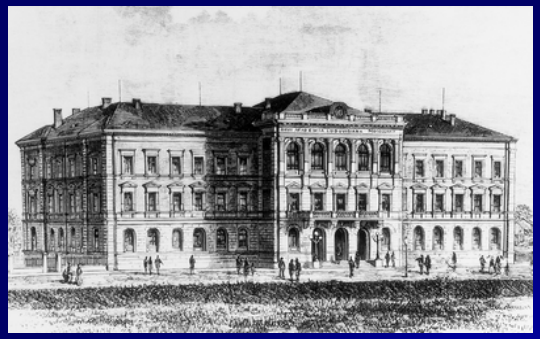
Hadron Physics with Electromagnetic Probes in Hall B

JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

II. Physikalisches Institut

- **Gießen Group**
- **Current Research**
  - **Physics**
  - **Instrumentation**
- **Involvement in CLAS**

Kai-Thomas Brinkmann, JLab, Mar 29, 2017



University of Gießen

founded in 1607

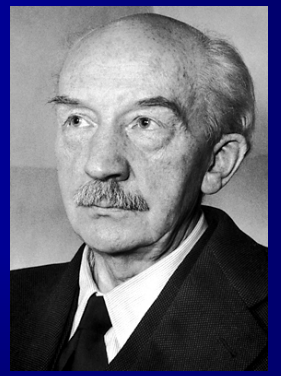
JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

- 28,000 students (as of winter semester 2013/14) in 11 faculties
- 4,500 employees including:
  - Teaching and research staff: 2,000 (333 professors)
  - Administrative and technical staff: 2,500

Justus Liebig

Heinrich Buff

Wilhelm Conrad Röntgen



Walther Bothe

Group

- Dr. M. Nanova, Dr. E. Gutz, Dr. H.-G. Zaunick
- Dr. S. Diehl, Dr. V. Dormenev, Dr. M. Moritz,
  Dr. T. Quagli

JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

II. Physikalisches Institut

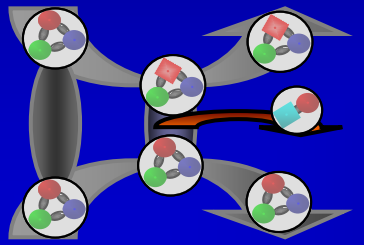
- 7 PhD students
- MSc and BSc students
- Technical staff

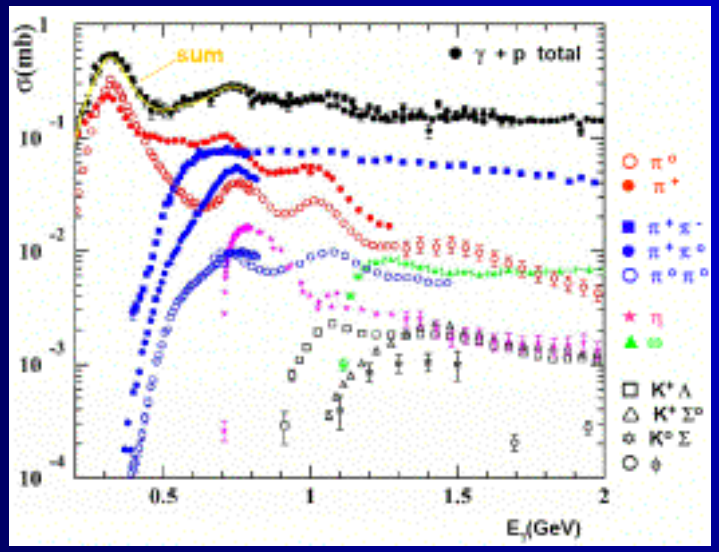
- **Experiments:**
  - $\bar{\text{P}}$ANDA at FAIR (hardware, simulations)
  - CBELSA/TAPS, Bonn
  - Eric, Stefan: CLAS 6 analysis

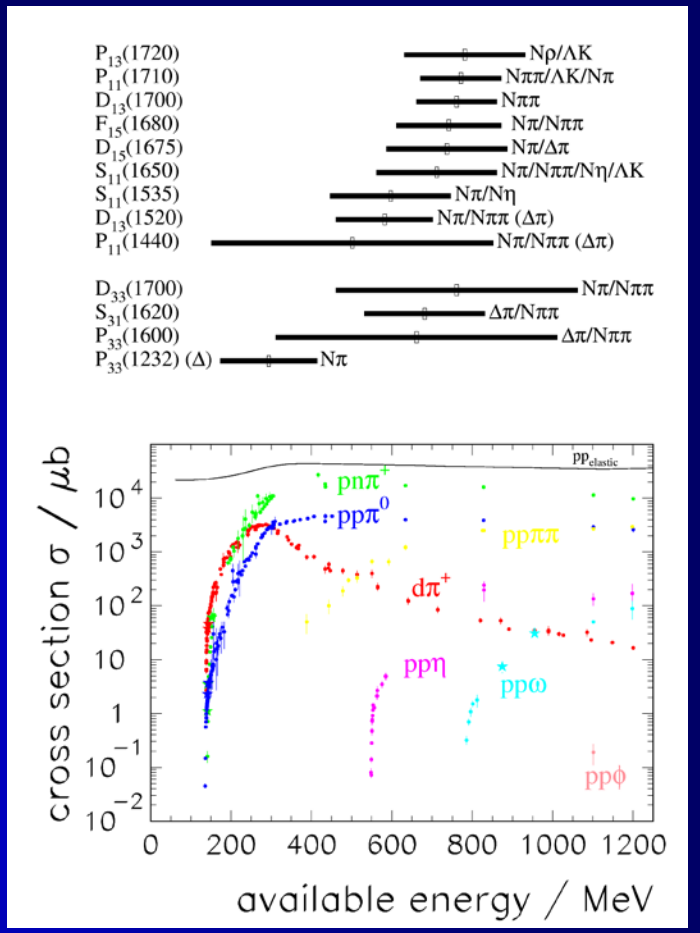
Physics

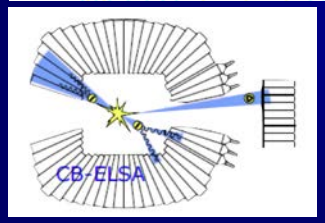
- **Reactions with hadronic probes:**

  pp collisions, meson production







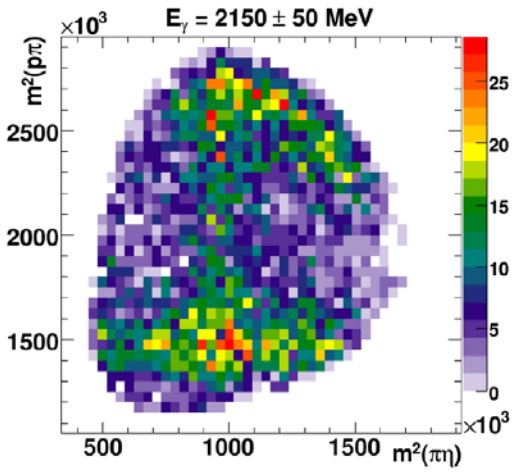


- **CBElsa/TAPS: single and double meson production**
- **Meson production off nuclei (ω, η´)**

$$\vec{\gamma}\vec{p} \rightarrow p\pi^0$$

Cascading Decays of Excited Baryons: Isobar Analysis

(E. Gutz, CLAS meeting 10/2015)

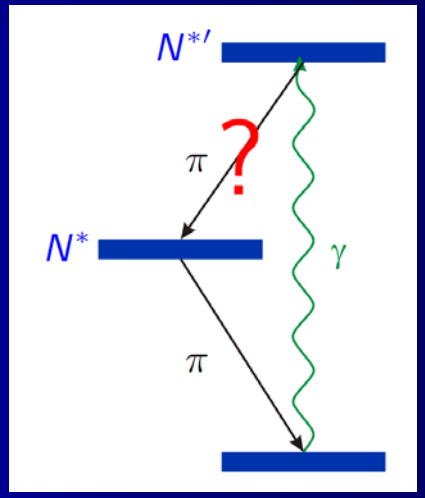


$\gamma p \to p\pi^0\eta$

E.G., V. Credé, V. Sokhoyan, H. van Pee *et al.*,
Eur. Phys. J. A **50** (2014) 74

Clear evidence for isobars in the reaction:

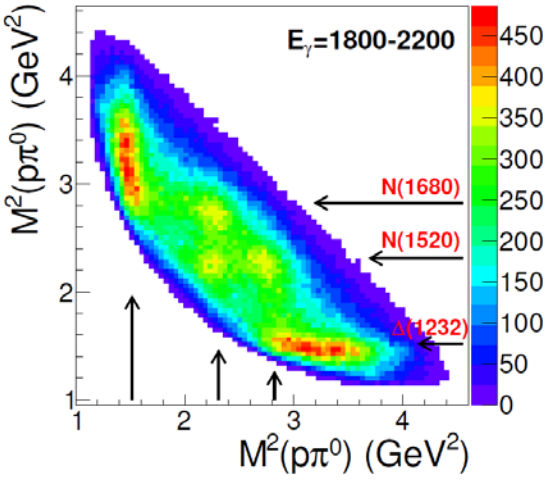
- $\Delta(1232)\frac{3}{2}^+\eta$
- $N(1535)\frac{1}{2}^-\pi^0$
- $a_0(980)p$



$\gamma p \to p\pi^0\pi^0$

V. Sokhoyan, E.G., V. Credé, H. van Pee *et al.*,
Eur. Phys. J. A **51** (2015) 51

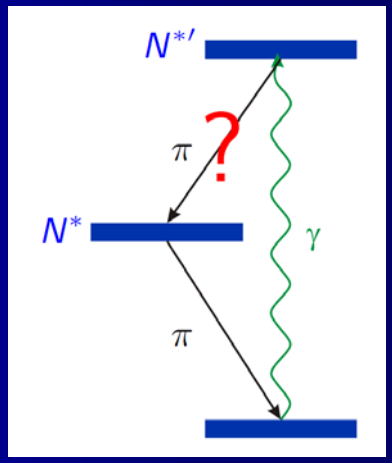
- $\Delta(1232)\frac{3}{2}^+\pi^0$
- $N(1520)\frac{3}{2}^-\pi^0$
- $N(1680)\frac{5}{2}^2\pi^0$
- also seen: $N(1440)\frac{1}{2}^+\pi^0$, $f_0(980)p$, ...



Cascading Decays of Excited Baryons: Isobar Analysis

(E. Gutz, CLAS meeting 10/2015)

- Check feasibility of approach with g11-/g12-run data in $\gamma p \to p\pi^+\pi^-$
- Check high-mass (scalar) meson isobars also in KK-decays
- Extension of analysis program to hyperon spectrum
- Extension of the approach to polarization observables possible

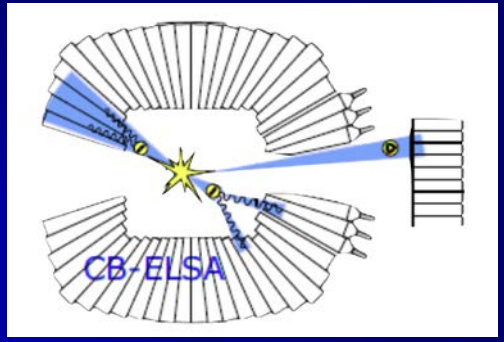


☞ Analysis E. Gutz, S. Diehl

(☞ Analysis M. Nanova CBElsa)

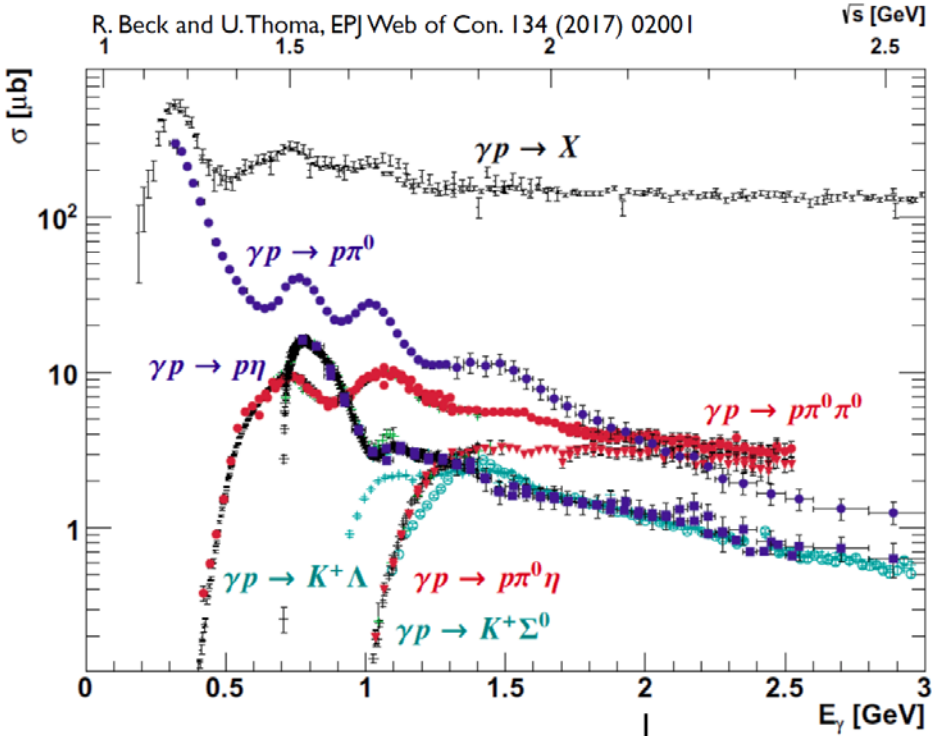
Cascading Decays of Excited Baryons

(M. Nanova, 2017)



Total Photon Absorption Cross section

R. Beck and U. Thoma, EPJ Web of Con. 134 (2017) 02001



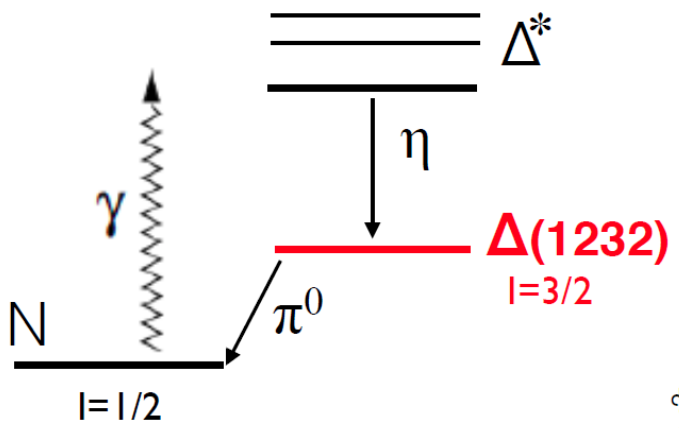
total cross sections for different final states

$\sigma^{tot}_{\gamma p \to p\pi^0\eta}$: used for the normalisation of the present data

increasing importance of multi-meson final states

14

Photoproduction of $\pi^0\eta$ pairs: $\gamma\, p \rightarrow p\pi^0\eta$

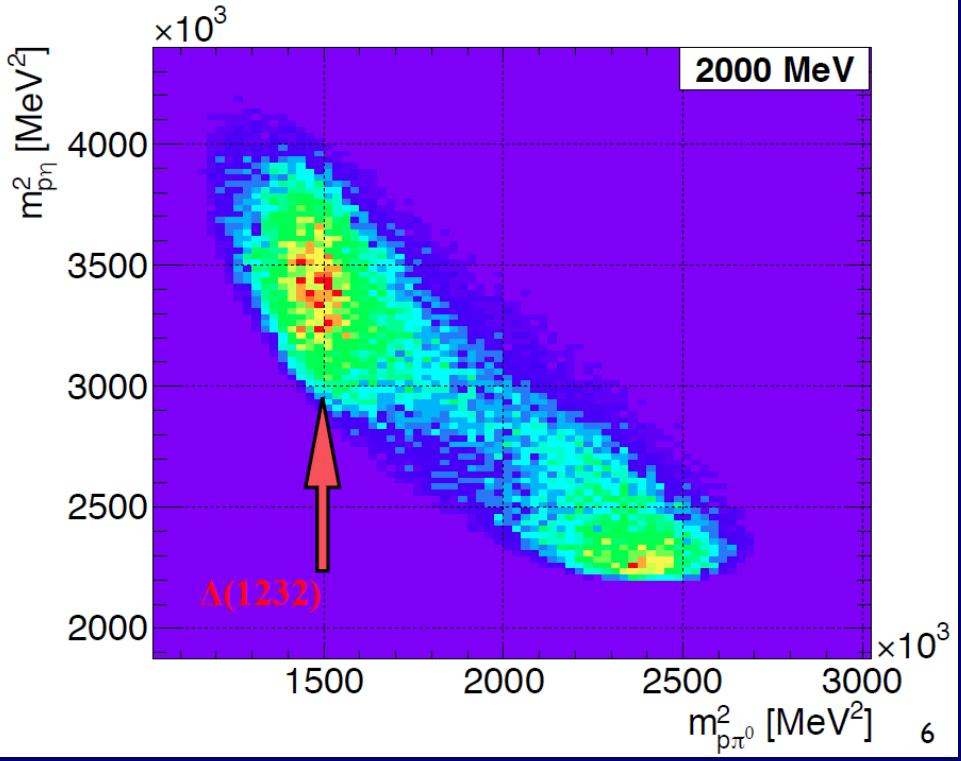


$\Delta^* \rightarrow \Delta(1232)\eta \rightarrow N\pi^0\eta$;

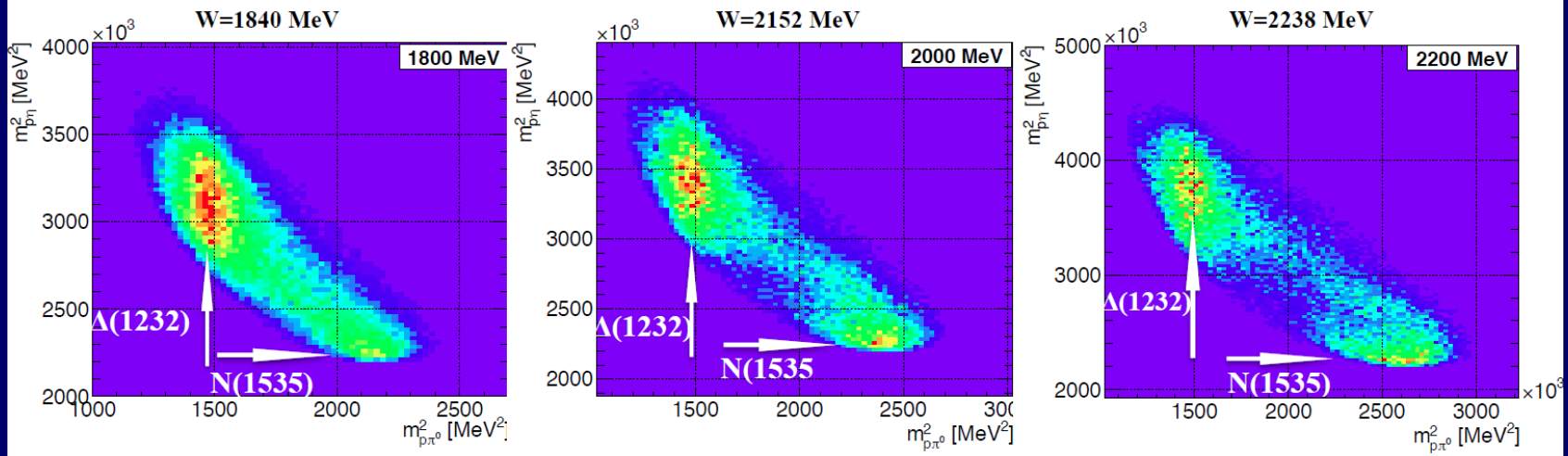
Δ^* resonances selected by $\Delta\eta$ decay mode

$I_\eta = 0$!

clear observation of baryon cascades!



$\gamma p \rightarrow p\pi^0\eta$: Dalitz plots



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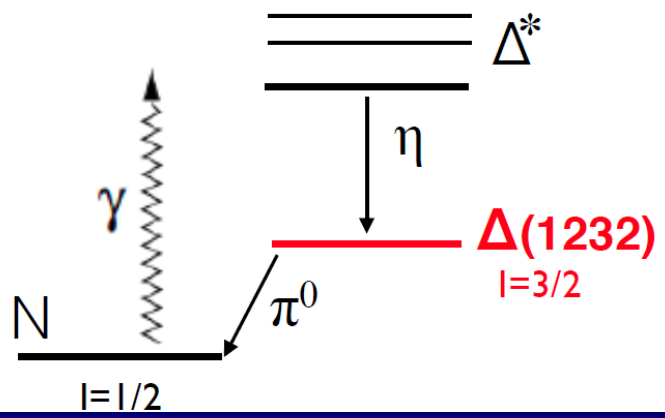
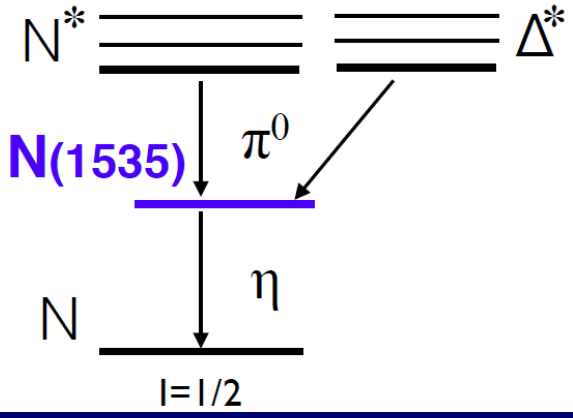
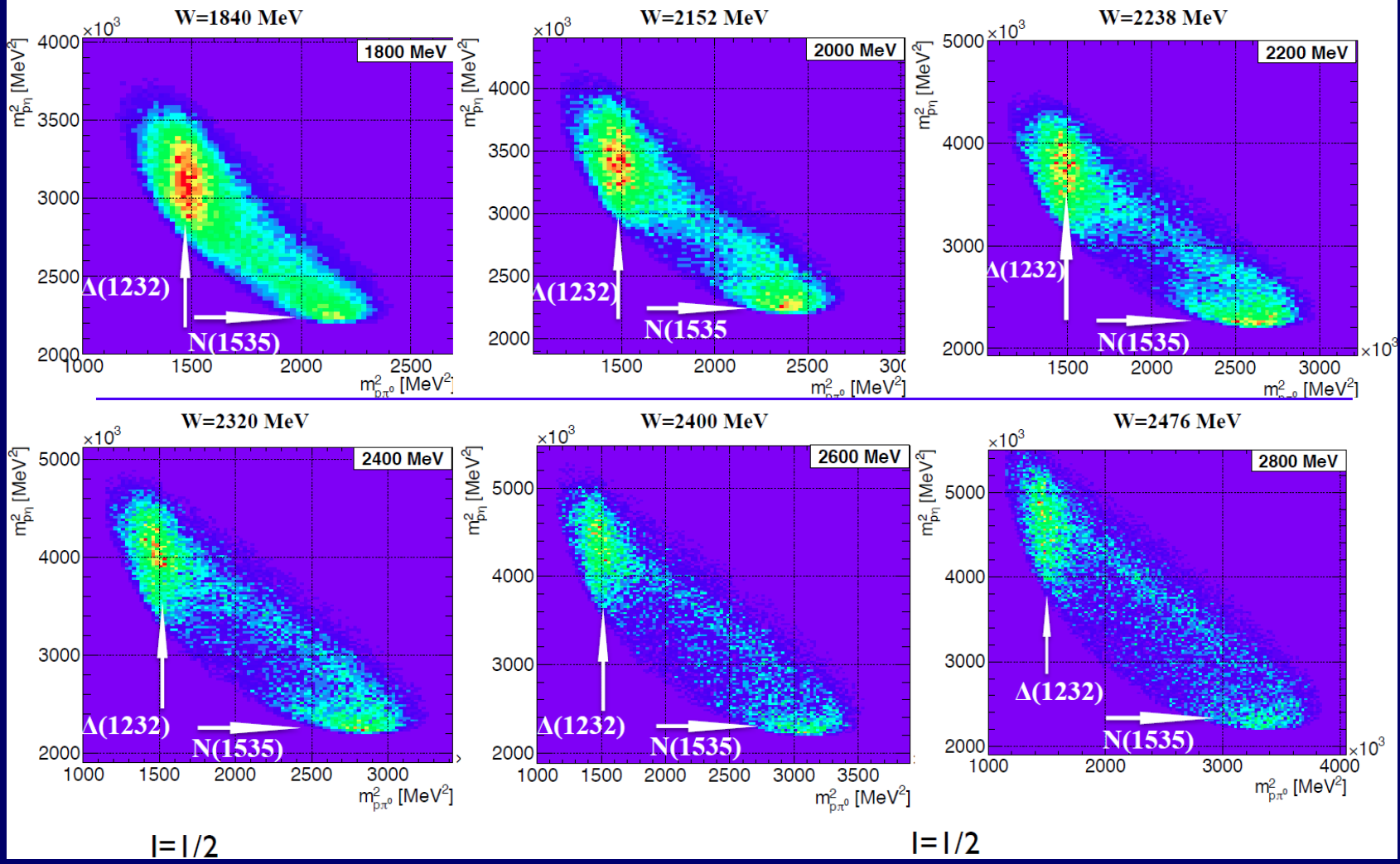
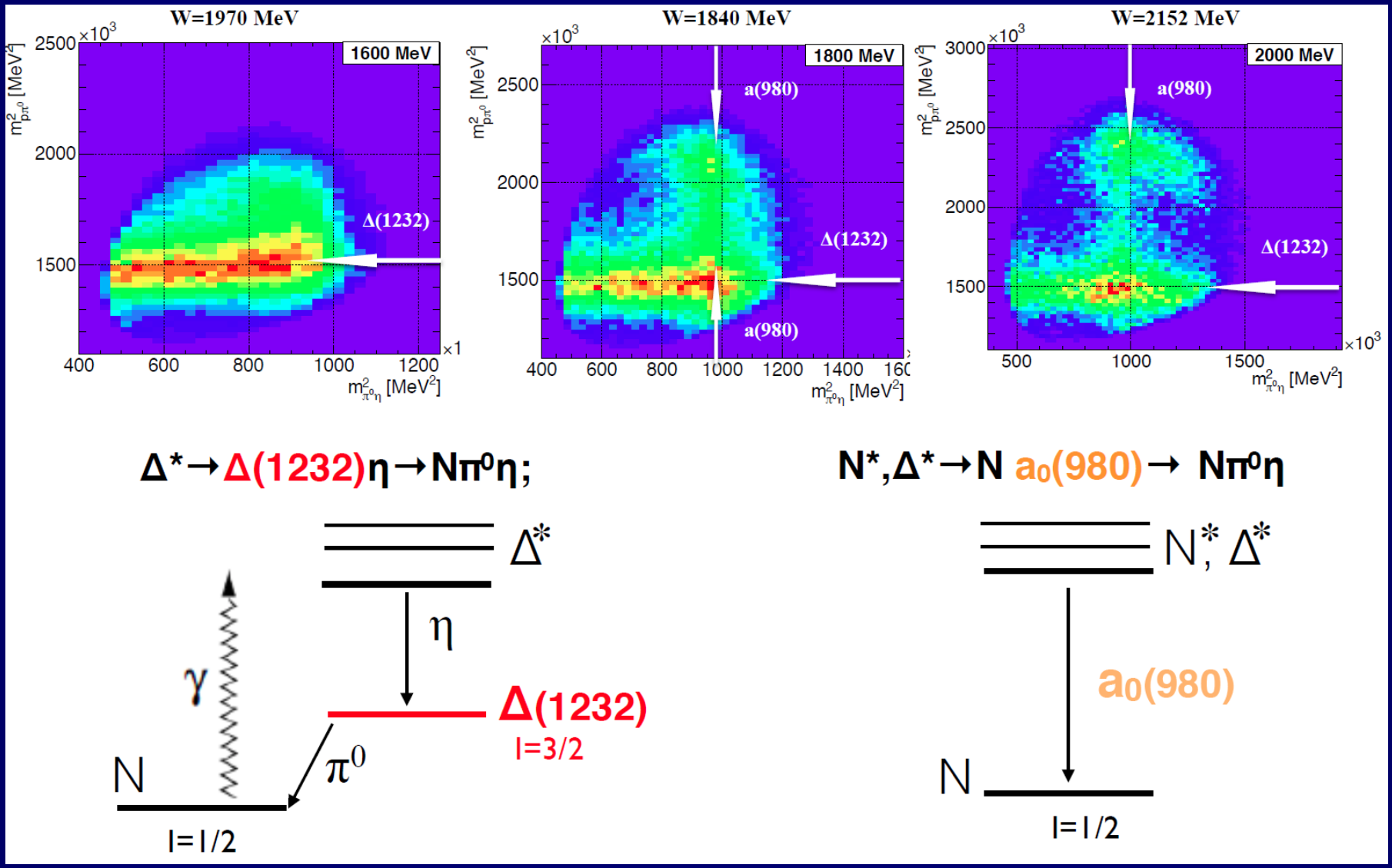


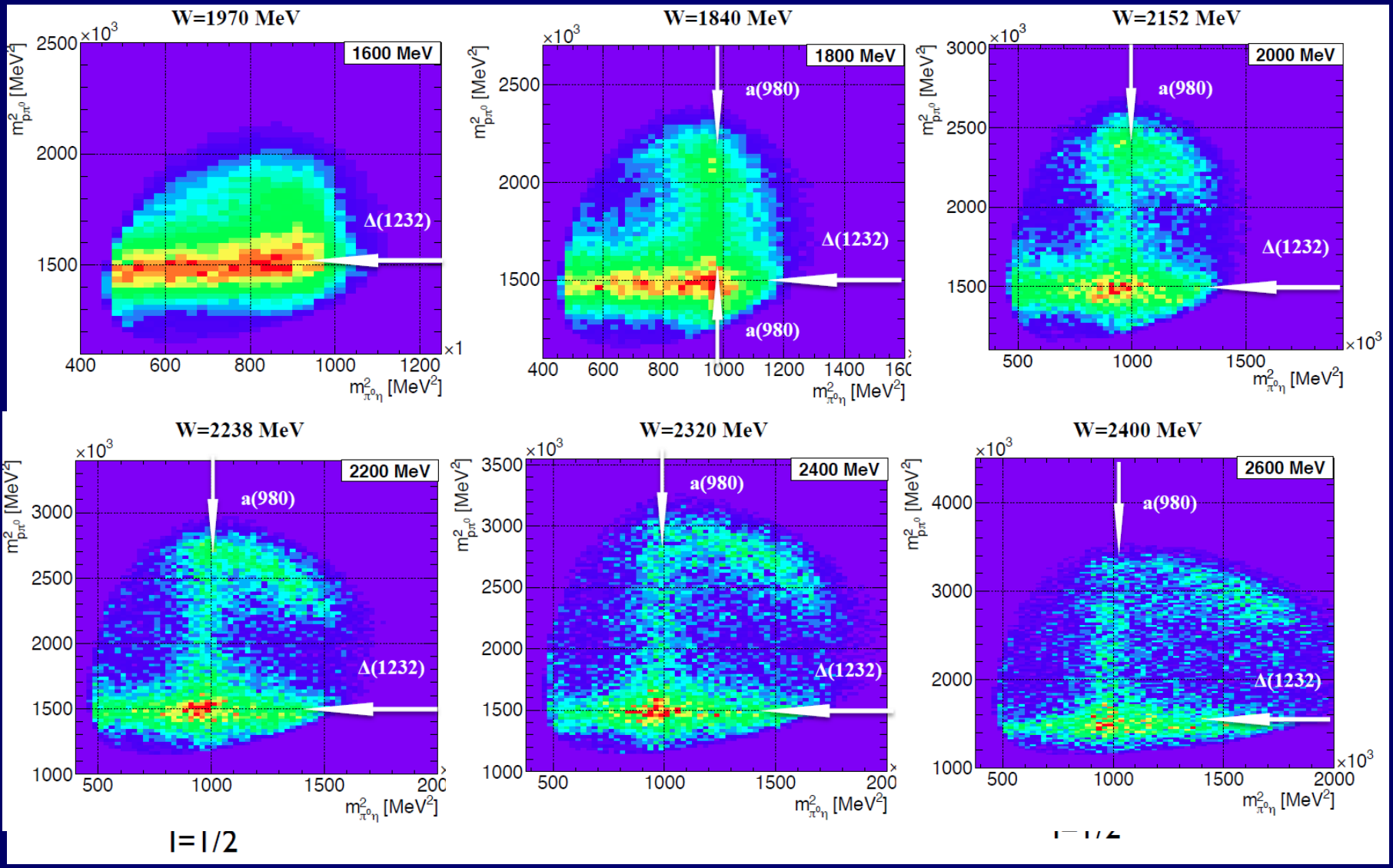
$N^*, \Delta^* \rightarrow N(1535)\pi^0 \rightarrow N\pi^0\eta$;



$\gamma p \rightarrow p\pi^0\eta$: Dalitz plots

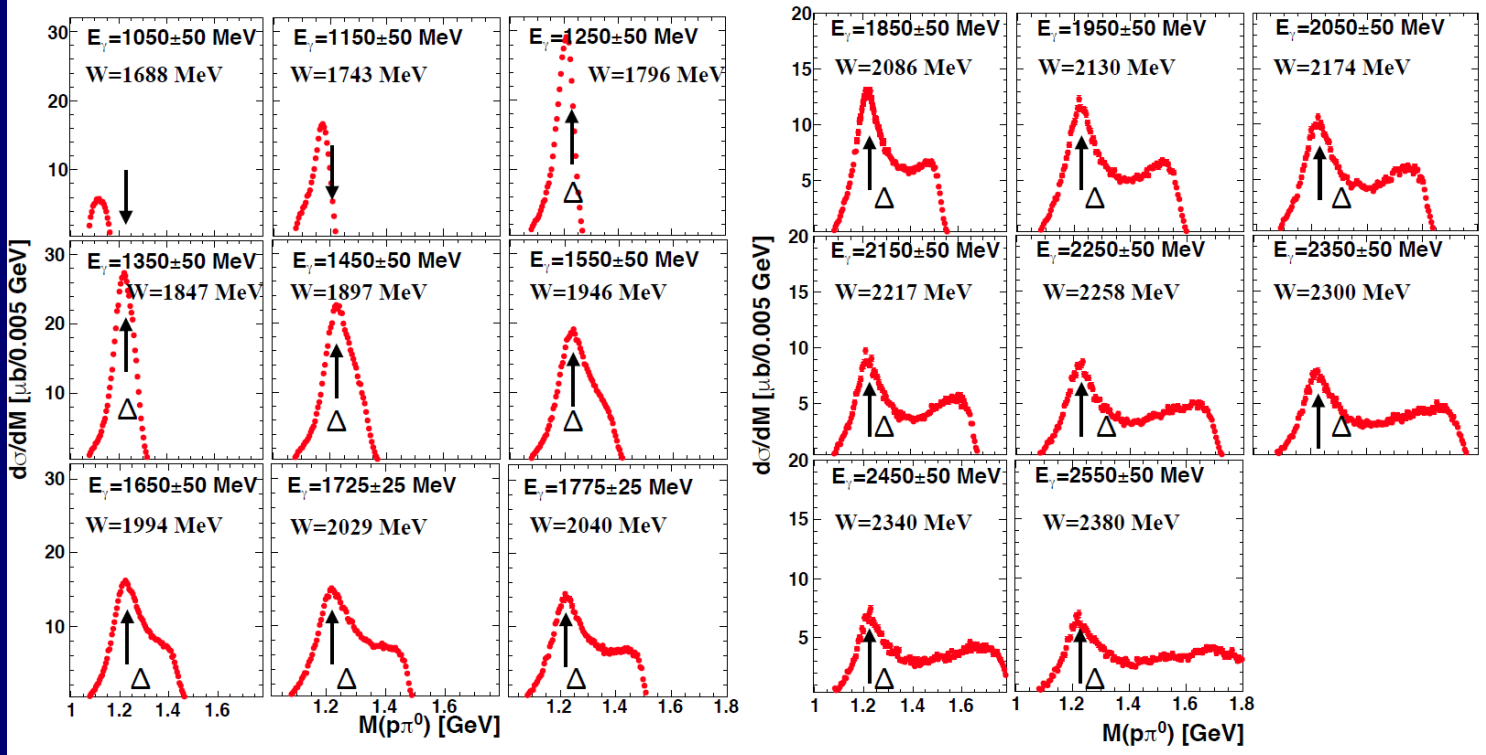



W=1970 MeV
1600 MeV
Δ(1232)
W=1840 MeV
1800 MeV
a(980)
Δ(1232)
a(980)
W=2152 MeV
2000 MeV
a(980)
Δ(1232)
$m^2_{p\pi^0}$ [MeV^2]
$m^2_{\pi^0\eta}$ [MeV^2]
Δ*→Δ(1232)η→Nπ⁰η;
Δ*
η
γ
Δ(1232)
I=3/2
N
π⁰
I=1/2
N*,Δ*→N a₀(980)→ Nπ⁰η
N*, Δ*
a₀(980)
N
I=1/2


W=1970 MeV
1600 MeV
Δ(1232)
W=1840 MeV
1800 MeV
a(980)
Δ(1232)
a(980)
W=2152 MeV
2000 MeV
a(980)
Δ(1232)
W=2238 MeV
2200 MeV
a(980)
Δ(1232)
W=2320 MeV
2400 MeV
a(980)
Δ(1232)
W=2400 MeV
2600 MeV
a(980)
Δ(1232)
I=1/2

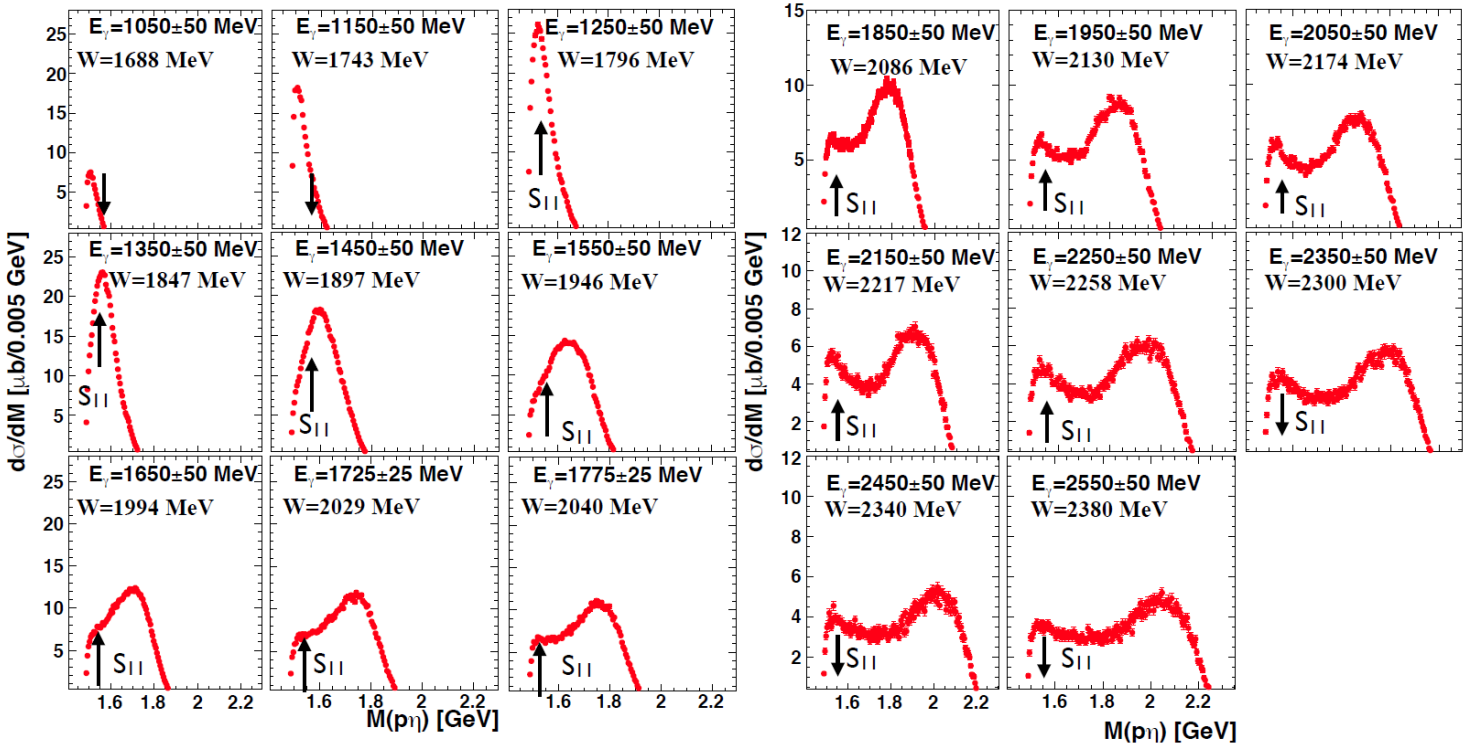
Invariant Mass Distribution M($p\pi^0$)

high statistics data!



Invariant Mass Distribution M(pη)

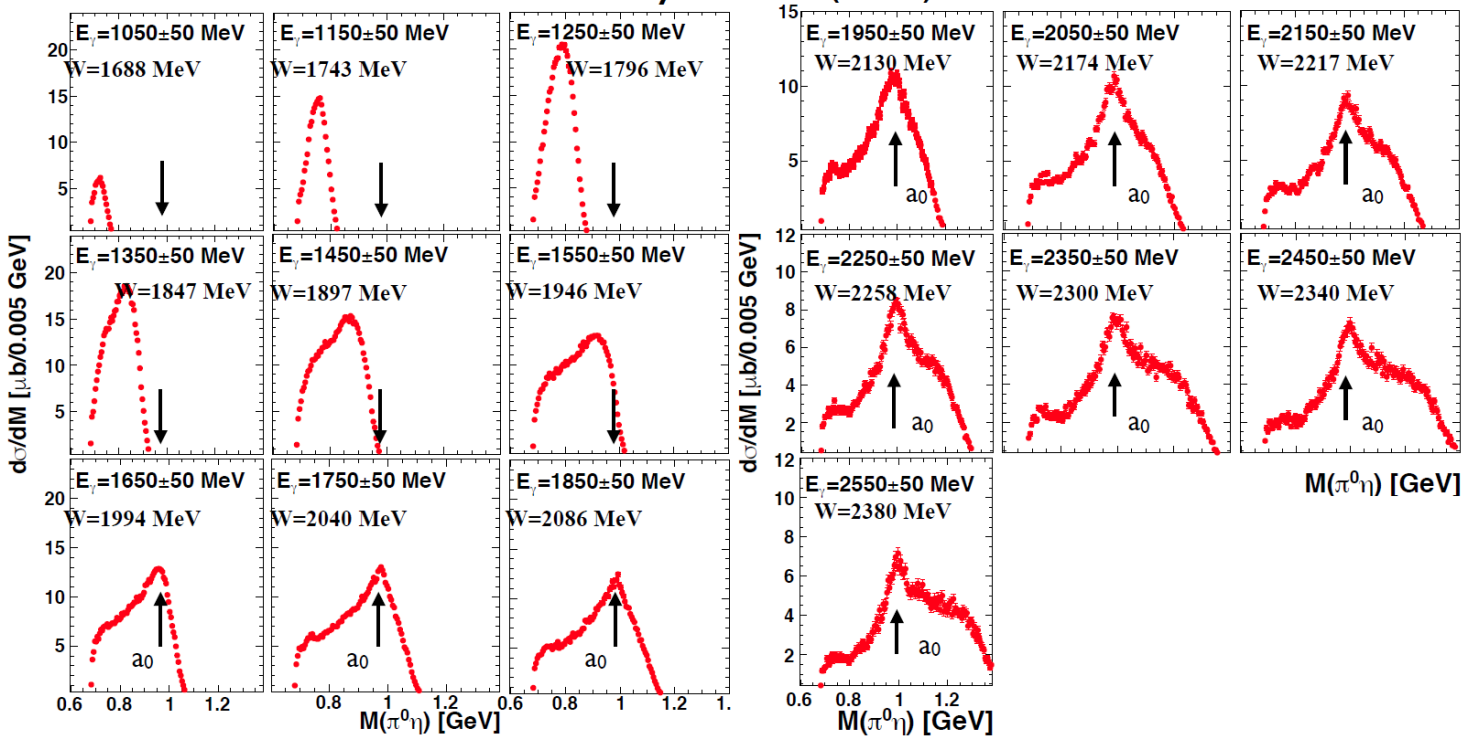
decays through N*(1535)



high statistics data!

Invariant Mass Distribution $M(\pi^0\eta)$

decays via $a_0(980)$

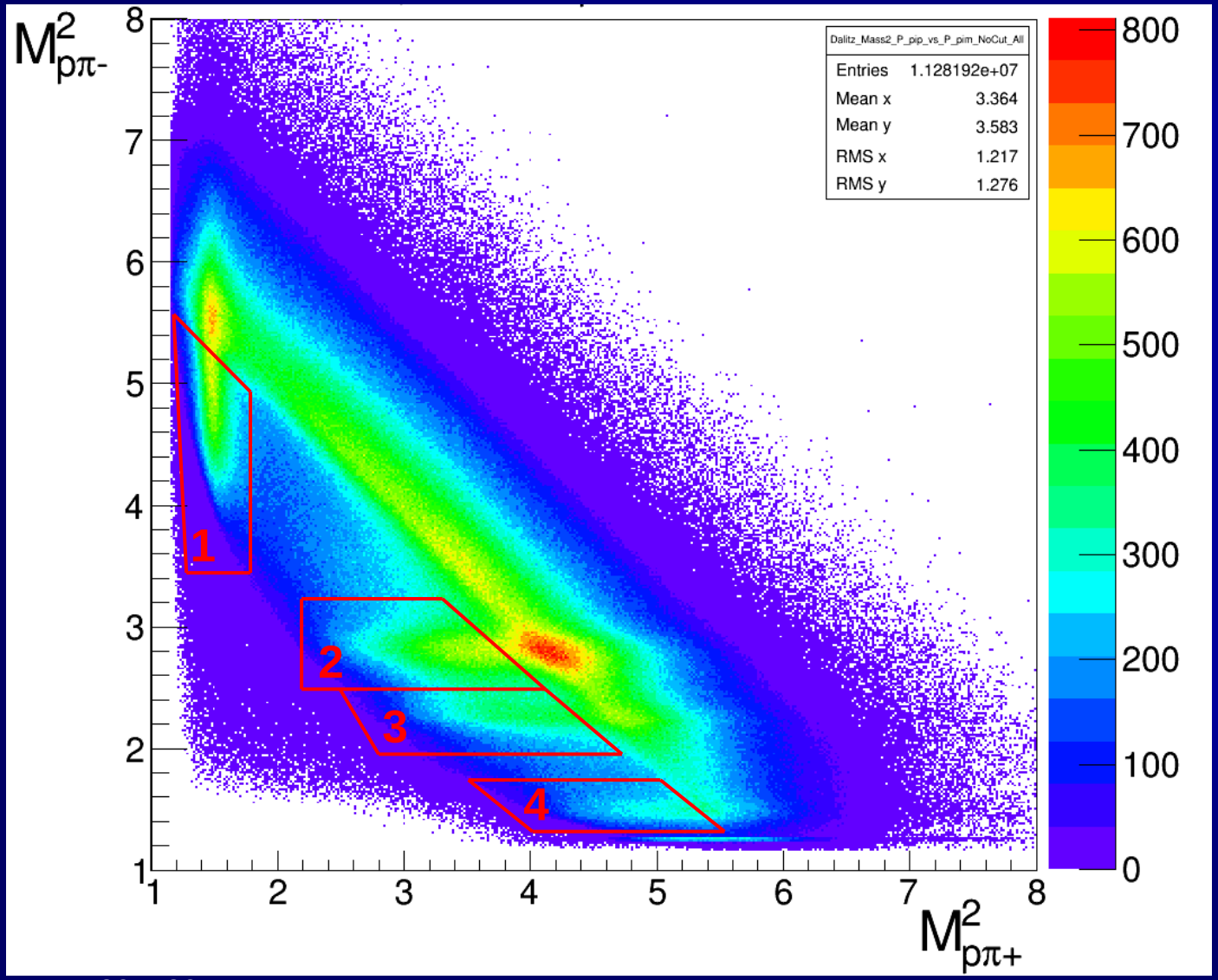


high statistics data!

also: $\gamma p \rightarrow p\pi\pi$

Cascading Decays of Excited Baryons

(S. Diehl, 2017)



$\gamma p \rightarrow p\pi^+\pi^-$

1: $\Delta^{++}(1232)$

2: $\Delta(1600)$

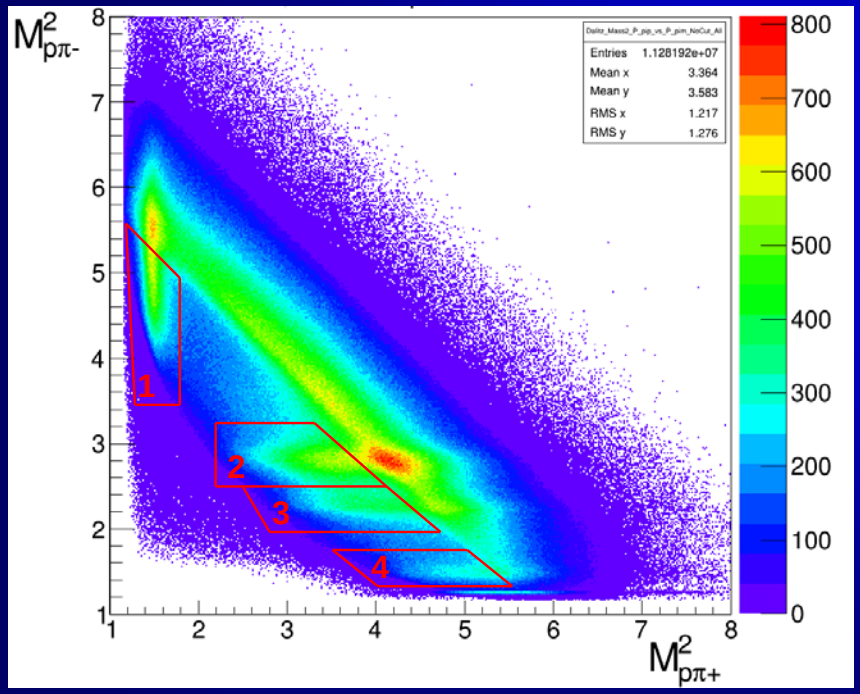
3: N(1520)

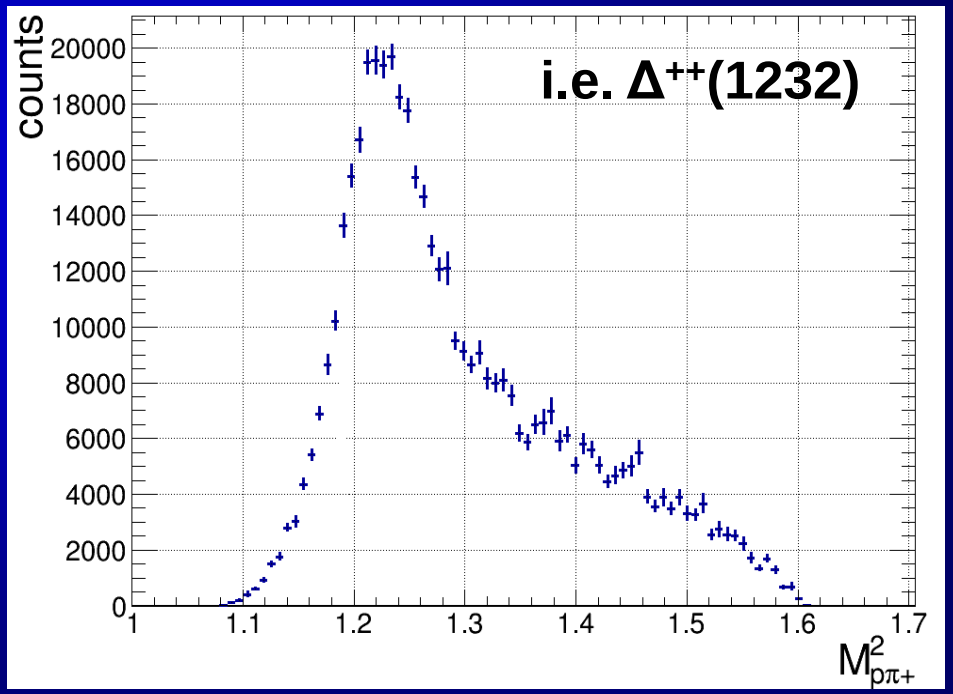
4: $\Delta(1232)$

B** → B* $\pi^{\pm}$

→ p π^+ π^-

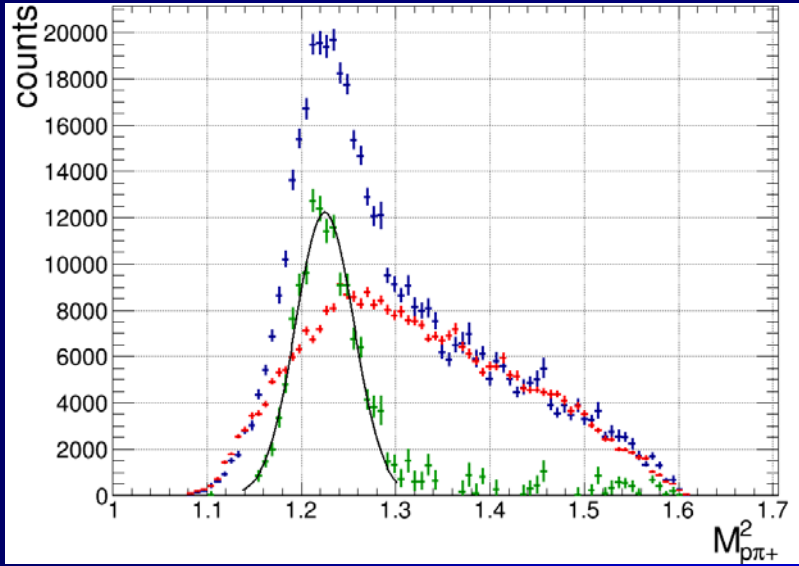
1. Event wise acceptance correction
2. Split the data in 20 MeV wide energy bins and do every analysis step for each of the 40 energy bins
3. Projection of resonance 1 ($\Delta^{++}(1232)$) to x-axis ($M^2(p\pi^+)$) and 2,3 and 4 (Δ, N) to y-axis ($M^2(p\pi^-)$)

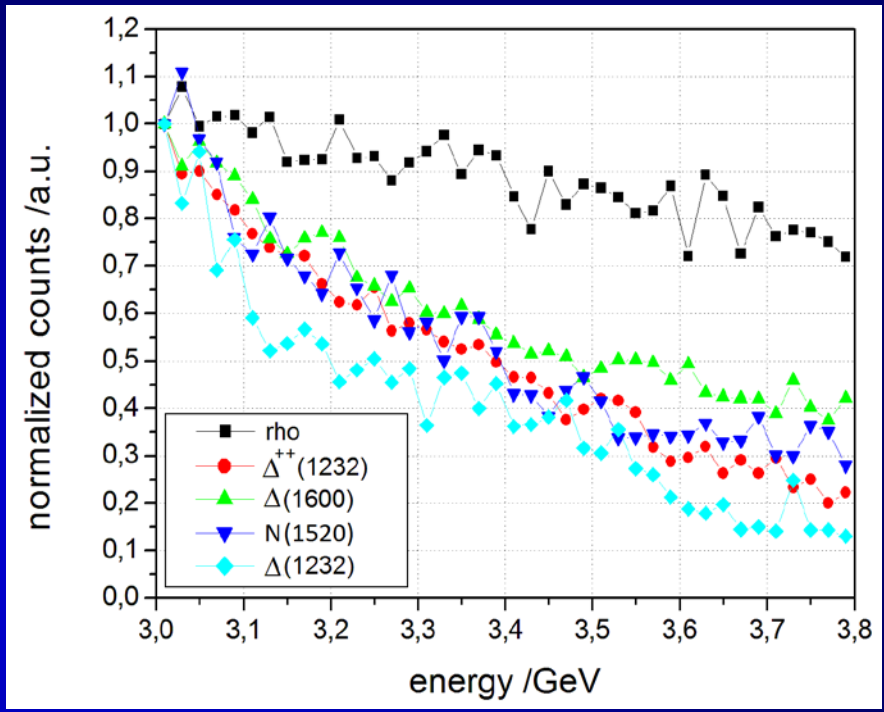




Excitation Functions

S. Diehl, CLAS6 data, ‘17





Excitation Functions

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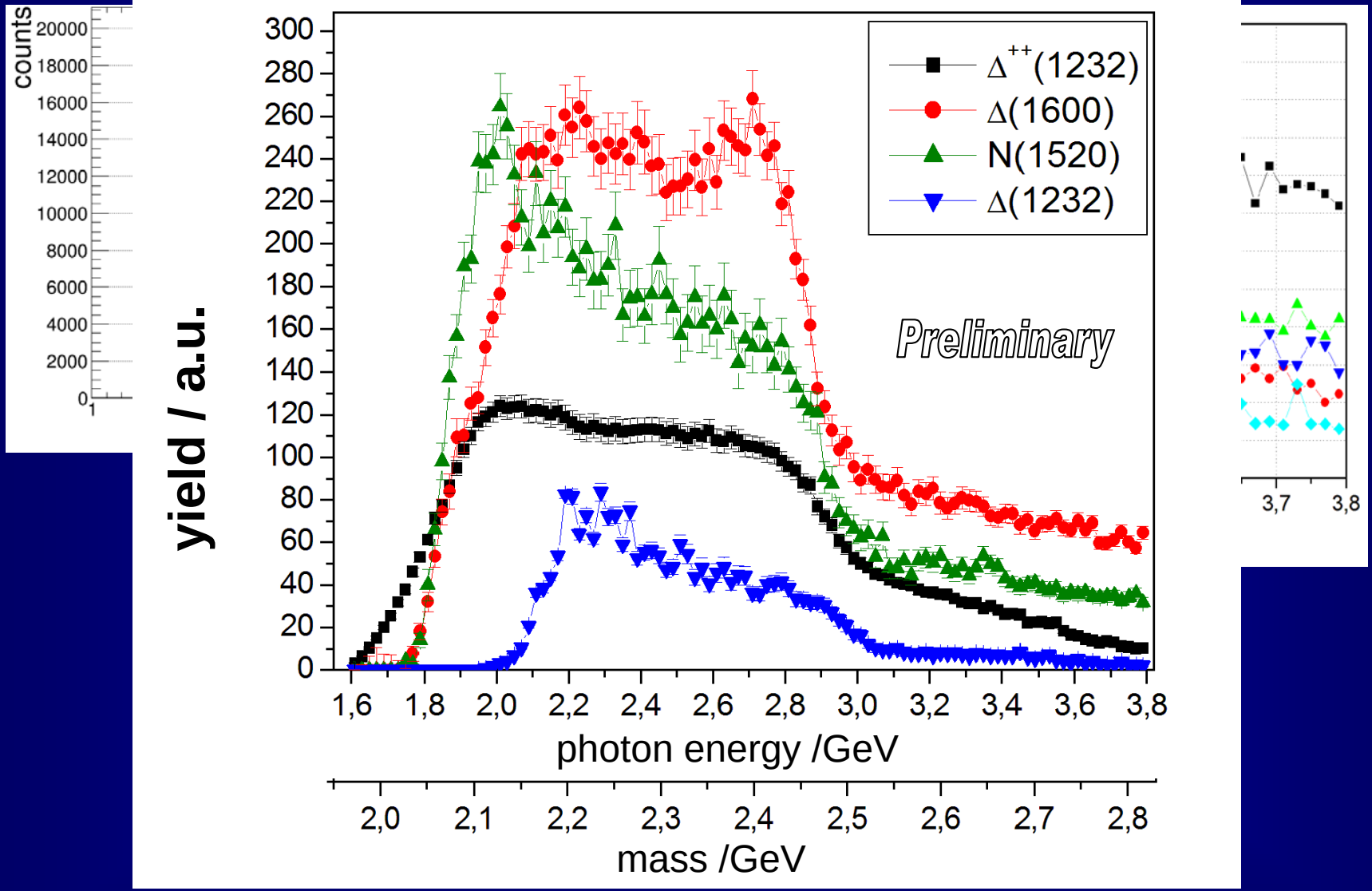

Instrumentation

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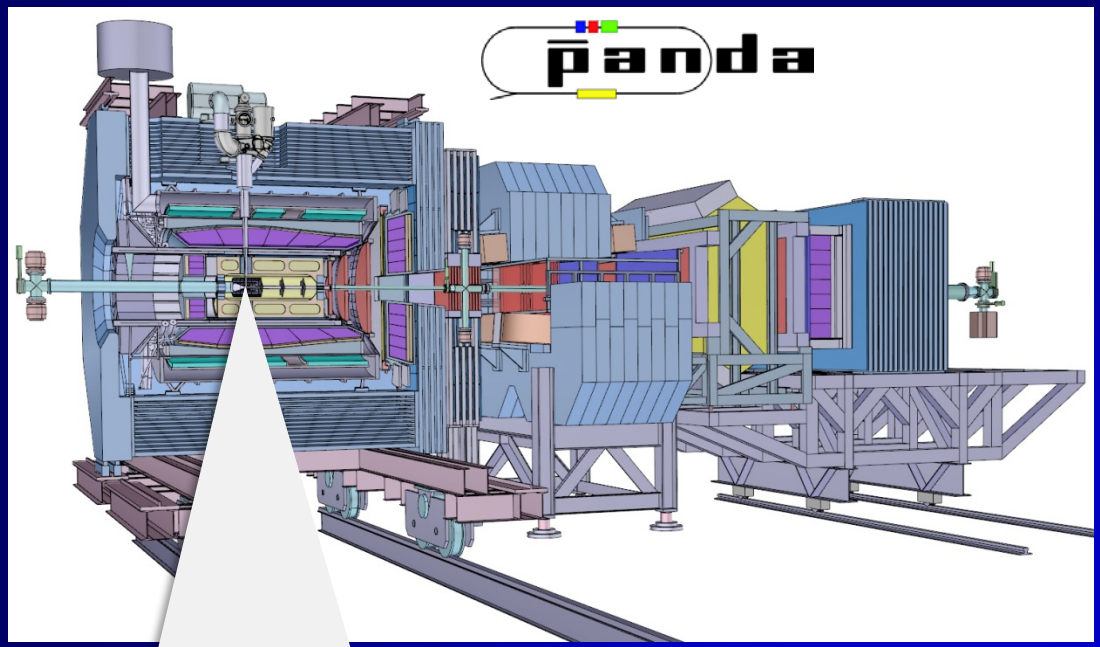
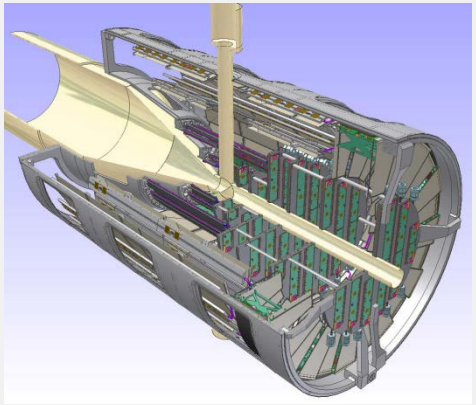
- Device Physics
- Charged Particle Tracking / Si Sensors
- Electromagnetic Calorimetry

Applications in $\bar{P}$ANDA, Medical Physics, Space Flight

Crystal research

PANDA



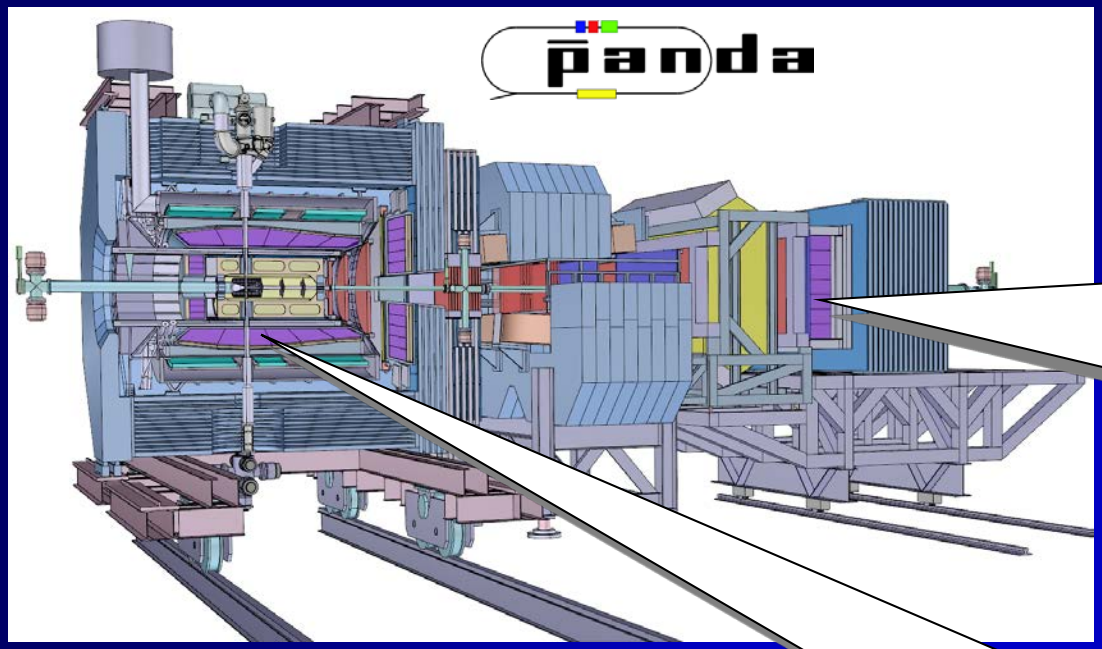


tracking

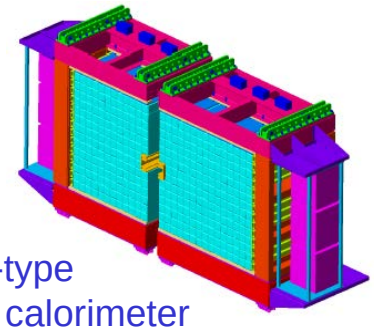
MVD panda

PANDA

HIC for FAIR
Helmholtz International Center

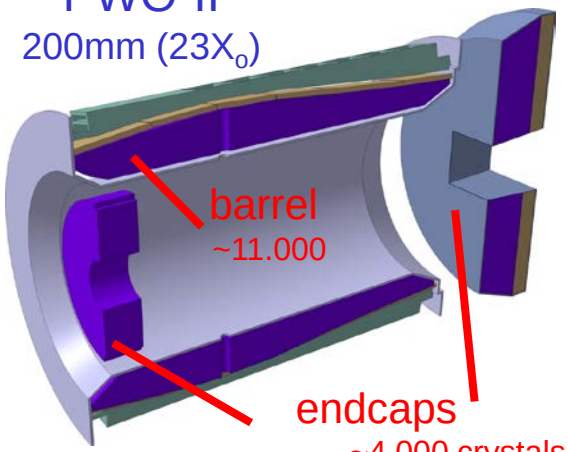


e.m. calorimetry: *e*, γ



shashlyk-type
sampling calorimeter

PWO-II
200mm ($23X_o$)



Future Involvement

- **Continued analysis of CLAS6 data**

  (Eric, Stefan)

- **Participation in preparations and running**

  CLAS12 (Eric, Stefan, PhD student)

  $e\,p \rightarrow e\,p\,\pi^0$ sim w/t Genova (S. Diehl, talk Thursday)

  $e\,p \rightarrow e\,p\pi^+\pi^-$

- **Hardware/services**

  ☞ Possibly contributions

  in forward tagger

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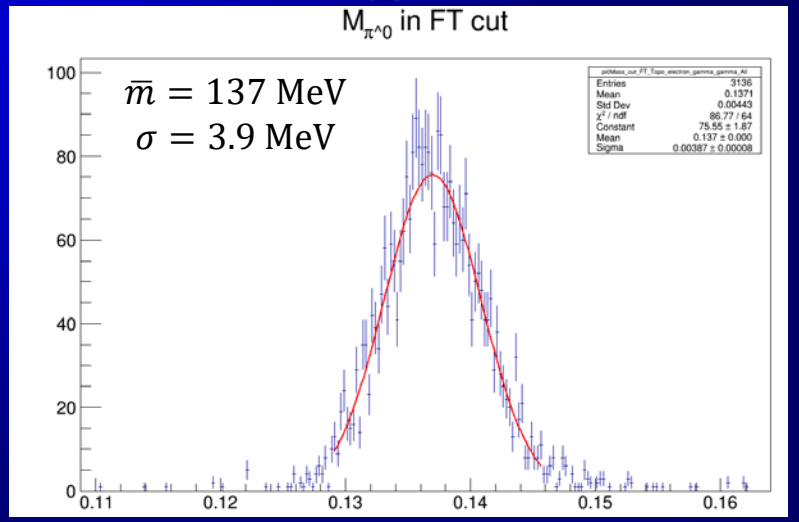

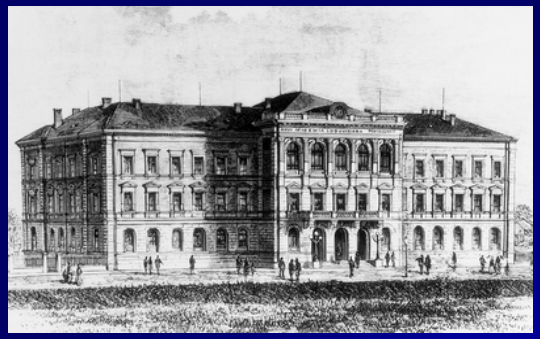

University of Gießen

founded in 1607

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UNIVERSITÄT
GIESSEN

Justus Liebig

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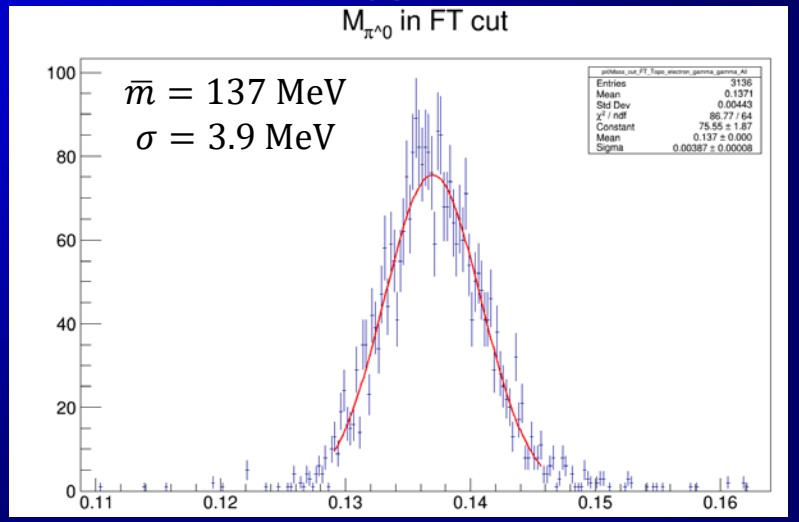
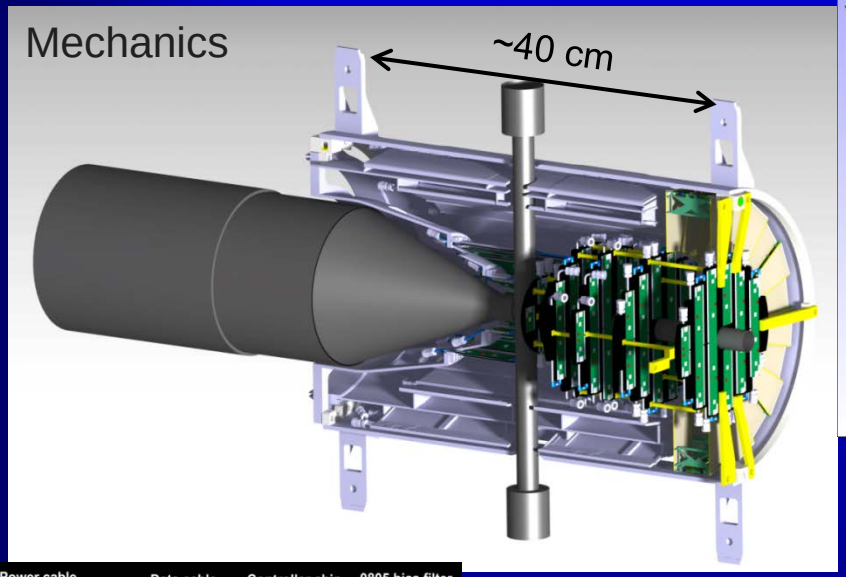
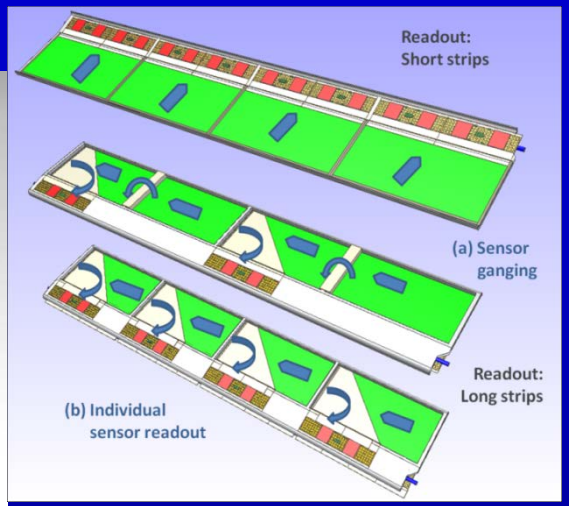
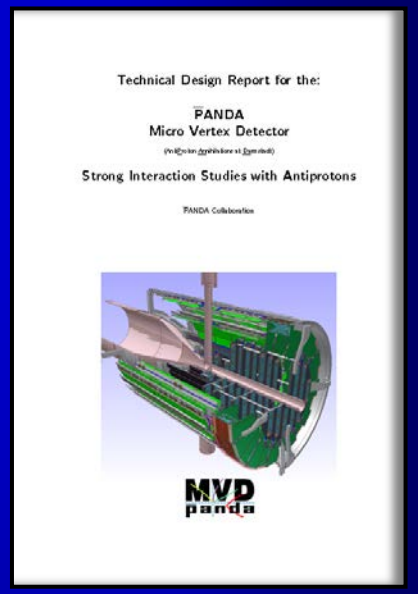
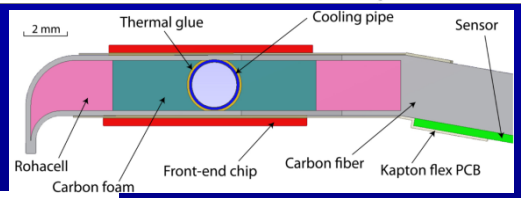


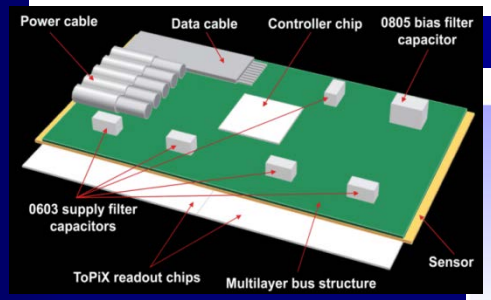
The $\bar{P}$ANDA MVD Project

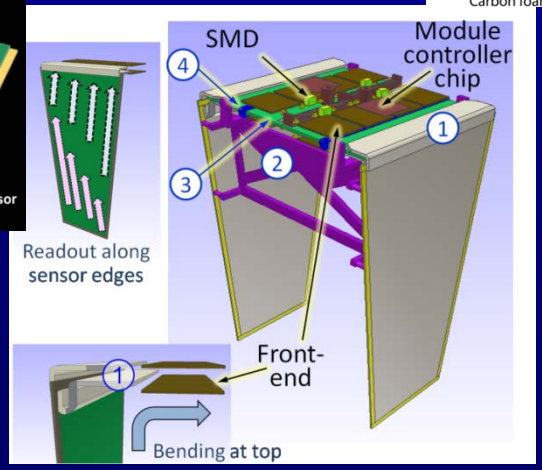


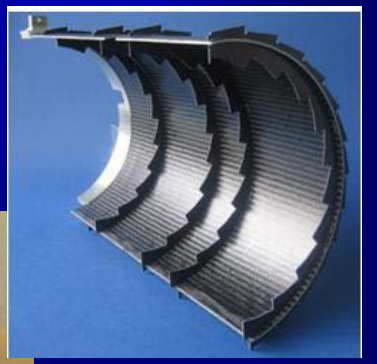


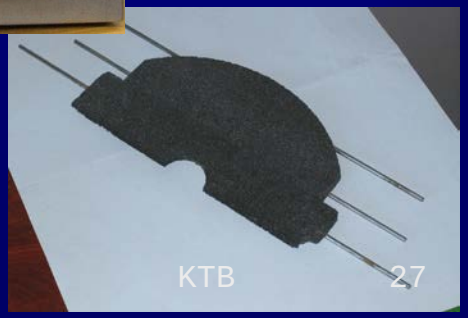






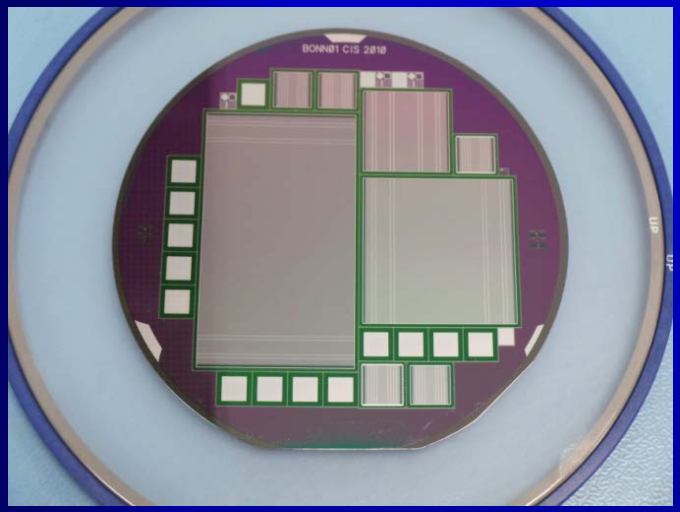




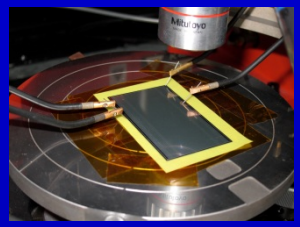


The P̄ANDA MVD Project

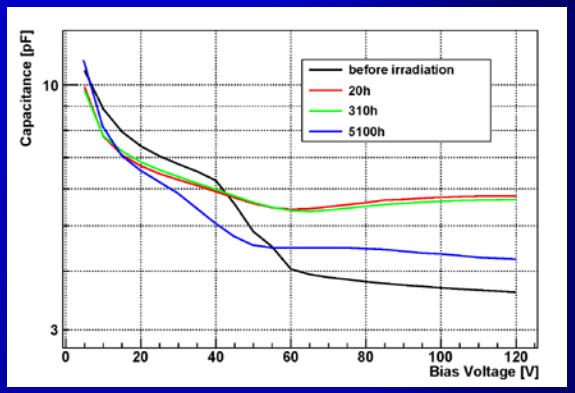
Hardware: double-sided Si strip sensors, P̄ANDA grade

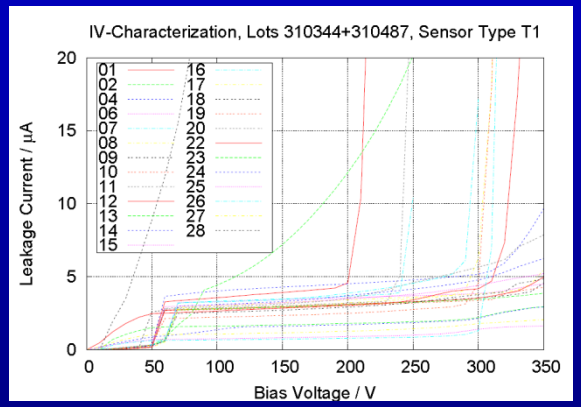


P̄ANDA wafer CiS Erfurt

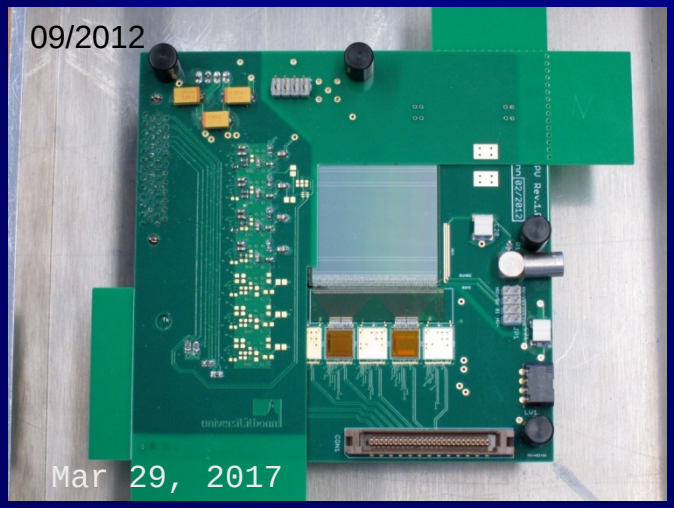


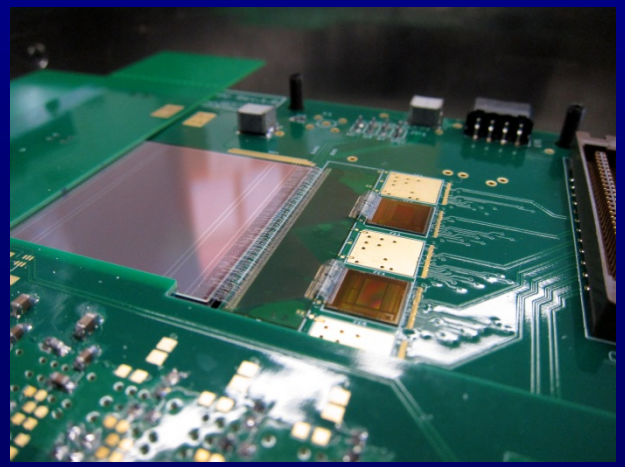
Radiation damage test

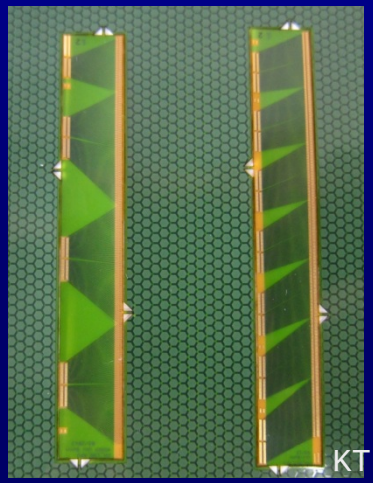




Probe station characterization





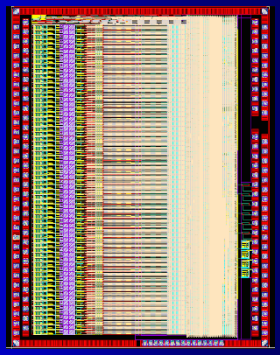


Flex PCB

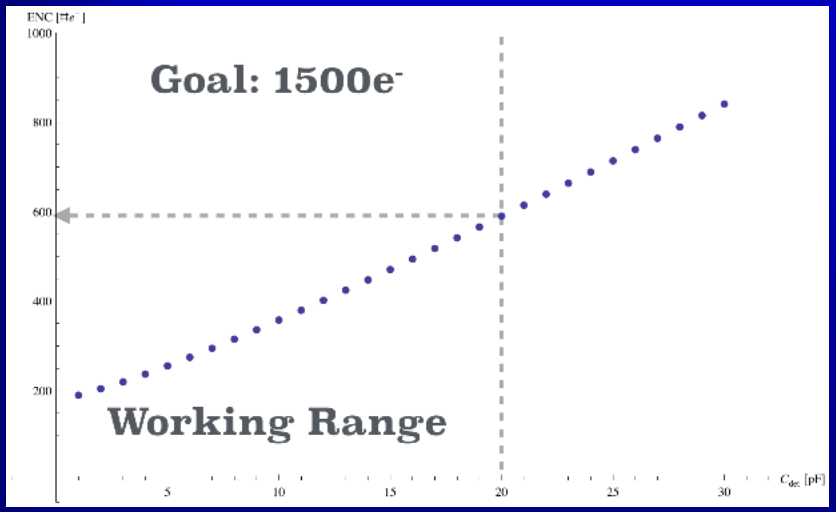
<25 µm Cu
30 µm solder resist,
25 µm dielectric /carrier

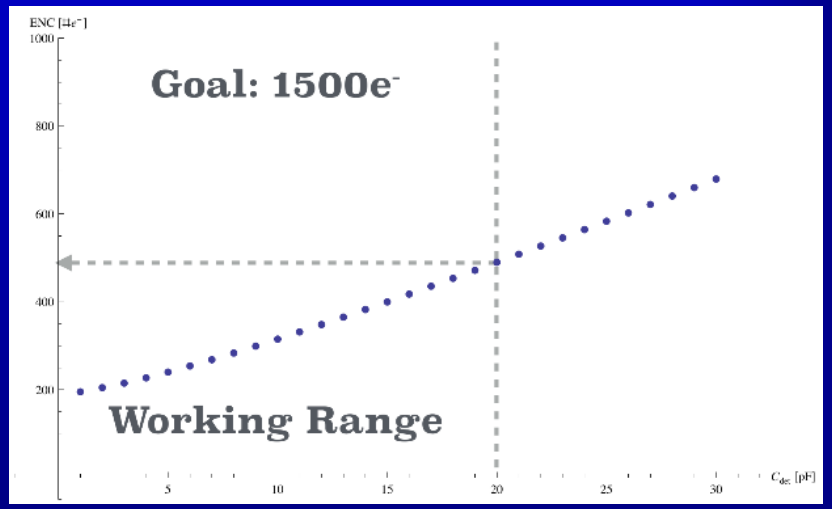
The $\bar{P}$ANDA MVD Project

Hardware: development of a non-triggered Frontend readout chip (PASTA)



First prototype under study (MPW run in 2015)





Features:

- 64 channels
- Time over threshold
- Small power consumption

First prototype operational, beam tests in 5/17
Re-submission
Final design planned in ~ 2 years
Module controller chip developed in parallel

Torino, Gießen, Jülich, Iserlohn

Si Lab Facilities

Hardware

Cleanroom facility (ISO class 6)

Workshop:
Specialized equipment in-house, customized, on short notice

- Bonding tools
- Mounting tools

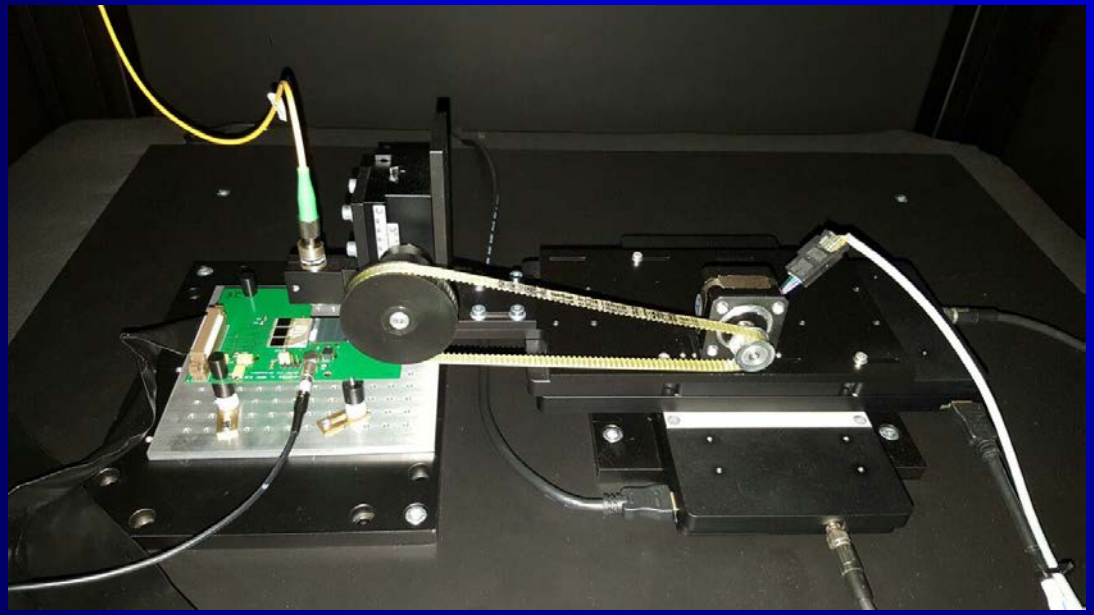
Semi-automatic wedge wire bonder

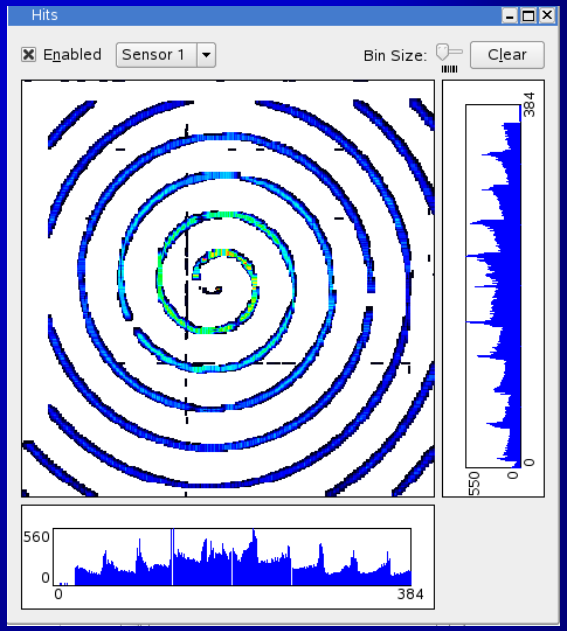
Automatic prober

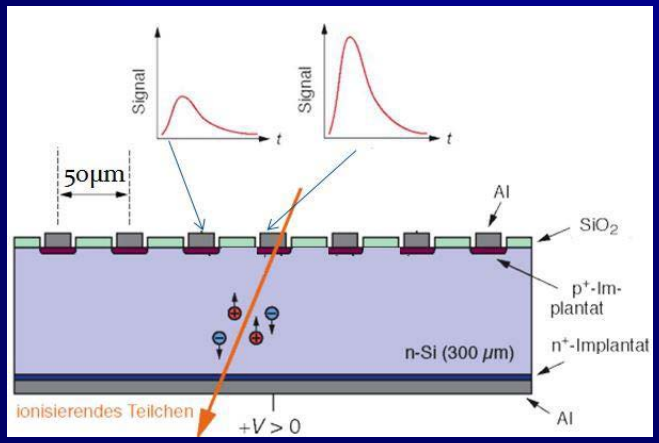
The $\bar{P}$ANDA MVD Project

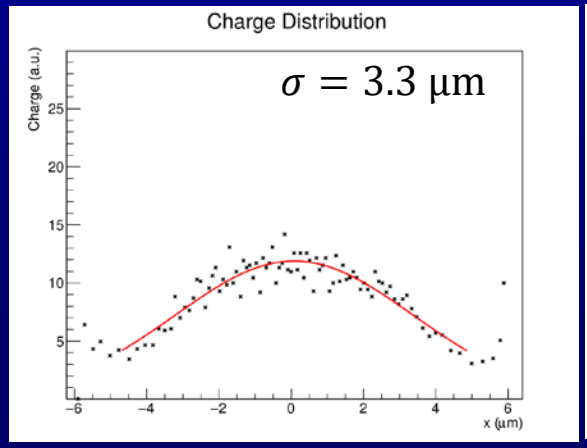
Hardware

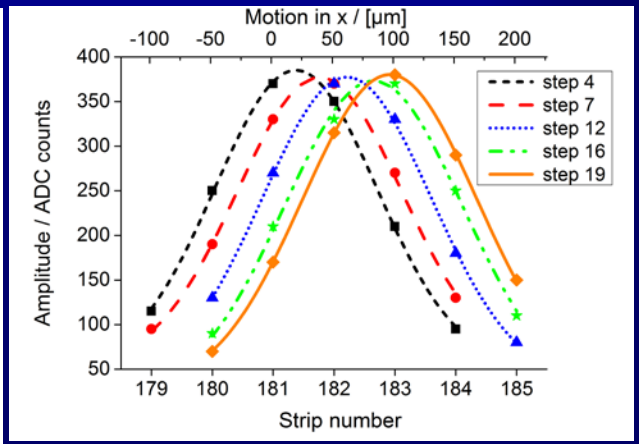
1060 nm laser test stand operational





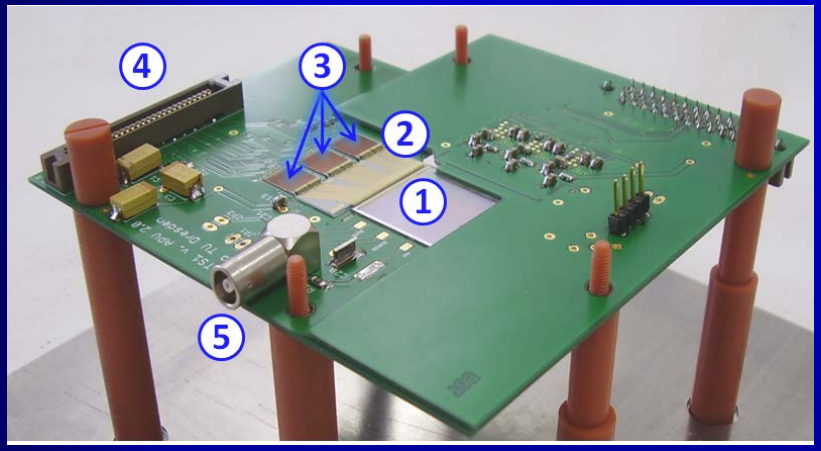






The PANDA MVD Project

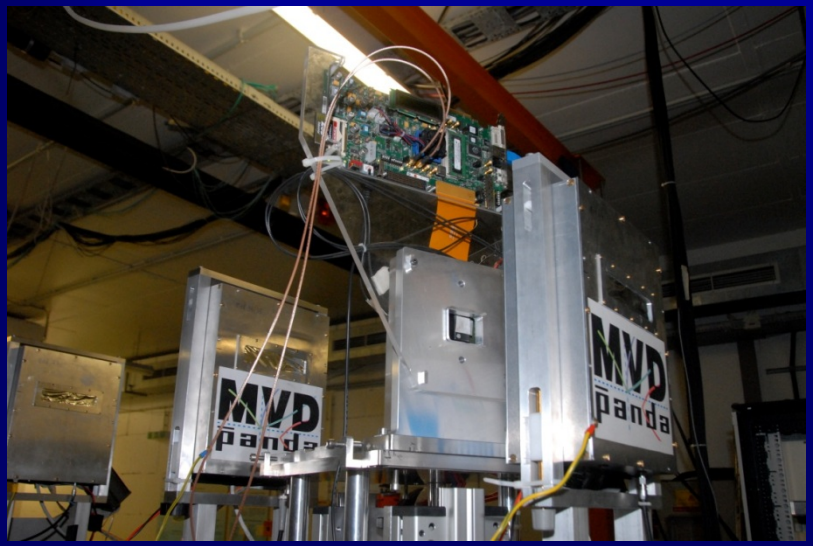
Hardware

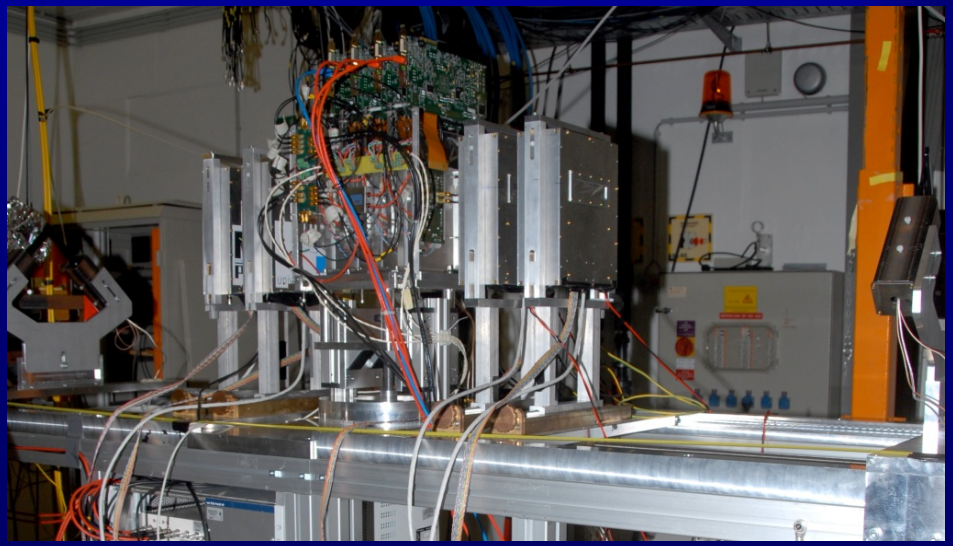


Tracking station:

Si strip sensors, 4 layers

- Handling
- Sensor tests
- Tracking development (soft/hard)
- Infrastructure



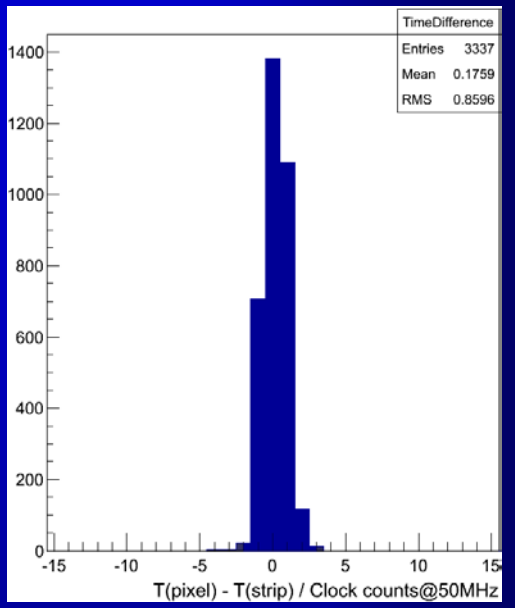


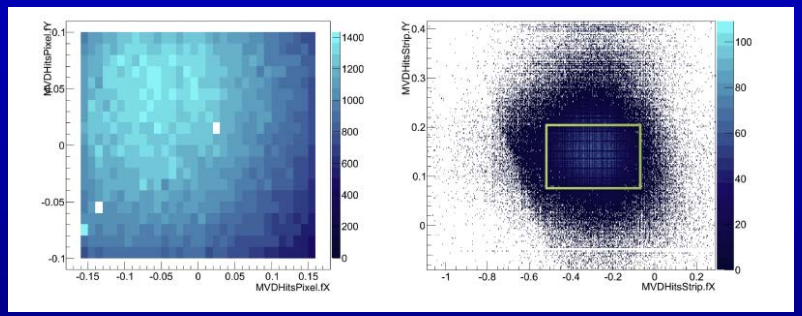
The P̄ANDA MVD Project

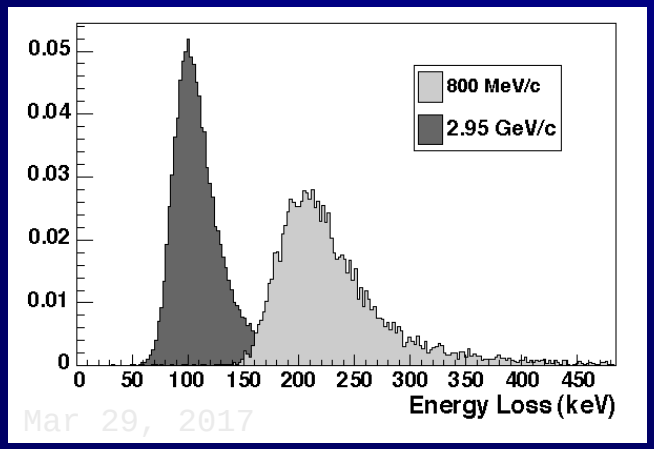
Measurements

CERN, COSY, DESY, ELSA:

- Pixel tracking station – triggerless readout
- Synchronisation with the strip telescope @50 MHz
- 10 GeV/c pions, pixel + strips: residuals $\sigma_{x,y}$ = 18 µm

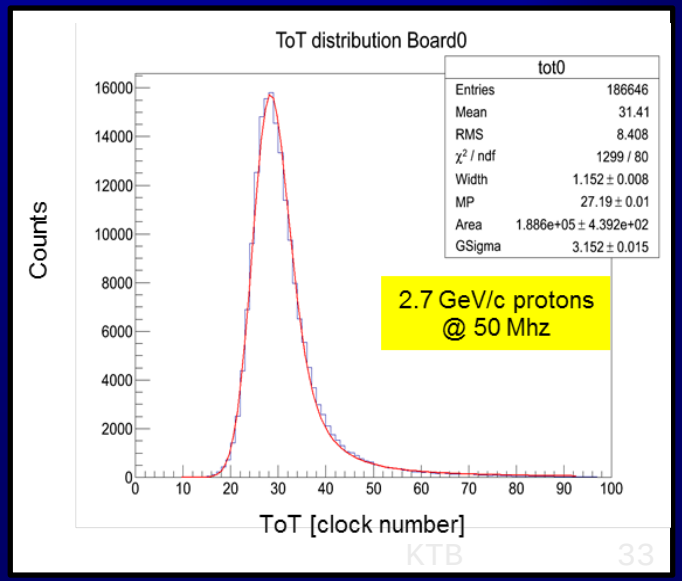




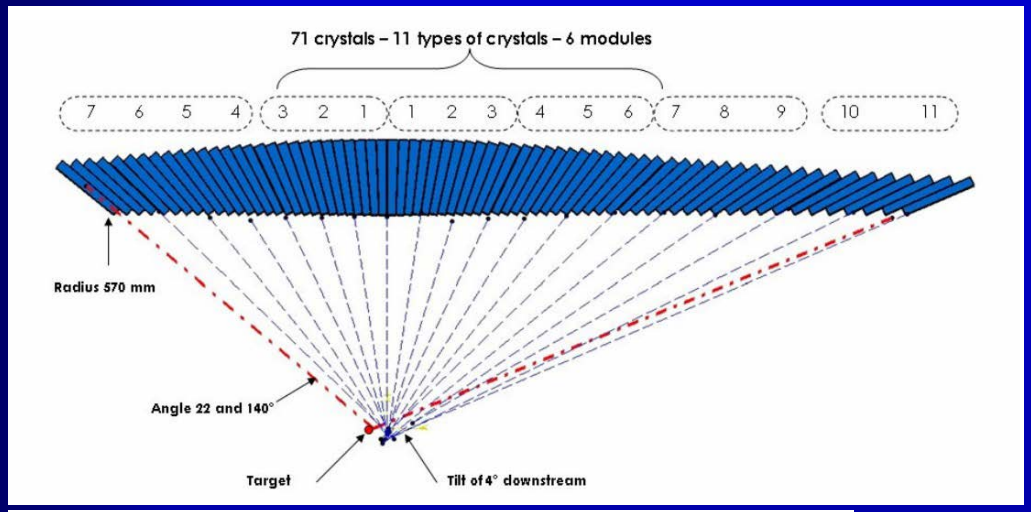


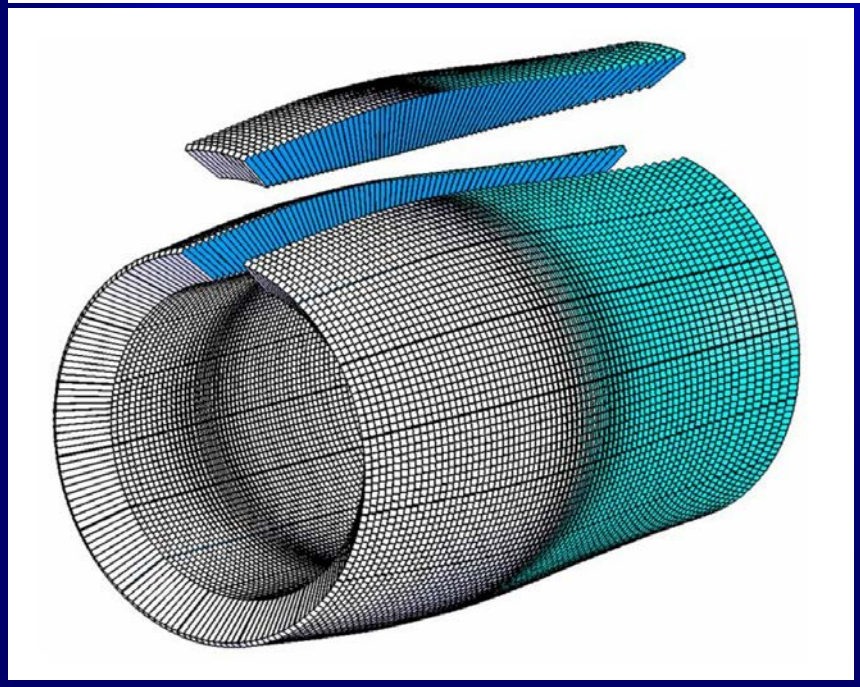
p, Si strips
APV S25

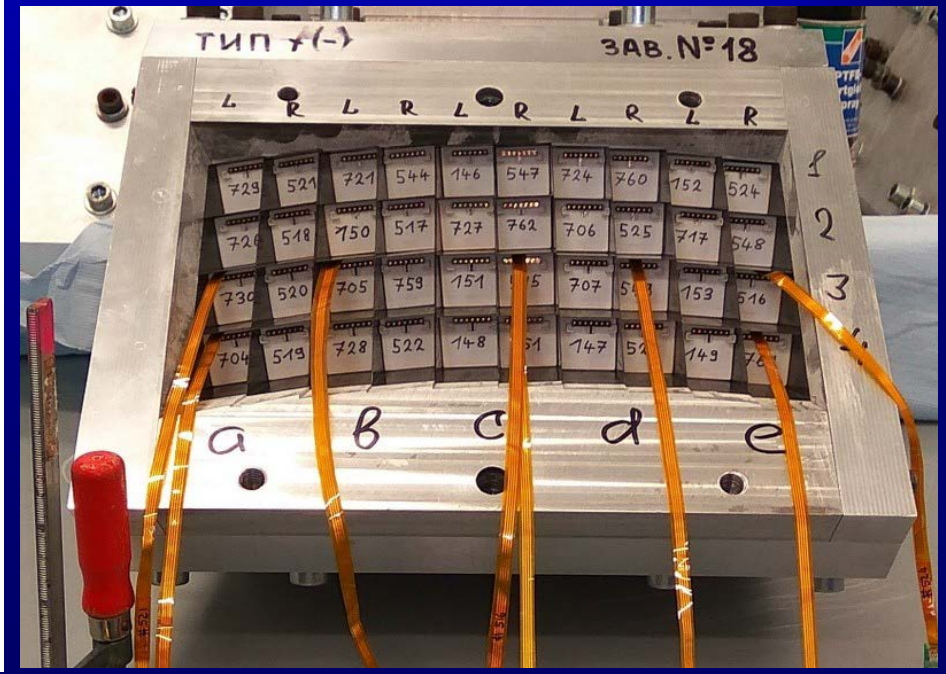
p, ToPix
pixel array



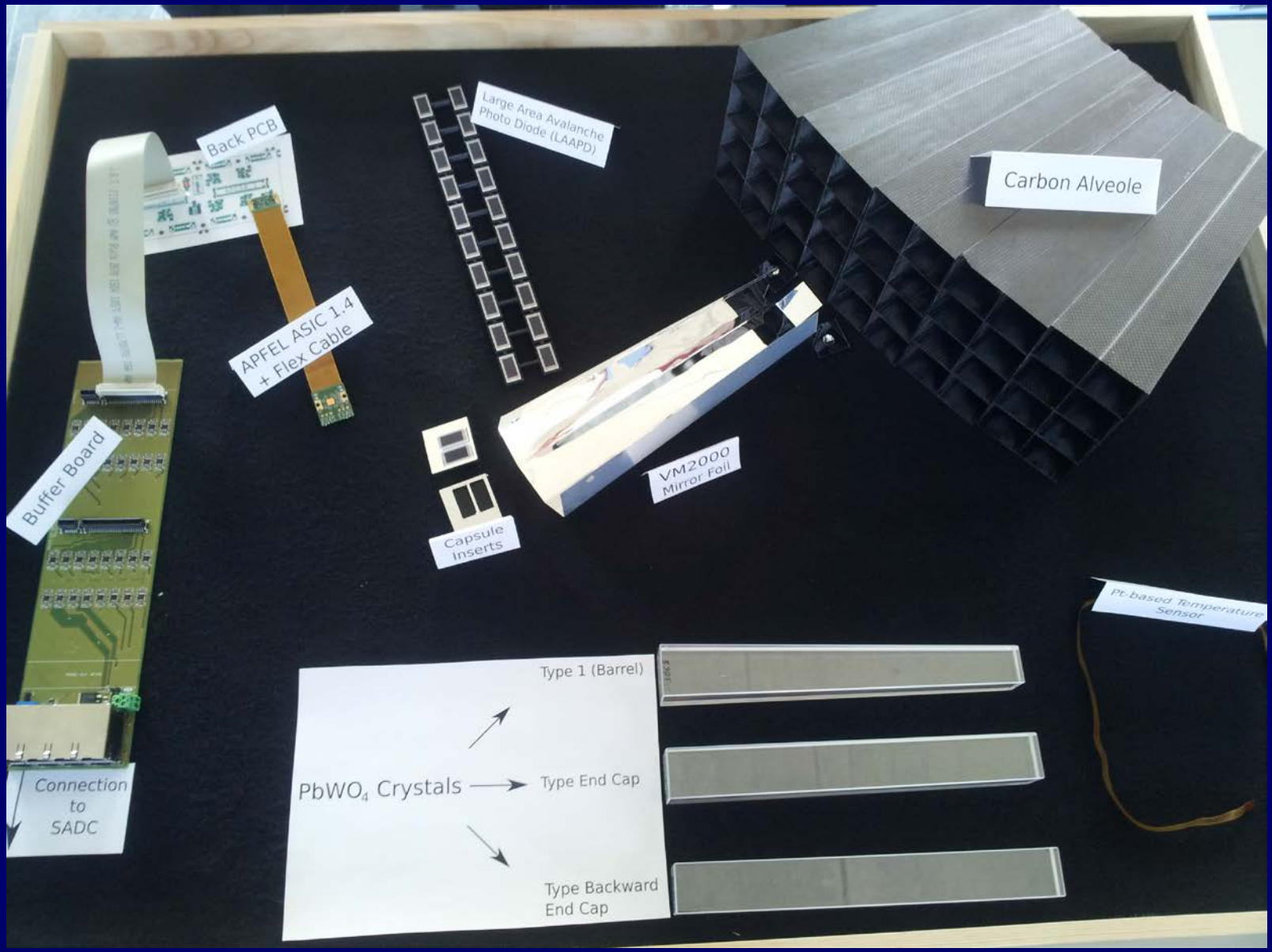
The P̄ANDA EMC



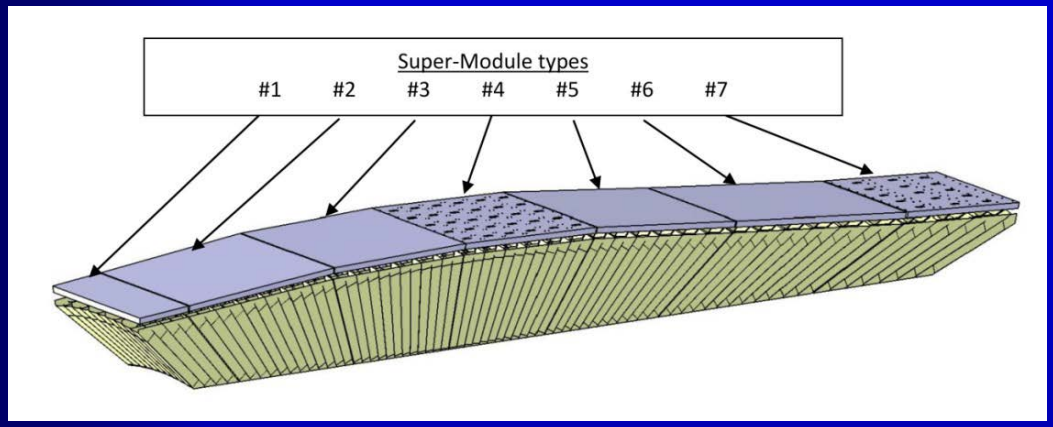




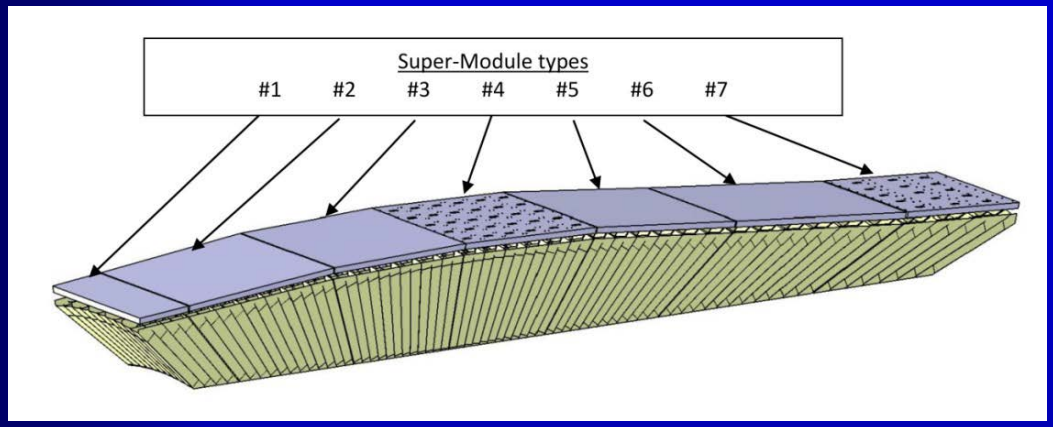
Next Step: $\bar{P}$ANDA Barrel Slice

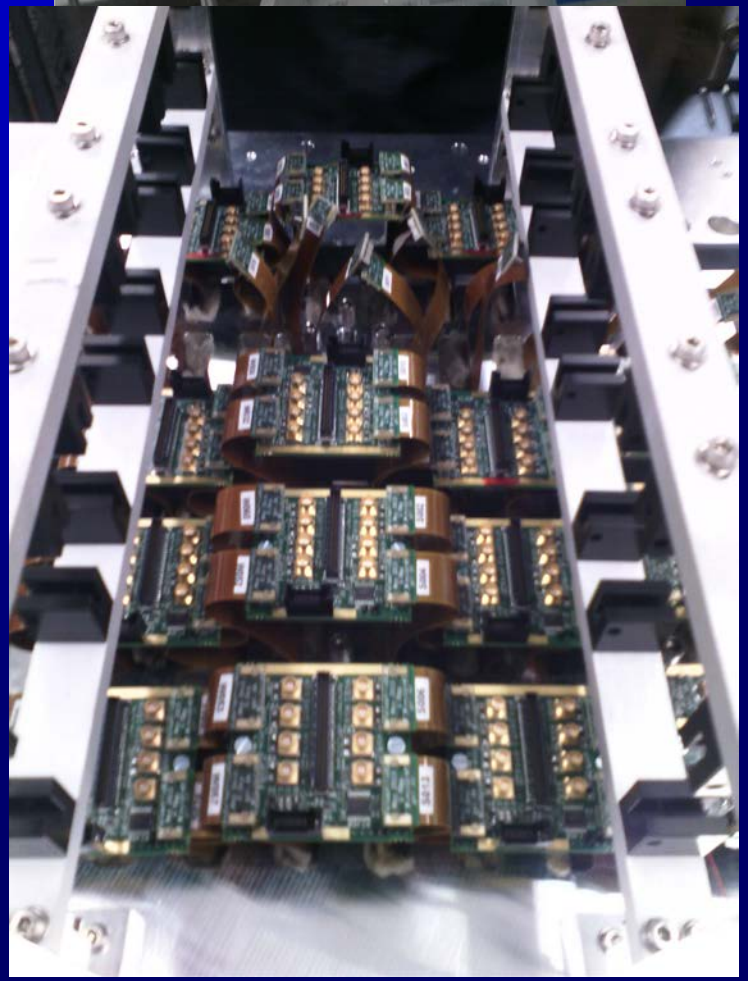


The PANDA EMC

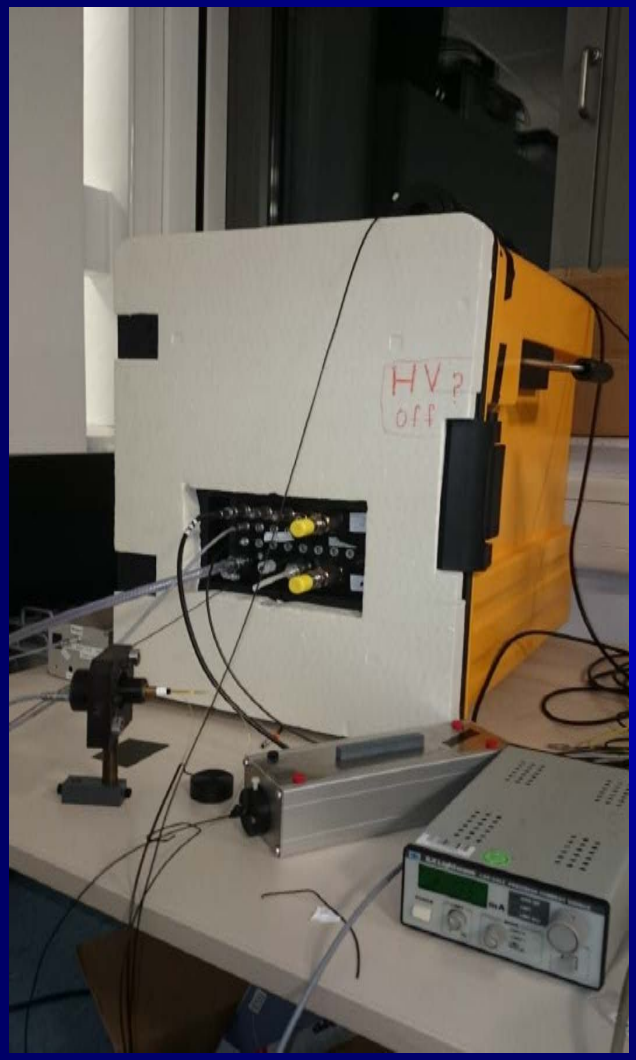


The $\bar{P}$ANDA EMC





$\bar{P}$ANDA EMC: Stimulated Recovery of Rad Damage



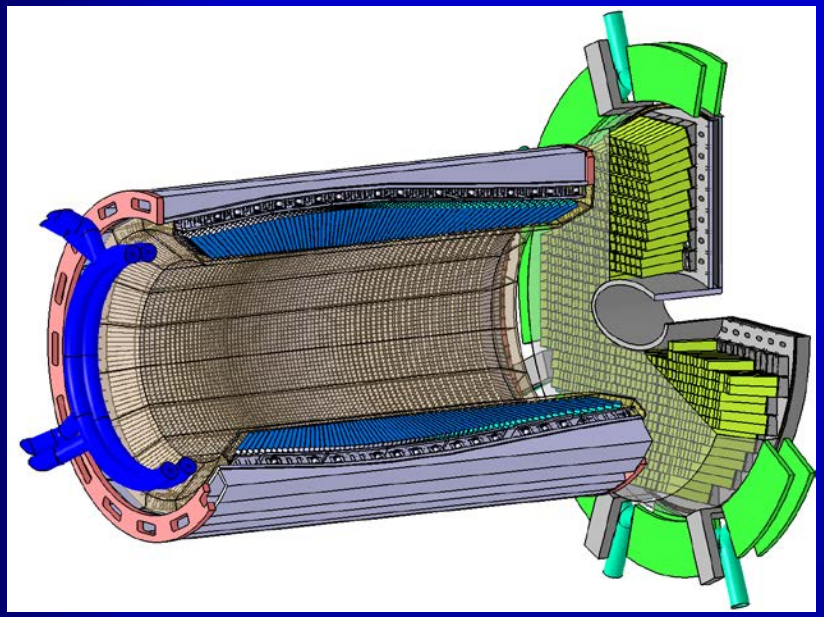
Prototype Setup for the FEC

- Stable operation at -25°C
- Monitoring with light pulser
- Precision control of laser diode flux

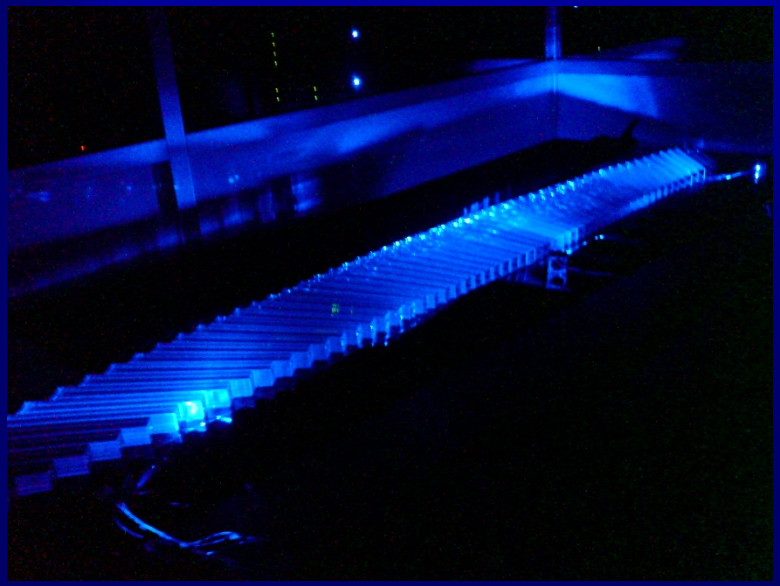
- Estimated maximum dose rate 2 ·10^{-6} Gy/s
- Leads to production of 10^{12} populated traps/s

- Minimum flux for recovery 10^{13} ph/s

The $\bar{P}$ANDA EMC



- ~ 15,000 PWO-II crystals
- 22 X_0 (2 cm x 2 cm x 20 cm)
- Readout by 2 Large Area APD
- Self-triggered data acquisition



$\bar{P}$ANDA EMC

- Prototyping of stimulated recovery of PWO crystals

  => standard procedure
- Hadron rad damage studies
- Light-yield uniformity studies
- Rad hardness of laAPDs

  => standard procedure under development
- Barrel prototype PROTO 120, many procedures and components standardized
- Proto analysis

Co-60 irradiation, JLU

PROTO120@MAMI