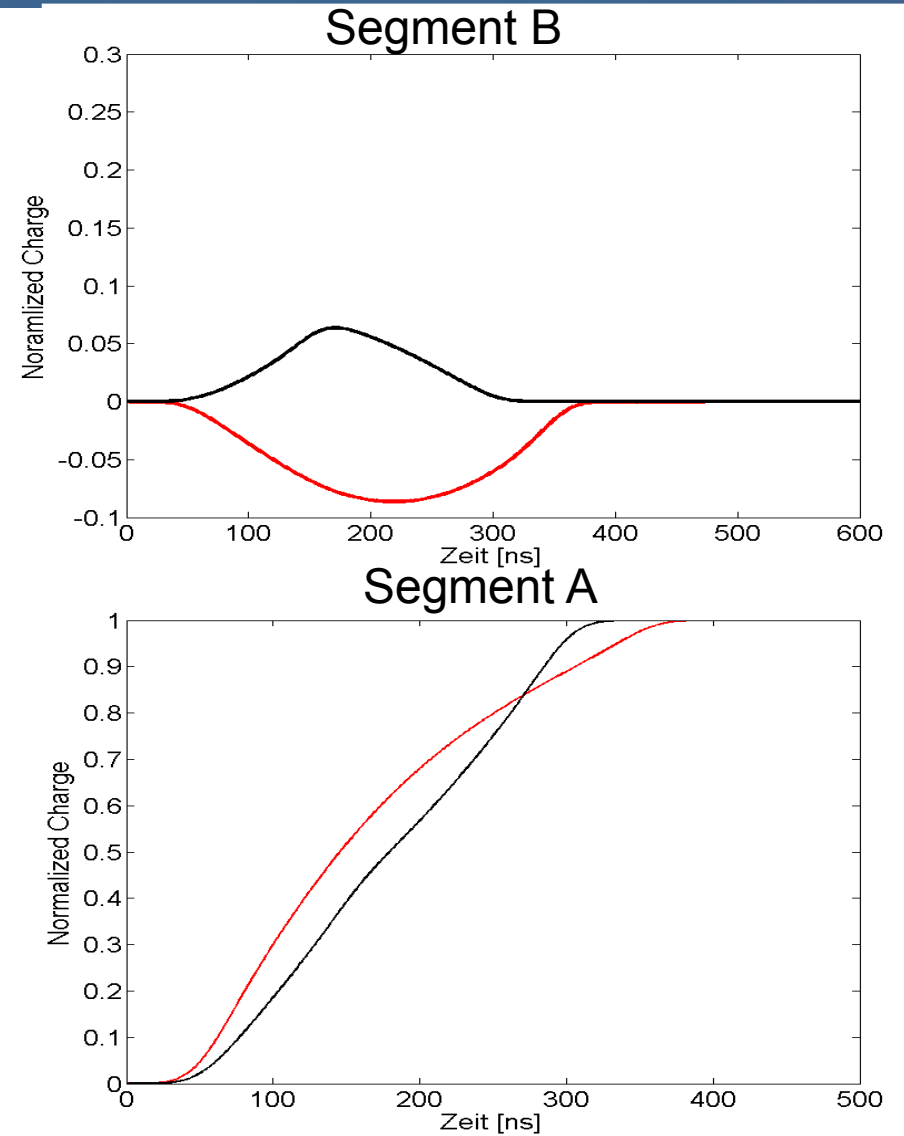
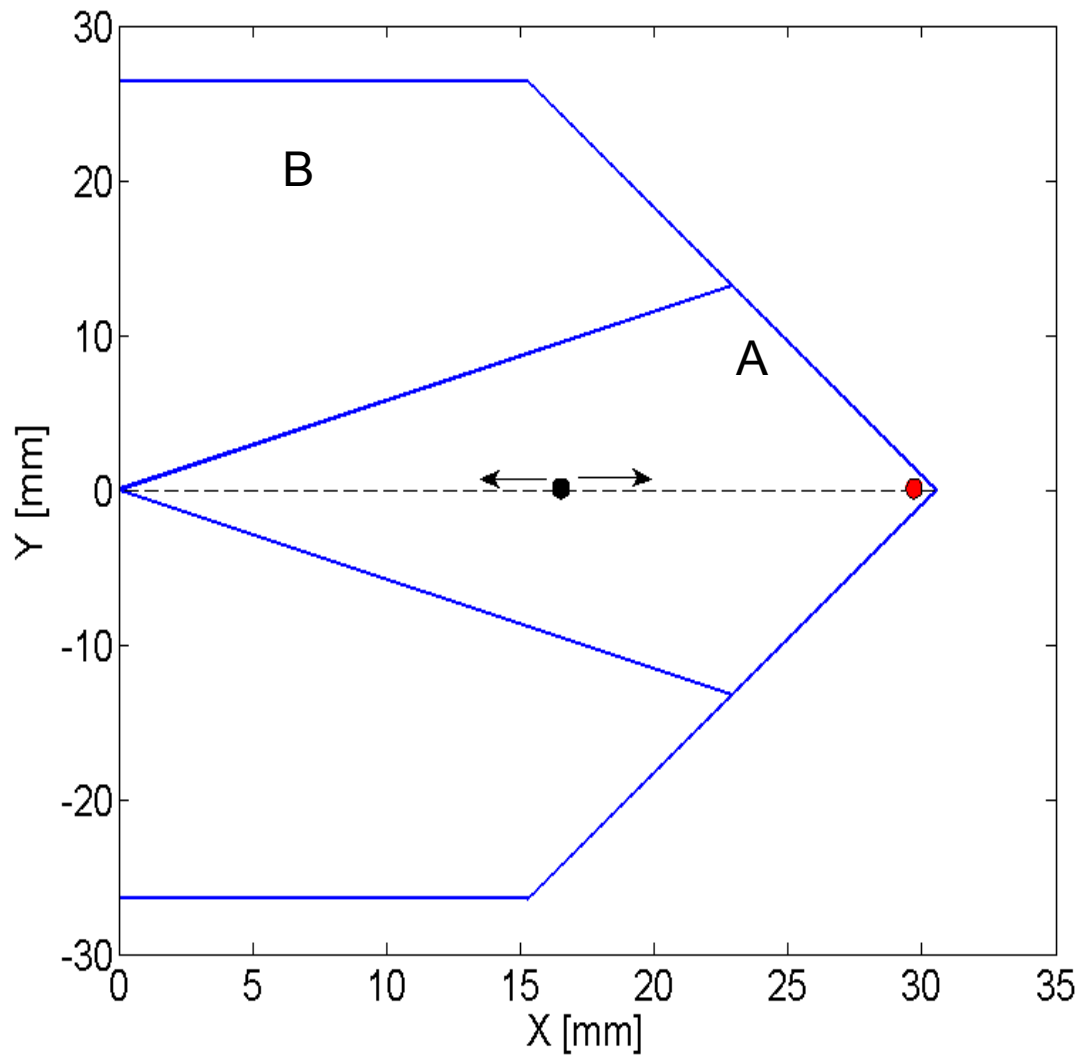
Reconstructed γ



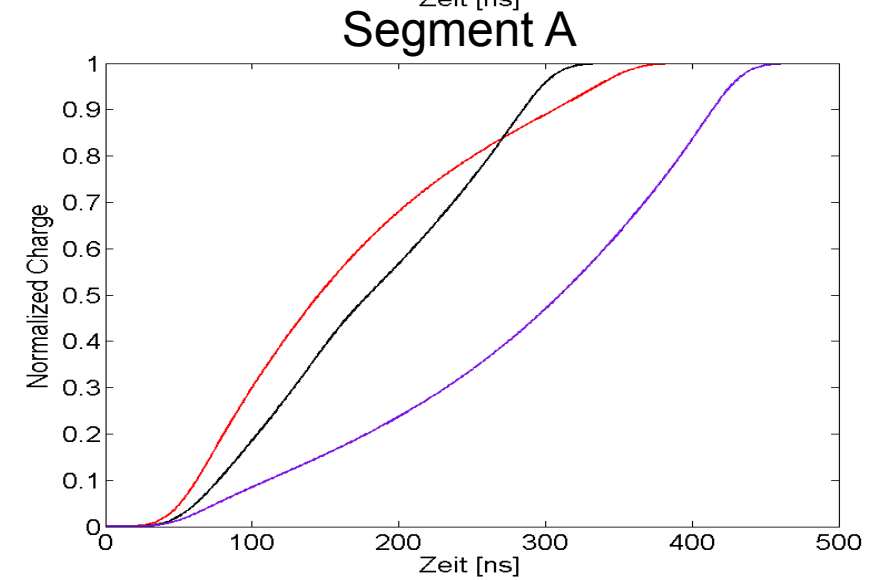
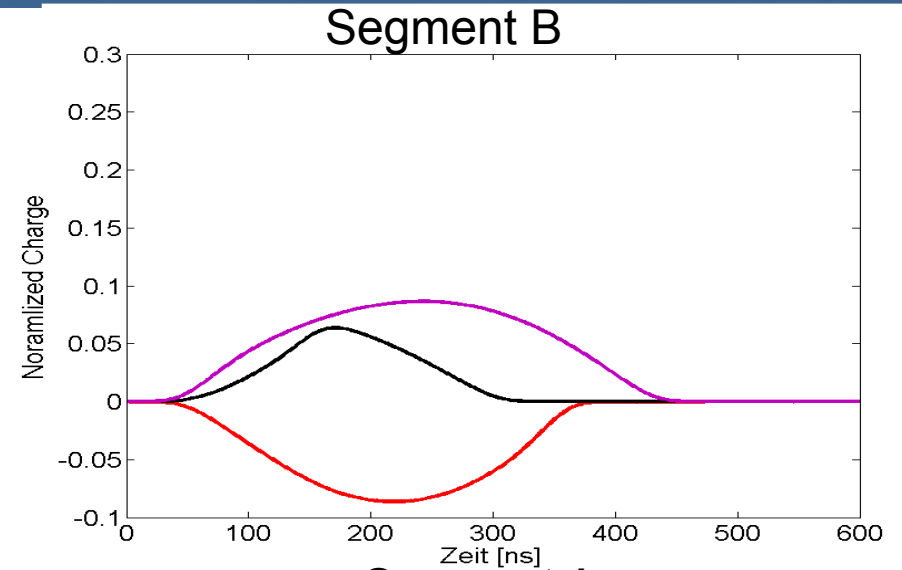
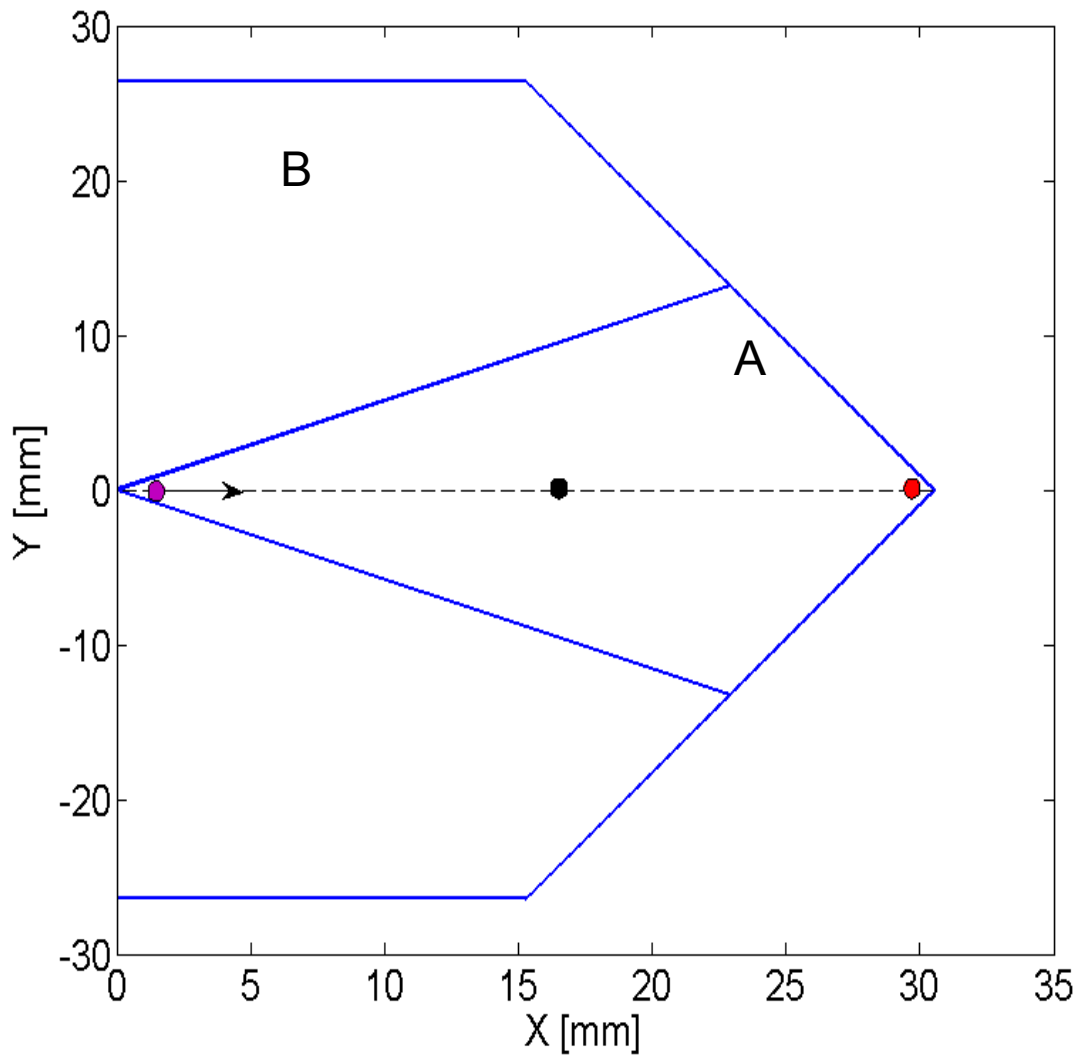
AGATA Pulse Shape Analysis (PSA)



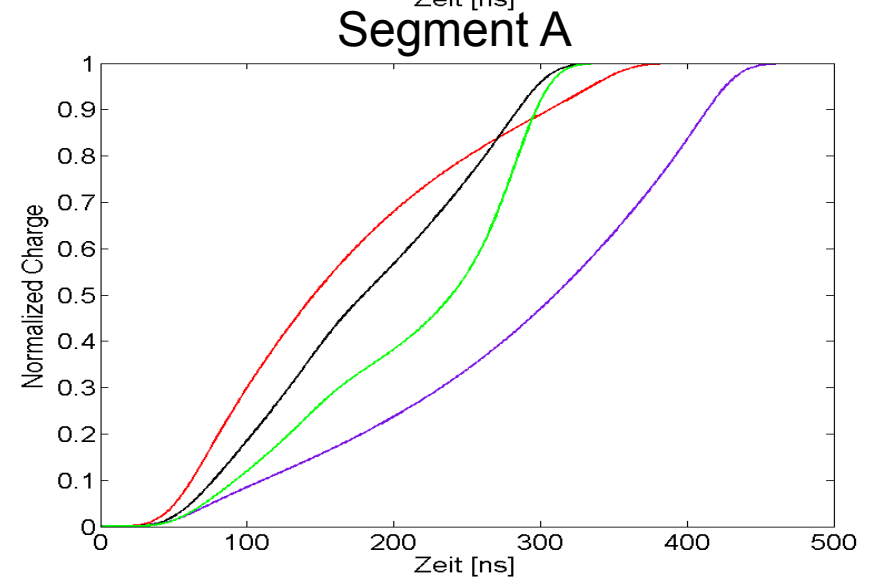
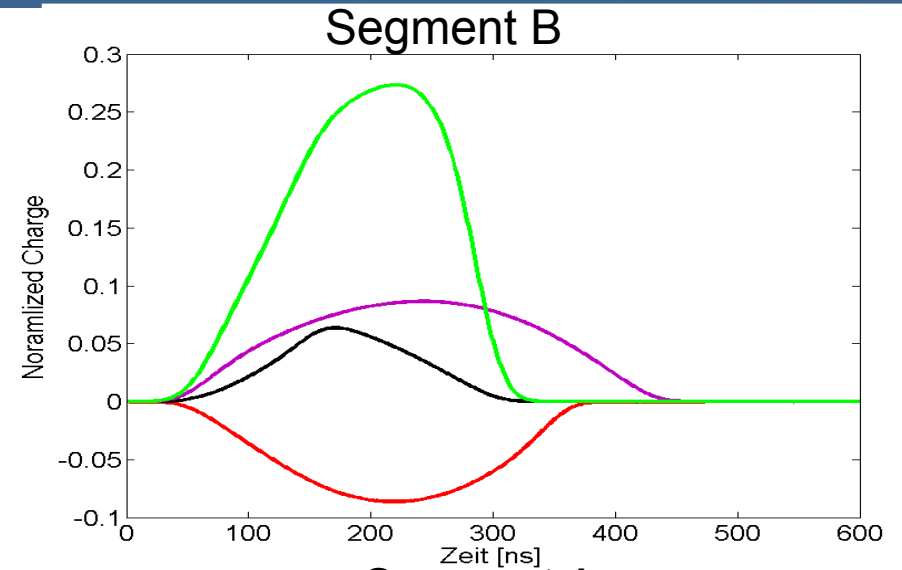
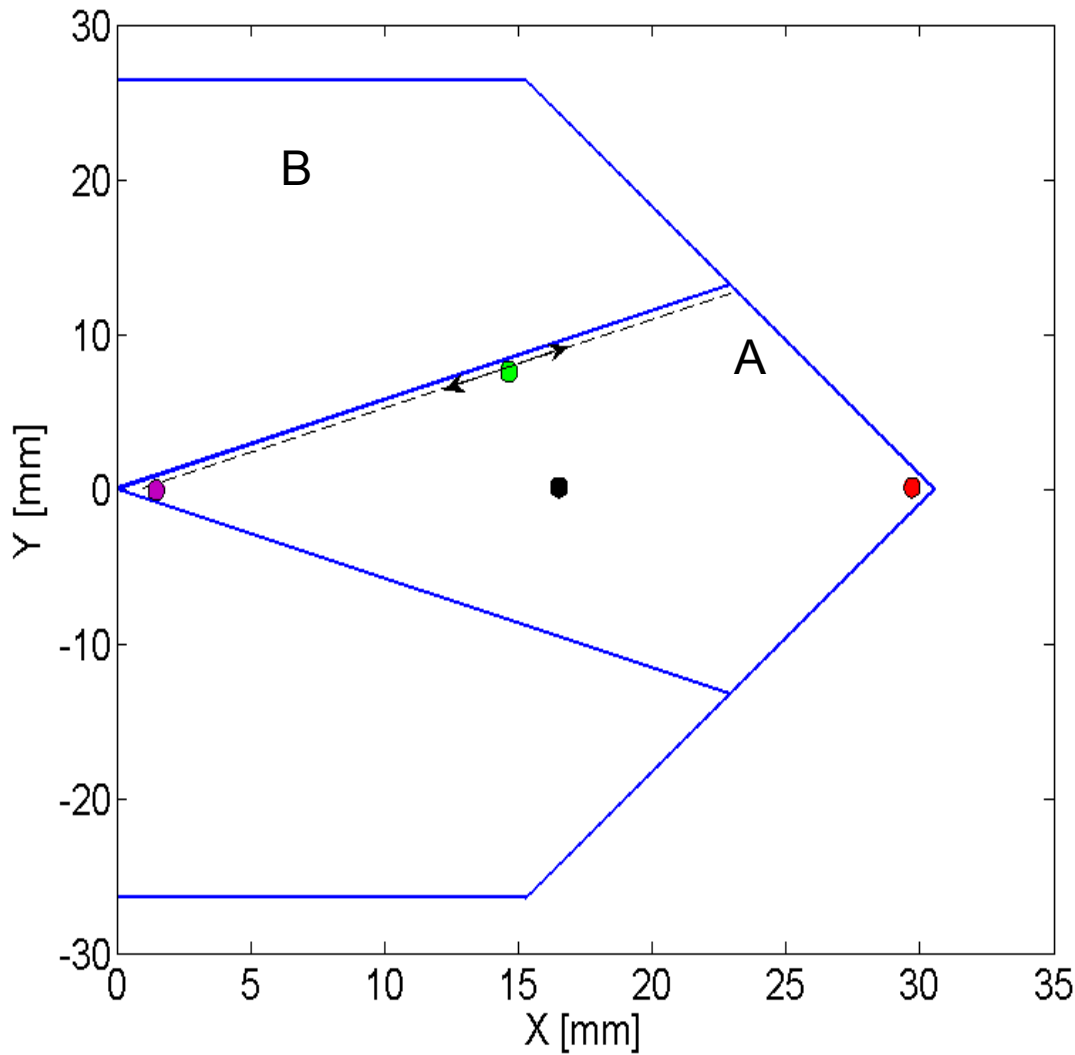
AGATA Pulse Shape Analysis (PSA)



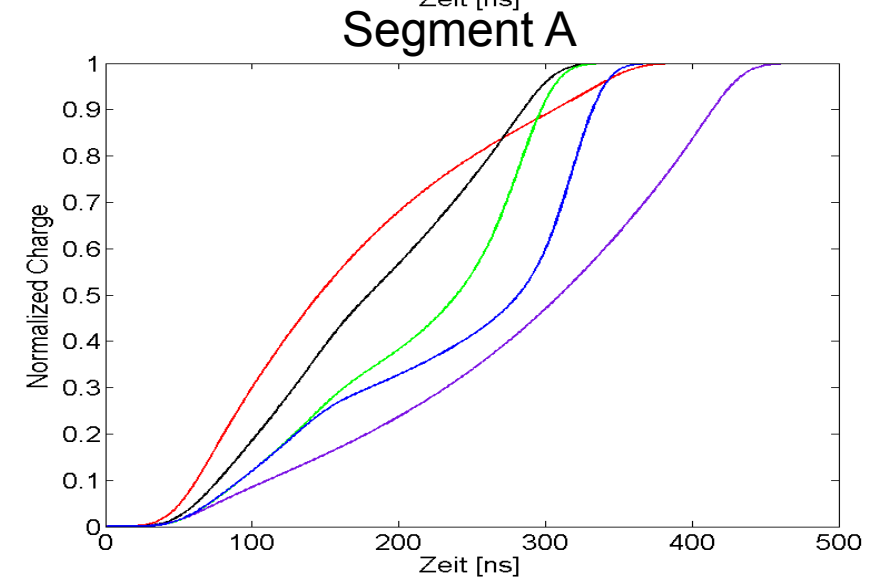
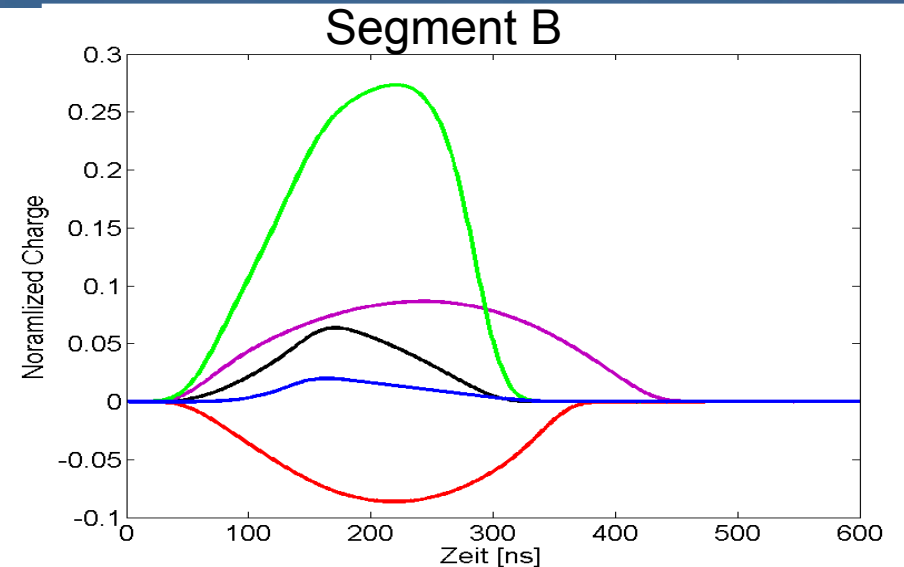
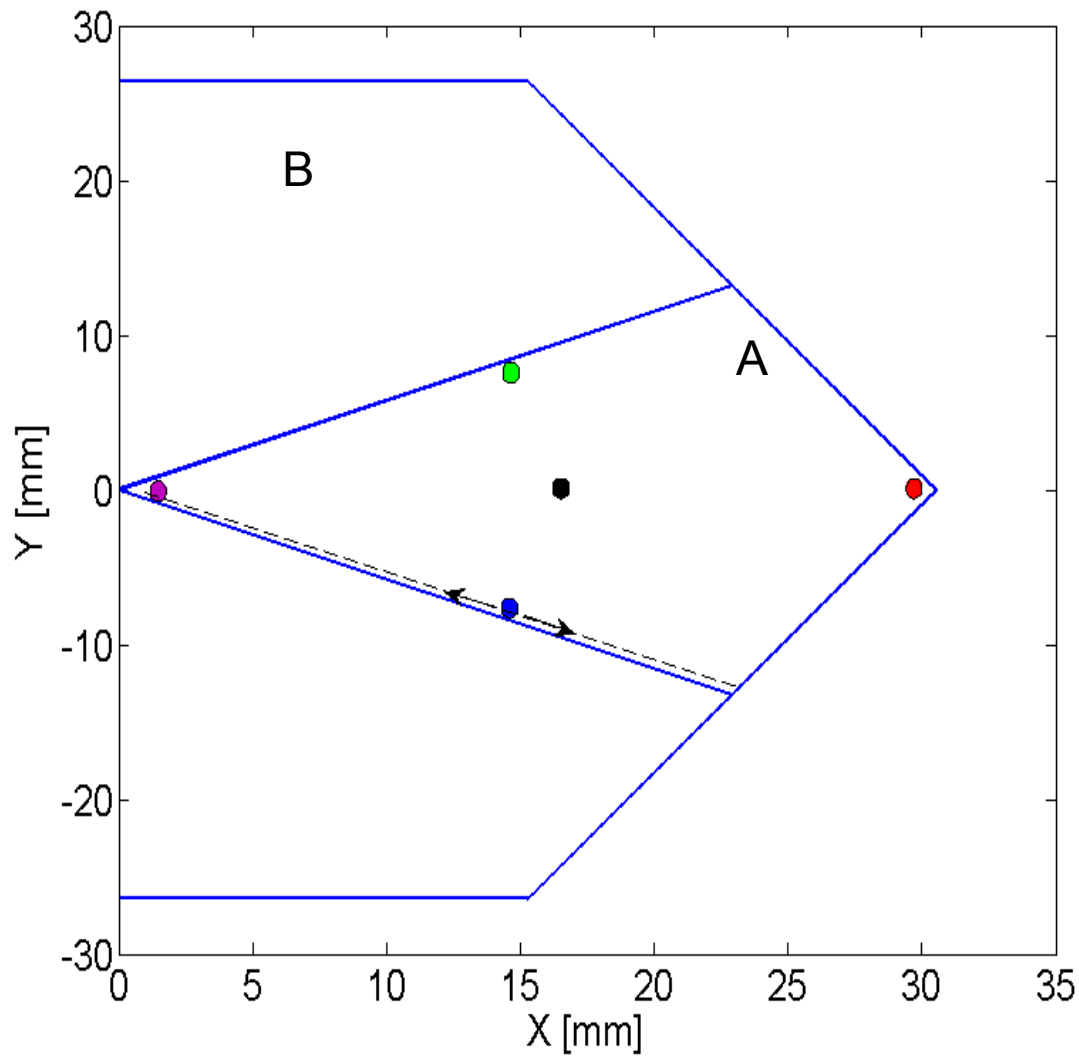
AGATA Pulse Shape Analysis (PSA)



AGATA Pulse Shape Analysis (PSA)

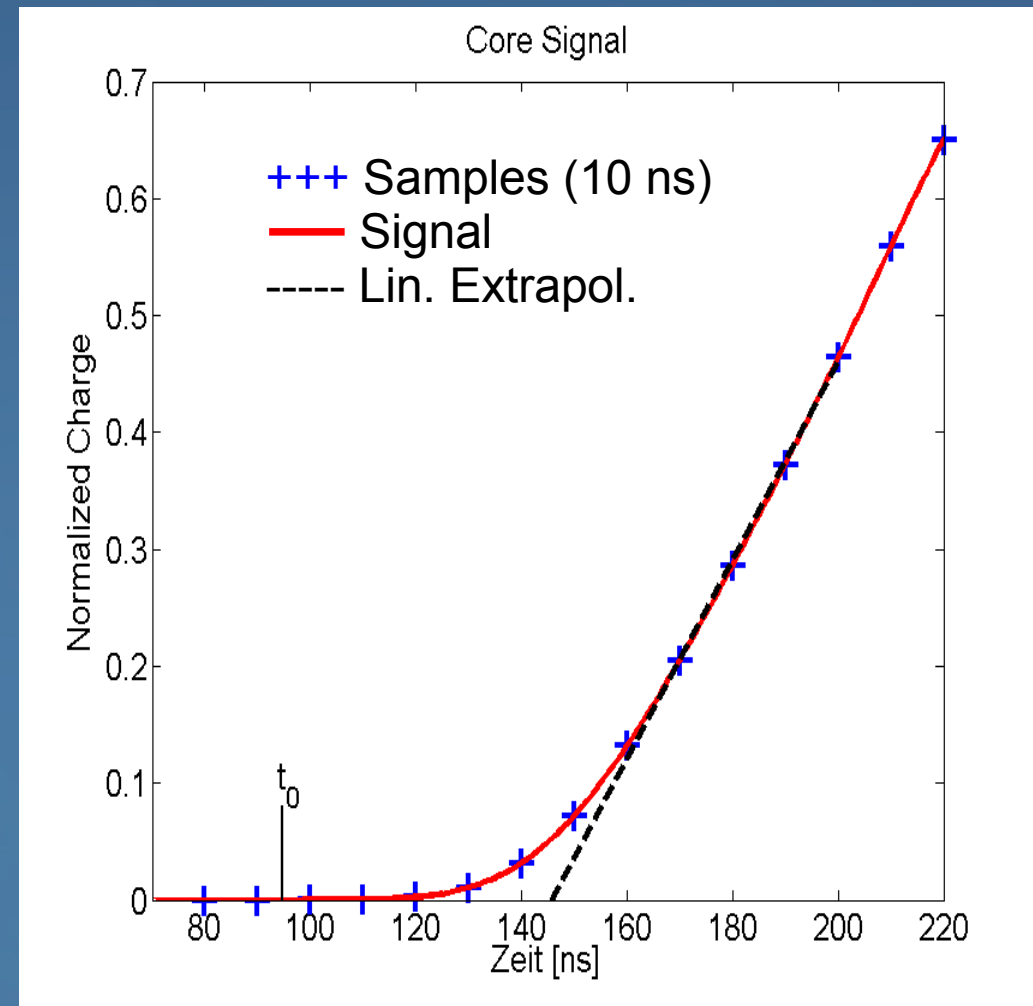


AGATA Pulse Shape Analysis (PSA)



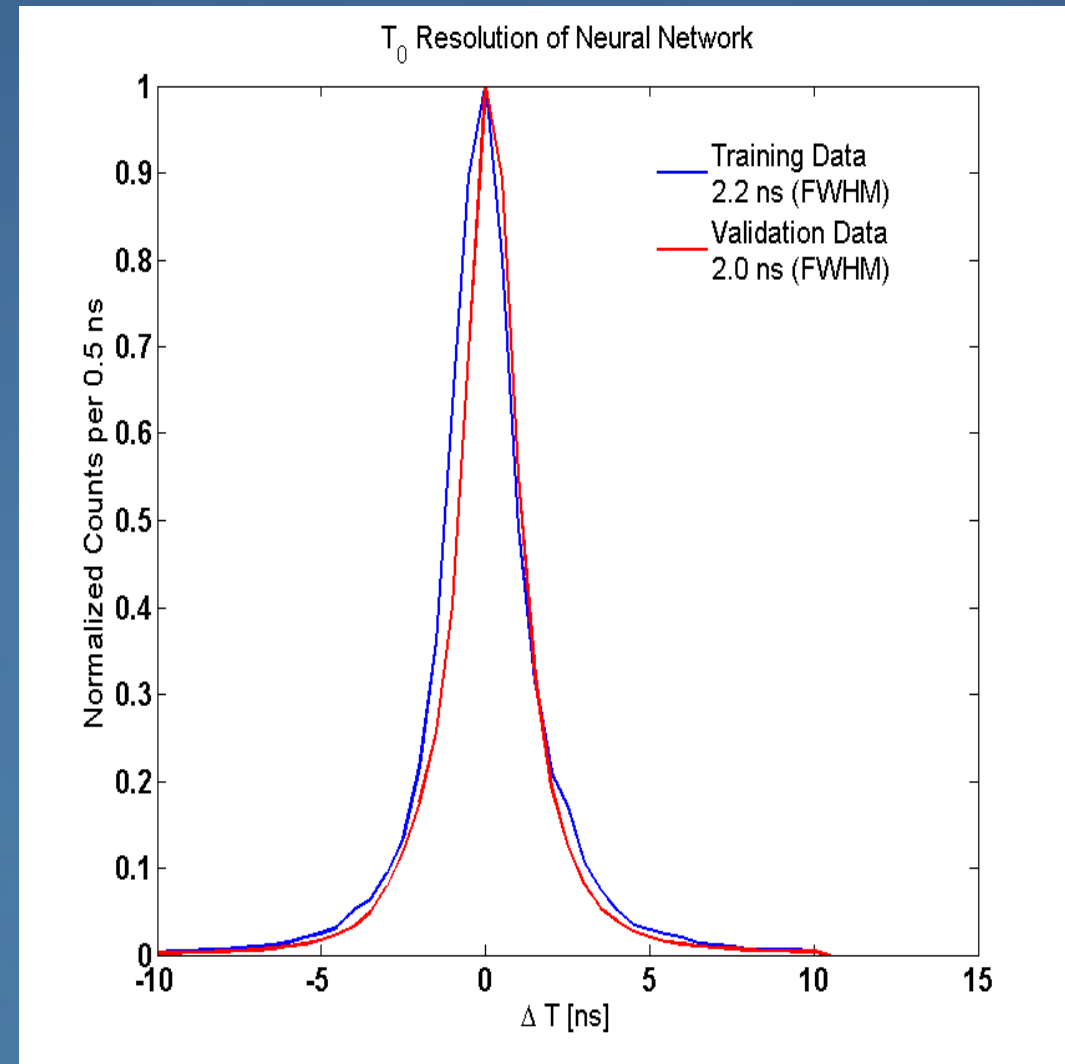
AGATA PSA – Ansatz and Challenges

- Position sensitive pulse shapes
- Experimental and simulated signals have to be time aligned
- Determine t_0 before PSA
 - Use only Core-Signal (GTS)
 - Linear Extrapolation
 - Neural Net
- Position reconstruction with PSA
 - Search in real time <10ms
 - Search space grows binomial with number of hits
 - 1 hit: 5000-15000
 - 2 hits: $10^7 - 10^8$
 - 3 hits: $10^{10} - 3 \cdot 10^{12}$
 - Intelligent search algorithm
 - Particle Swarm Optimization



AGATA PSA – Ansatz and Challenges

- Position sensitive pulse shapes
- Experimental and simulated signals have to be time aligned
- Determine t_0 before PSA
 - Use only Core-Signal (GTS)
 - Linear Extrapolation
 - Neural Net
- Position reconstruction with PSA
 - Search in real time <10ms
 - Search space grows binomial with number of hits
 - 1 hit: 5000-15000
 - 2 hits: $10^7 - 10^8$
 - 3 hits: $10^{10} - 3 \cdot 10^{12}$
 - Intelligent search algorithm
 - Particle Swarm Optimization

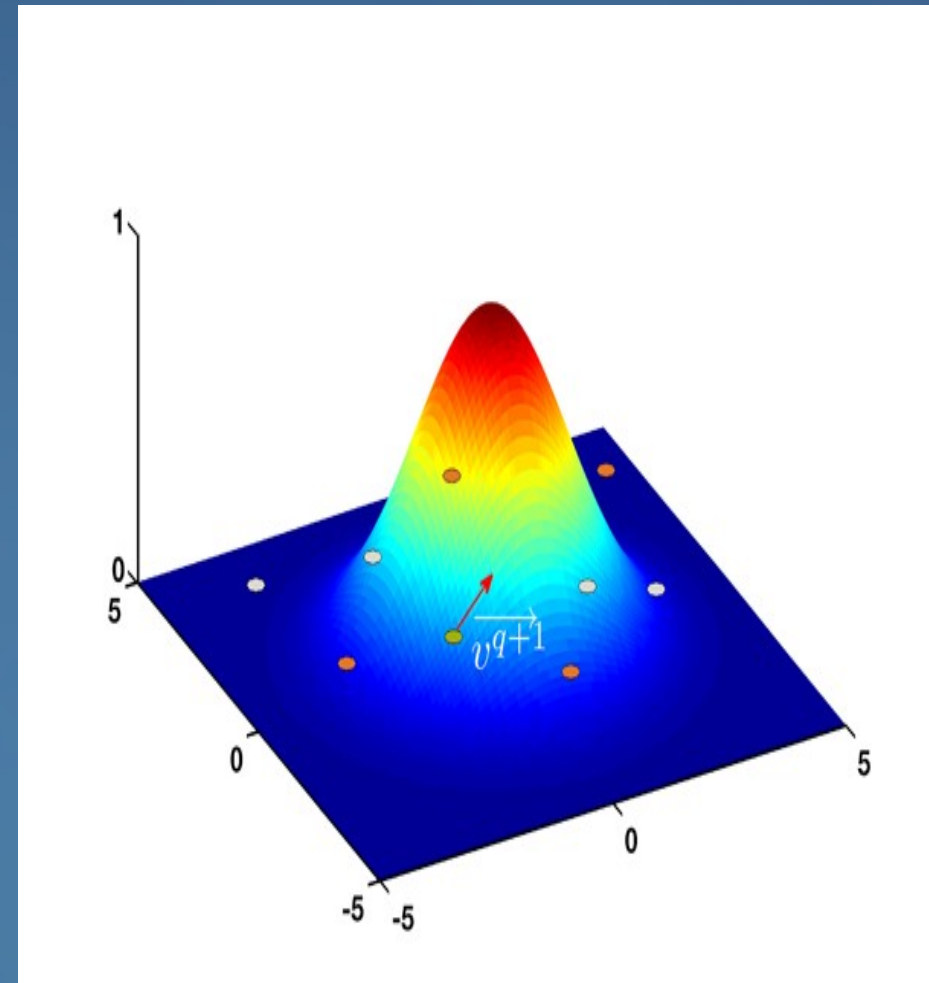


AGATA PSA with Particle Swarm Optimization

- Particle Swarm Optimization
 - Imitates behavior of flock of birds looking for food
 - Particles
 - Possible solution
 - Move through search space
 - Exchange information with neighboring particles
 - Various static topologies
- Fully Informed Particle Swarm (FIPS)

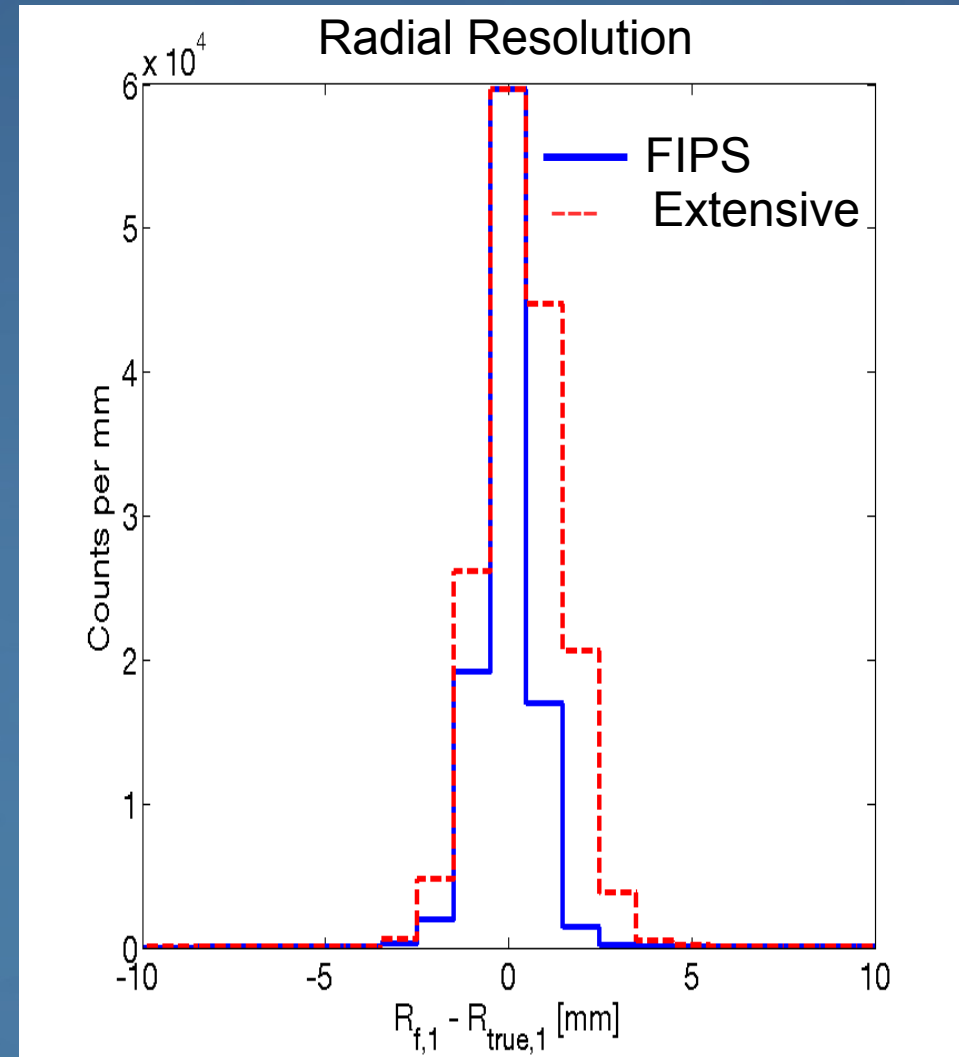
$$v_i^{q+1} = \chi \cdot \left\{ v_i^q + \sum_{n=1}^{N_i} c \cdot r \cdot (\vec{P}_n^q - \vec{X}_i^q) \cdot 1 / N_i \right\}$$

$$X_i^{q+1} = \vec{X}_i^q + v_i^{q+1}$$



AGATA PSA with Fully Informed Particle Swarm (FIPS)

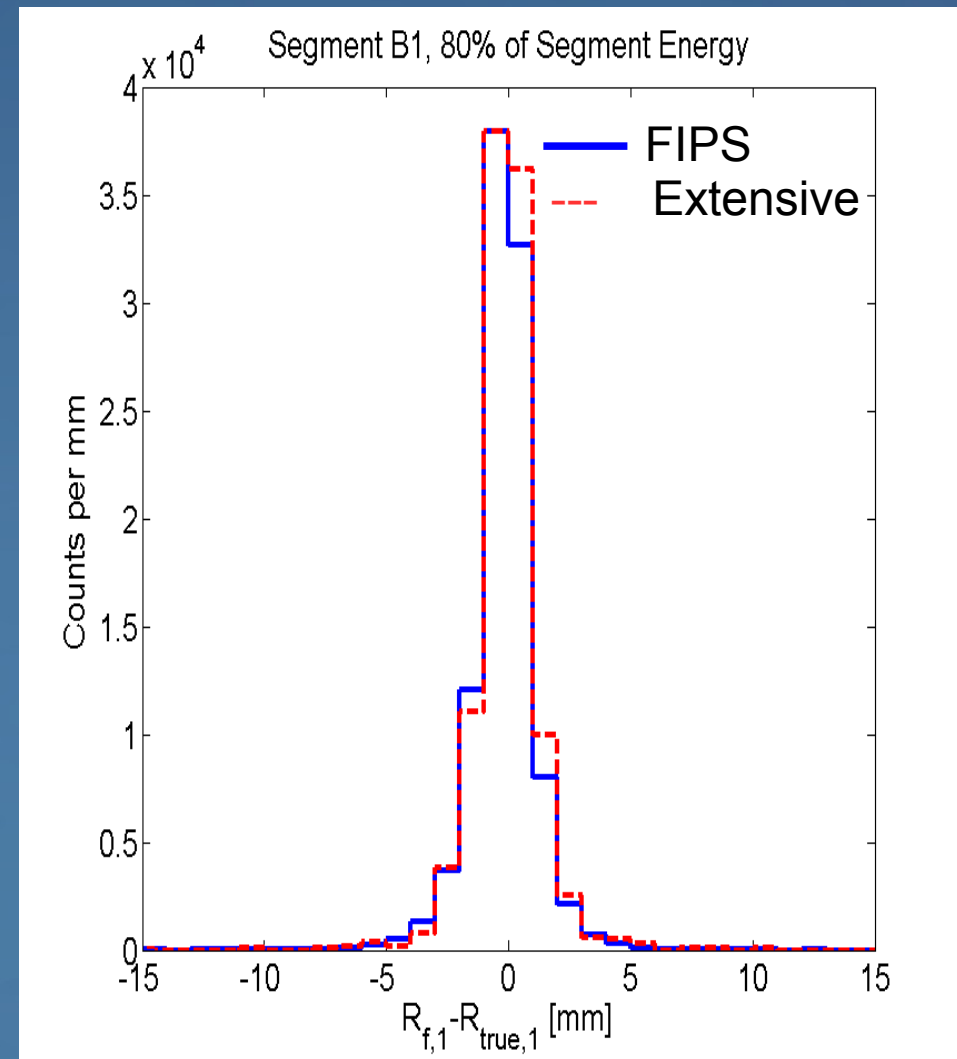
- Swarm of 20 Particles
 - Initialization of starting position according to rise time
- Single hits
 - Run time 10 Iterations / 0.7 ms
 - Comparable to extensive search (~ 40-200 ms)
- 2/3 hit segments
 - Run time 20/30 Iterations (4-12 ms)
 - Higher energetic hit comparable to extensive search
 - Extensive search takes ~2000 ms
 - Limited to matching rise times
- Two hits in one segment
 - Run time 20 Iterations/ 5 ms
 - Energysplit via fitalgorithm
 - Higher energetic hit comparable to extensive search
 - Extensive search takes ~ 10^7 ms



AGATA PSA with Fully Informed Particle Swarm (FIPS)

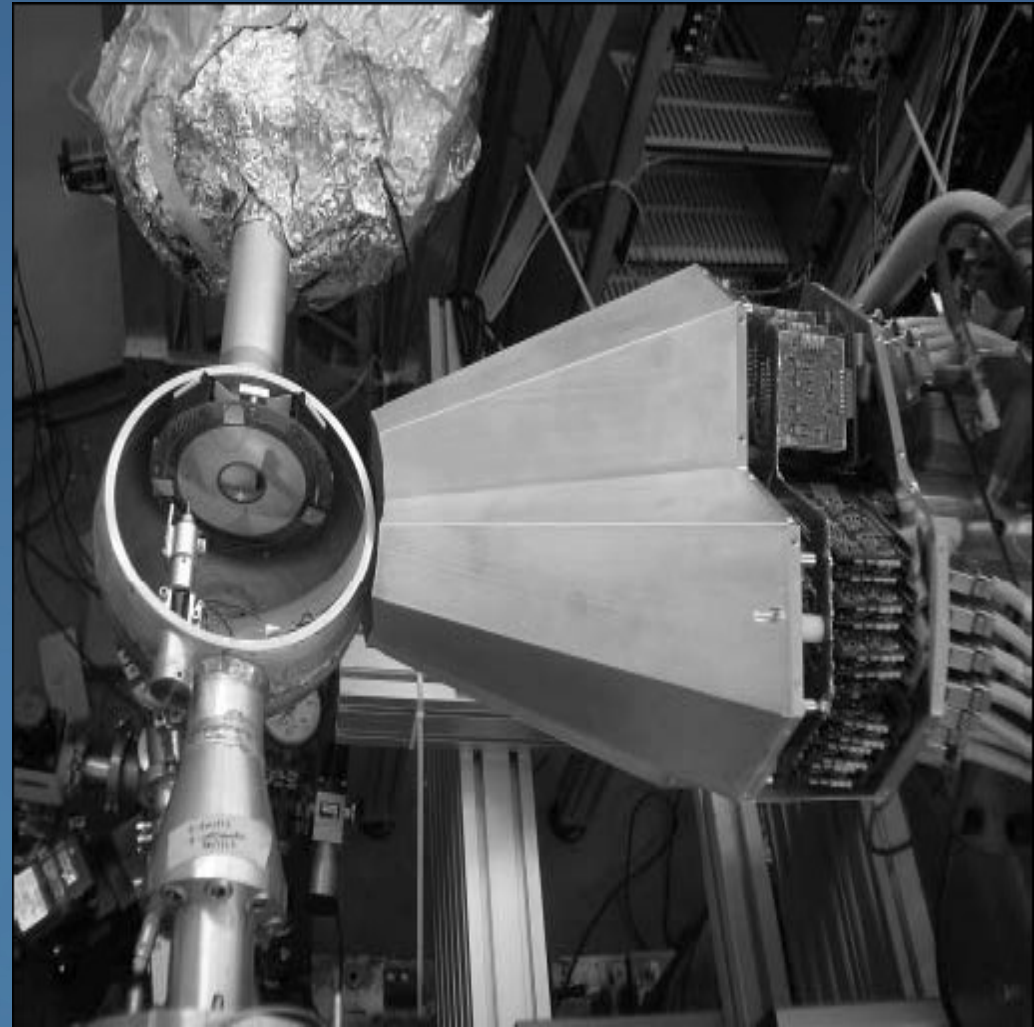
Radial Resolution

- Swarm of 20 Particles
 - Initialization of starting position according to rise time
- Single hits
 - Run time 10 Iterations / 0.7 ms
 - Comparable to extensive search (~ 40-200 ms)
- 2/3 hit segments
 - Run time 20/30 Iterations (4-12 ms)
 - Higher energetic hit comparable to extensive search
 - Extensive search takes ~2000 ms
 - Limited to matching rise times
- Two hits in one segment
 - Run time 20 Iterations/ 5 ms
 - Energysplit via fitalgorithm
 - Higher energetic hit comparable to extensive search
 - Extensive search takes ~ 10^7 ms



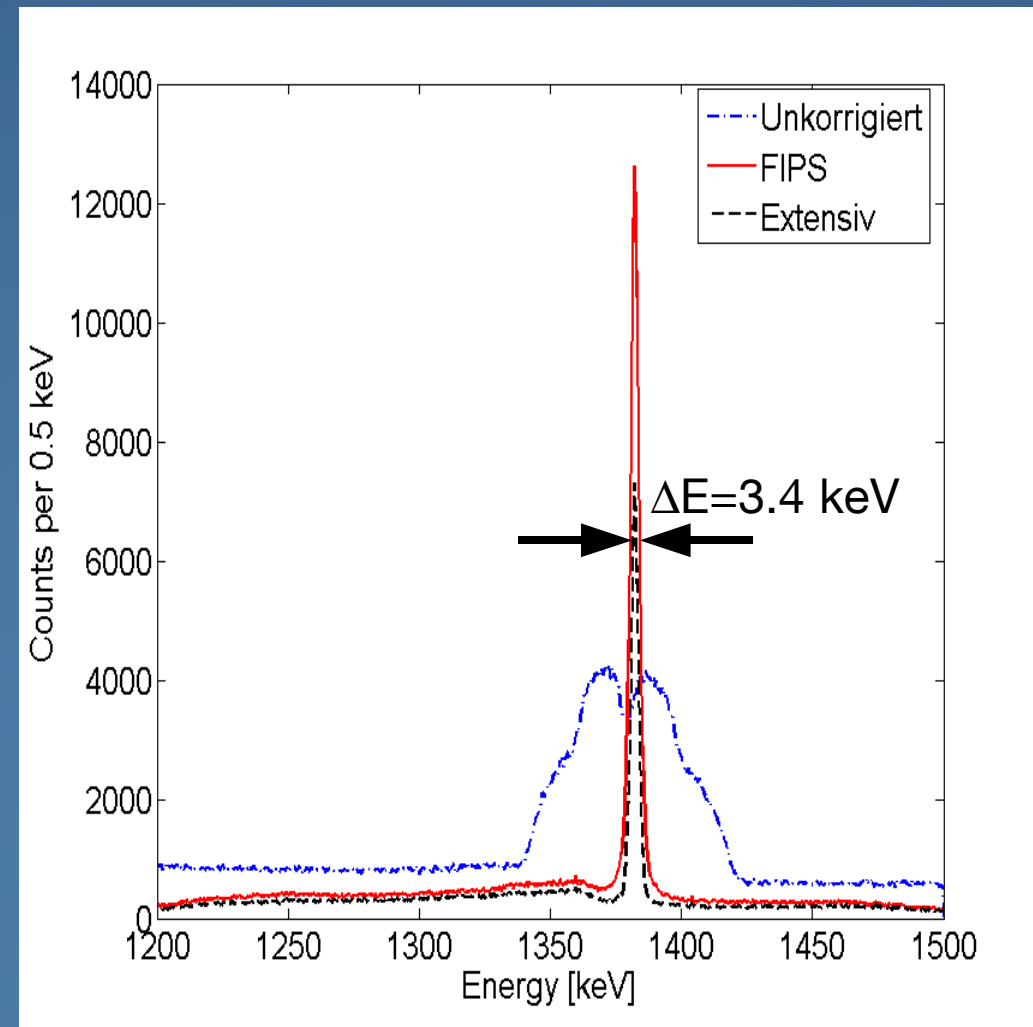
Application to simulated Test Experiment

- $^{48}\text{Ti}(d,p)^{49}\text{Ti}$ @100MeV in inverse Kinematic
 - AGATA at 90°
 - Line at 1382 keV
 - $\beta \sim 6.5\% c$
- PSA with extensive Search
 - Average duration 25 ms
 - Only single hits
 - Resolution 2.8 keV (FWHM)
- PSA with Fully Informed Particle Swarm (FIPS)
 - Average duration 2.2 ms
 - Single hit resolution 3.3 keV (FWHM)
 - Multiple hit resolution 3.4 keV (FWHM)
 - Almost twice as much statistics
 - No difference between single and multiple hit resolutions



Application to simulated Test Experiment

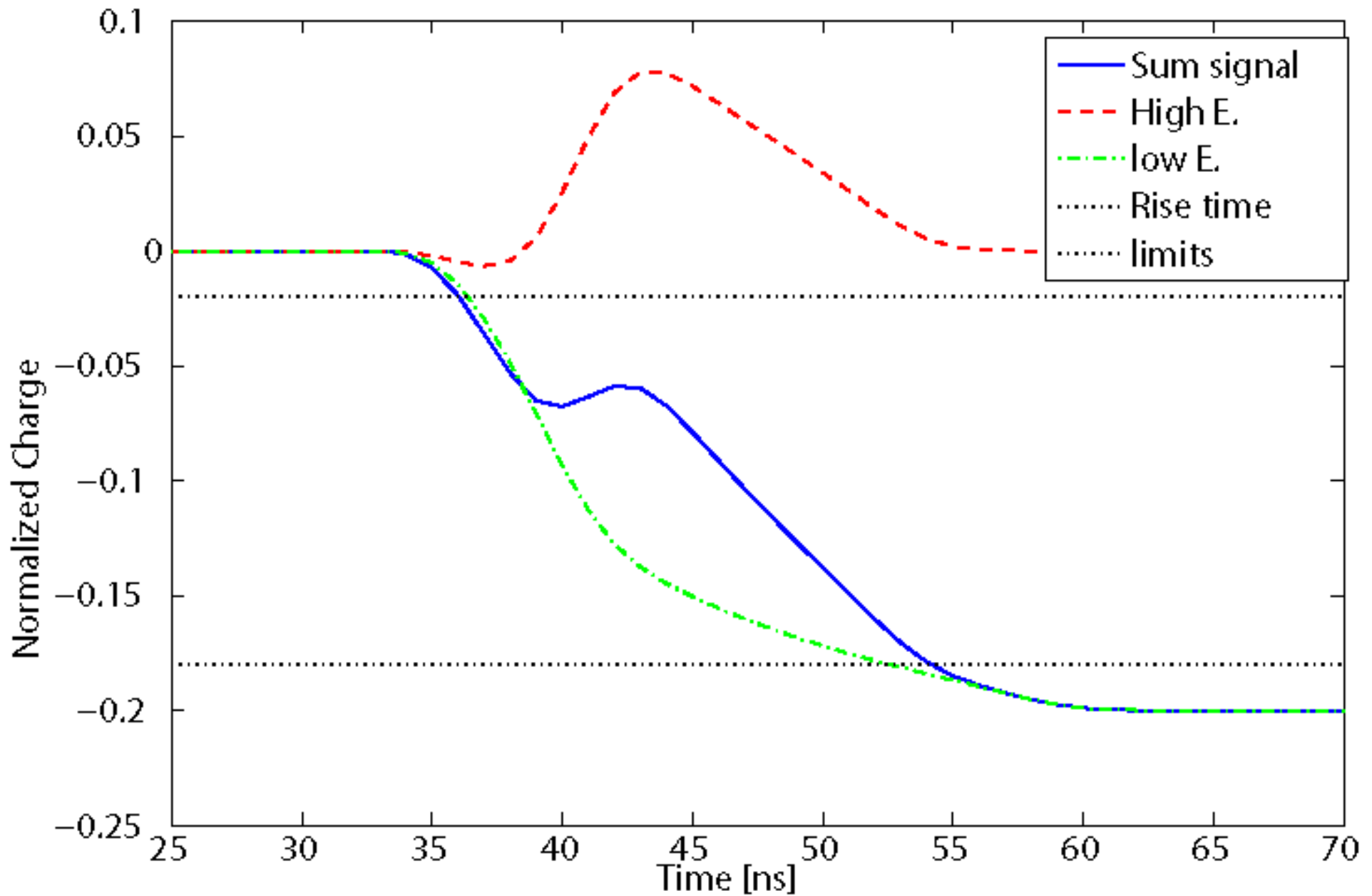
- $^{48}\text{Ti}(d,p)^{49}\text{Ti}$ @100MeV in inverse Kinematic
 - AGATA at 90°
 - Line at 1382 keV
 - $\beta \sim 6.5\% c$
- PSA with extensive Search
 - Average duration 25 ms
 - Only single hits
 - Resolution 2.8 keV (FWHM)
- PSA with Fully Informed Particle Swarm (FIPS)
 - Average duration 2.2 ms
 - Single hit resolution 3.3 keV (FWHM)
 - Multiple hit resolution 3.4 keV (FWHM)
 - Almost twice as much statistics
 - No difference between single and multiple hit resolutions



Summary & Outlook

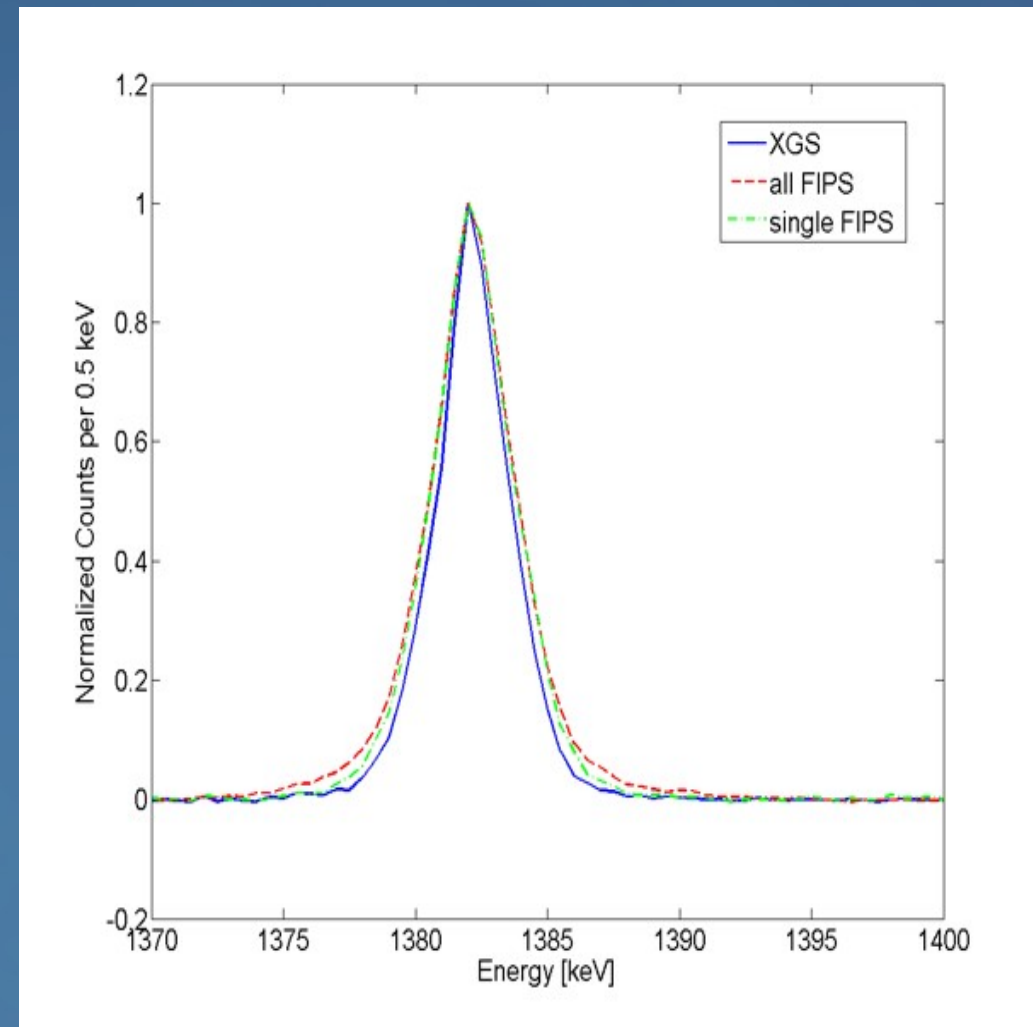
- Pulse Shape Analysis
 - Position reconstruction well within time constraints
 - Resolution of single hits comparable to extensive search
 - Multiple Hits:
 - Higher energetic interaction well resolved
 - Initialization of lower energetic interaction
- Simulated Experiment
 - Energy resolution $\sim 40\%$ above native HPGe-Resolution
 - FIPS resolution independent of γ -multiplicity
- Integration into AGATA DAQ-System





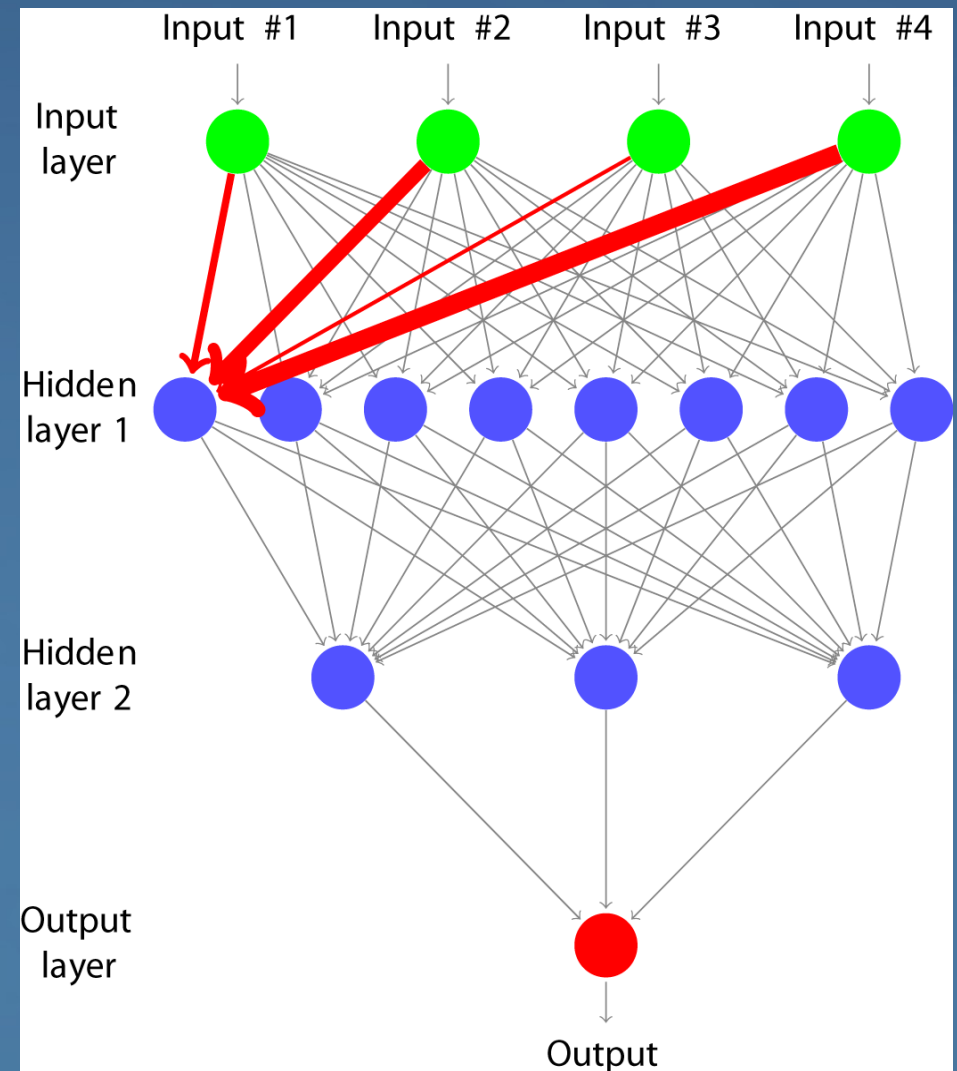
Anwendung auf simuliertes Experiment

- $^{48}\text{Ti}(d,p)^{49}\text{Ti}$ @100MeV in inverser Kinematik
 - Agata unter 90° zur Strahlachse
 - Linie bei 1382 keV
 - $\beta \sim 6.5\%$ c
- PSA mit extensiver Suche
 - Durchschnittl. Dauer 25 ms
 - Nur Einfach-WW.
 - Auflösung 2.8 keV (FWHM)
- PSA mit FIPS
 - Durchschnittl. Dauer 2.2 ms
 - Einfach-WW. Auflösung 3.3 keV (FWHM)
 - Mehrfach-WW. Auflösung 3.4 keV (FWHM)
 - Annähernd doppelte Statistik
 - Kein Unterschied zwischen Einfach- und Mehrfach Wechselwirkungen



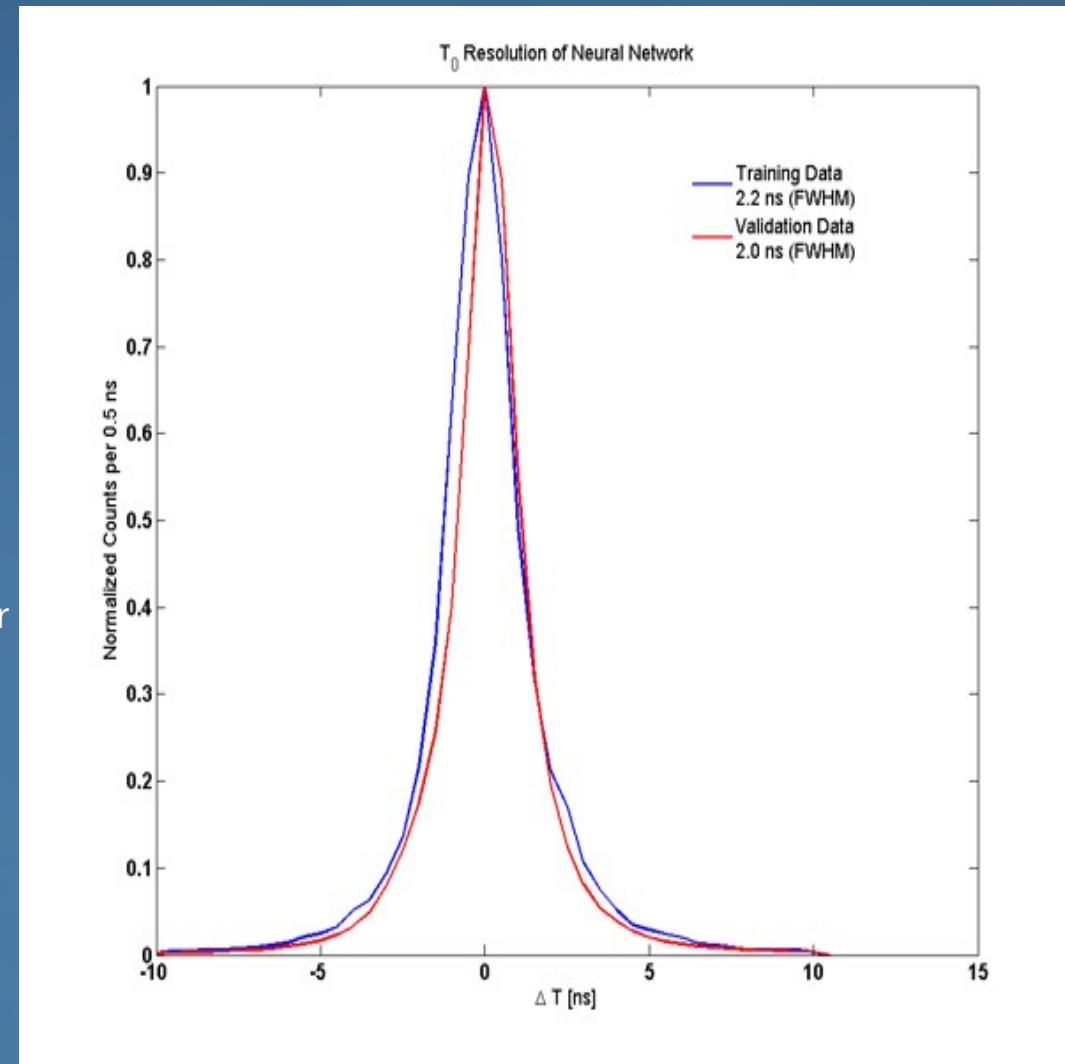
AGATA PSA - Neuronales Netz

- Ortsabhängige Pulsformen
- Ansatz:
 - Simulierte Basissignale auf 1 mm Gitter
 - Suche nach bester Übereinstimmung mit experimentellem Signal
 - Zeitsynchronisierte Signale (GTS)
 - Bestimmung von t_0 vor PSA
 - Neuronales Netz
- Herausforderungen
 - Suche in Echtzeit $<10\text{ms}$
 - Suchraum wächst binomial mit der Anzahl der Wechselwirkungen
 - 1 WW: 5000-15000
 - 2 WW: $10^7 - 10^8$
 - 3 WW: $10^{10} - 3 \cdot 10^{12}$
 - Intelligenter Suchalgorithmus
 - Particle Swarm Optimization



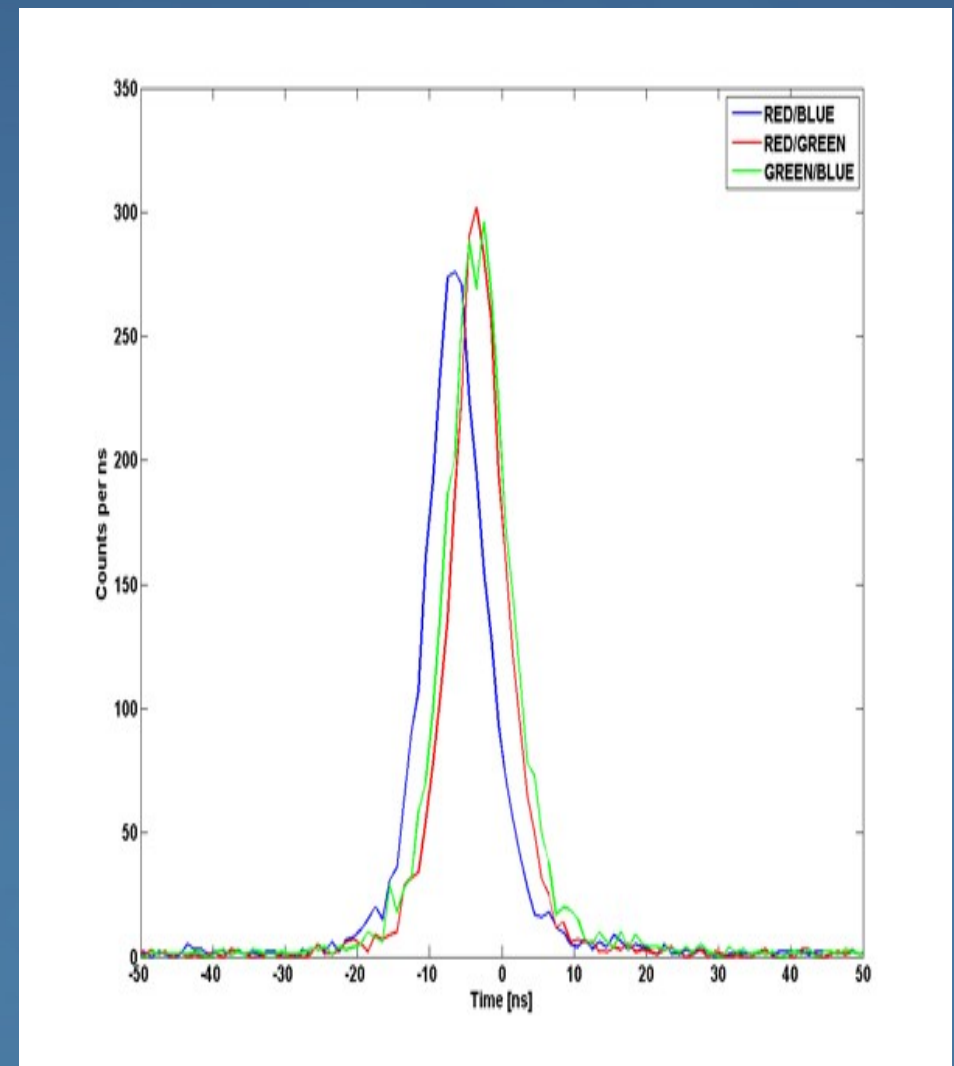
AGATA PSA - Neuronales Netz

- Ortsabhängige Pulsformen
- Ansatz:
 - Simulierte Basissignale auf 1 mm Gitter
 - Suche nach bester Übereinstimmung mit experimentellem Signal
 - Zeitsynchronisierte Signale (GTS)
 - Bestimmung von t_0 vor PSA
 - Neuronales Netz
- Herausforderungen
 - Suche in Echtzeit $< 10\text{ms}$
 - Suchraum wächst binomial mit der Anzahl der Wechselwirkungen
 - 1 WW: 5000-15000
 - 2 WW: $10^7 - 10^8$
 - 3 WW: $10^{10} - 3 \cdot 10^{12}$
 - Intelligenter Suchalgorithmus
 - Particle Swarm Optimization



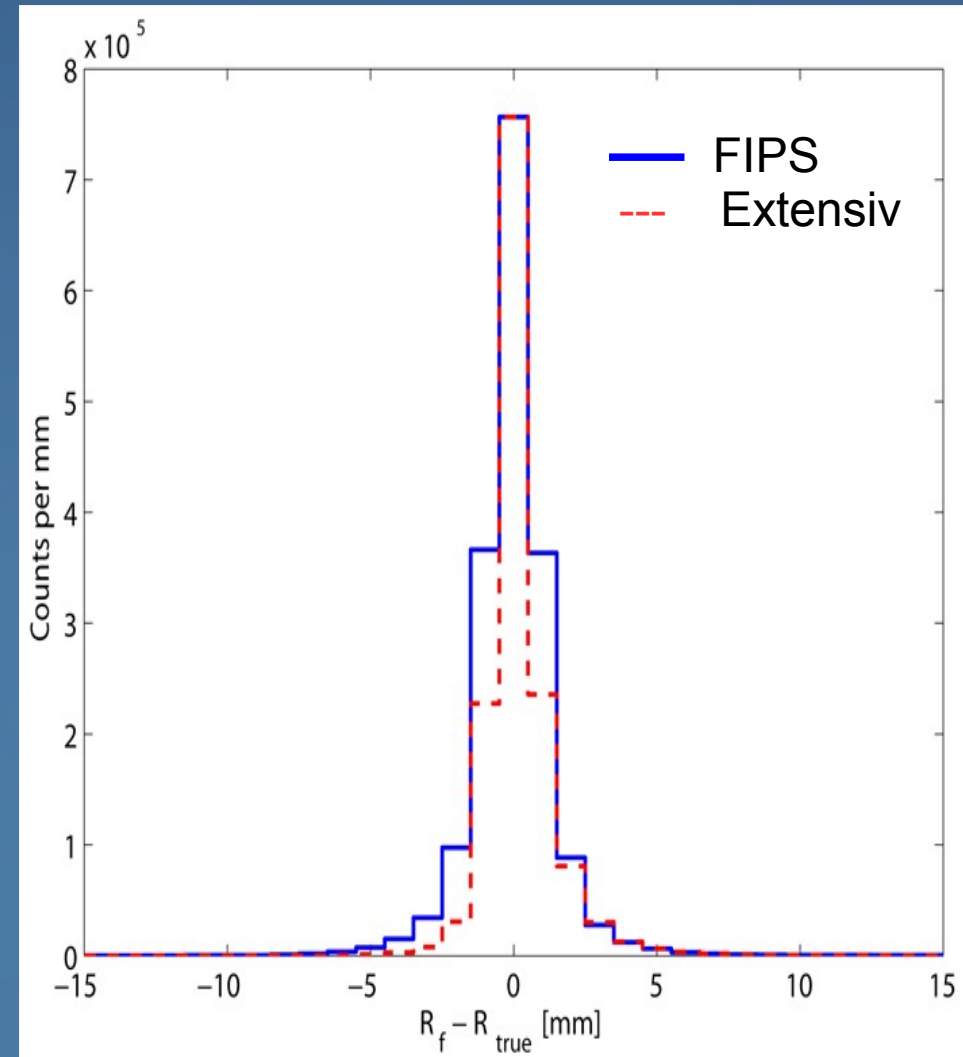
AGATA PSA - Neuronales Netz

- Ortsabhängige Pulsformen
- Ansatz:
 - Simulierte Basissignale auf 1 mm Gitter
 - Suche nach bester Übereinstimmung mit experimentellem Signal
 - Zeitsynchronisierte Signale (GTS)
 - Bestimmung von t_0 vor PSA
 - Neuronales Netz
- Herausforderungen
 - Suche in Echtzeit $< 10\text{ms}$
 - Suchraum wächst binomial mit der Anzahl der Wechselwirkungen
 - 1 WW: 5000-15000
 - 2 WW: $10^7 - 10^8$
 - 3 WW: $10^{10} - 3 \cdot 10^{12}$
 - Intelligenter Suchalgorithmus
 - Particle Swarm Optimization



AGATA PSA mit Particle Swarm Optimization

- Schwarm mit 20 Teilchen
 - Initialisierung der Startposition anhand Anstiegszeit
- Einfach-Wechselwirkungen
 - Laufzeit 10 Iterationen / 0.7 ms
 - Vergleichbare Ergebnisse zur extensiven Suche (~ 40-200 ms)
- 2/3 getroffene Segmente
 - Laufzeit 20/30 Iterationen (4-12 ms)
 - Höherenergetische WW. vergleichbar aufgelöst wie bei extensiver Suche
 - Extensive Suche benötigt ~2000 ms
- Zwei WW. in einem Segment
 - Laufzeit 20 Iterationen/ 5 ms
 - Energiesplit über Fitalgorithmus
 - Höherenergetische WW. vergleichbar aufgelöst wie bei extensiver Suche
 - Extensive Suche benötigt ~ 10⁷ ms

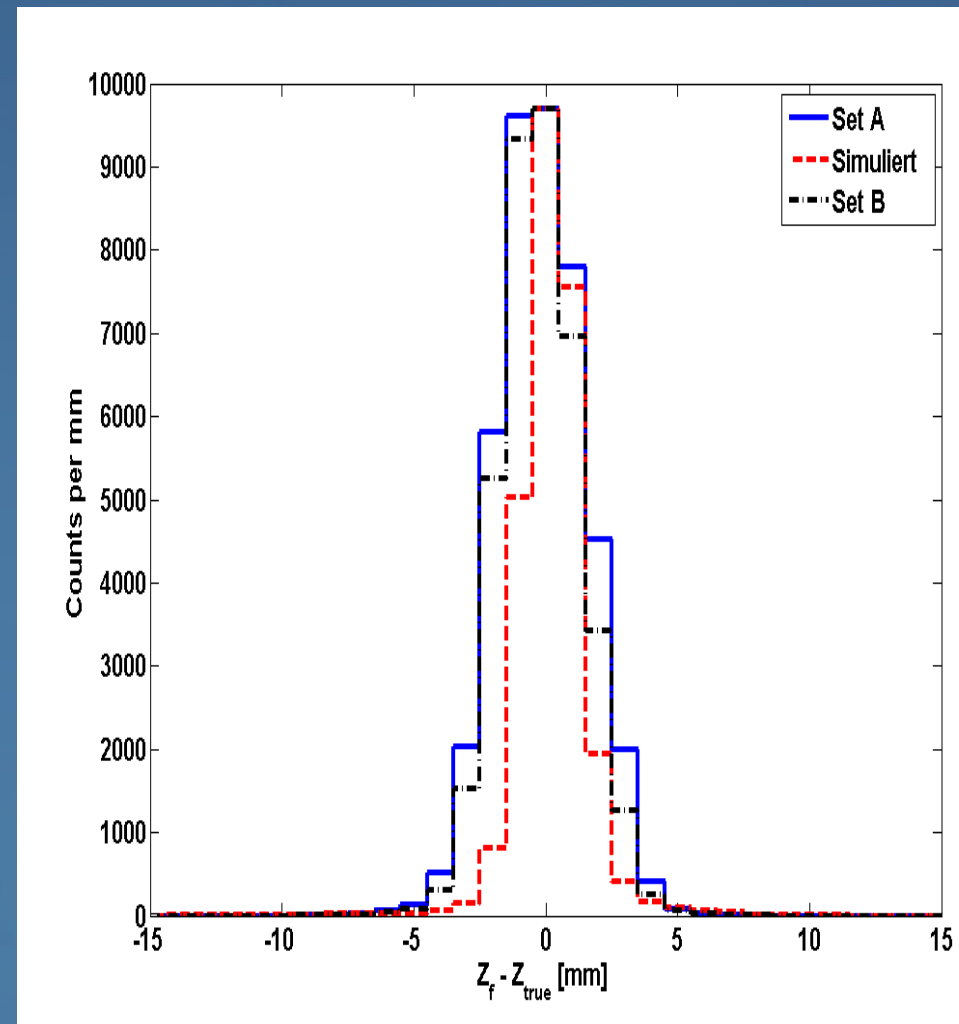


$$\sum_{i=1}^{i=37} \phi(x) = 1 \quad \forall x$$



Verifikation von JASS

- Pulsformen mit bekannter Position
 - 90° Compton-gestreute γ -Strahlen
 - Detektion in Koinzidenz mit NaI-Zählern
 - Systematische Unsicherheiten
- Simulation von Pulsformen auf 1 mm Gitter für beide Parametersätze A/B
- Extensive Suche auf Gitter im getroffenen Segment
- Vergleich der Ergebnisse mit theoretisch erwarteten
 - Parametersatz B besser
 - Größte Abweichung bei Winkelauflösung
 - Übereinstimmung abhängig von Segmentreihe



Verifikation von JASS

- Pulsformen mit bekannter Position
 - 90° Compton-gestreute γ -Strahlen
 - Detektion in Koinzidenz mit NaI-Zählern
 - Systematische Unsicherheiten
- Simulation von Pulsformen auf 1 mm Gitter für beide Parametersätze A/B
- Extensive Suche auf Gitter im getroffenen Segment
- Vergleich der Ergebnisse mit theoretisch erwarteten
 - Parametersatz B besser
 - Größte Abweichung bei Winkelauflösung
 - Übereinstimmung abhängig von Segmentreihe

