Spectroscopy of Baryon Resonances

-Status report A1-project-

R. Beck, R. Novotny, U. Thoma

- Recent results and publications
- Status of the new CB set up
- Future plans

Recent results and publications

physics : Spectroscopy of baryon resonances

tools : Photoproduction of mesons with unpolarized/polarized photons and unpolarized/polarized targets

1.) O. Bartholomy et al., PRL 94 (2005) 012003

$$\gamma + p \rightarrow p + \pi^0 \qquad 300\,MeV < E_\gamma < 3.0\,GeV$$

2.) H. van Pee et al., long write up, submitted to EPJA

3.) V. Crede et al., PRL 94 (2005) 012004

$$\gamma + p \rightarrow p + \eta \qquad 300\,MeV < E_\gamma < 3.0\,GeV$$

4.) O. Bartholomy et al., long write up, prepared for EPJA

5.) J. Junkersfeld et al., prepared to EPJA

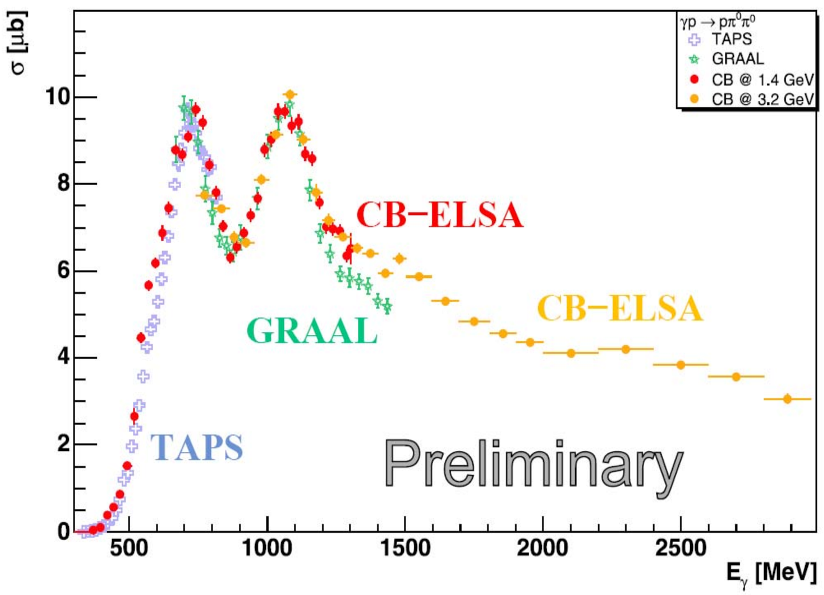
$$\gamma + p \rightarrow p + \omega + \pi^0$$

6.) U. Thoma et al., prepared for PRL

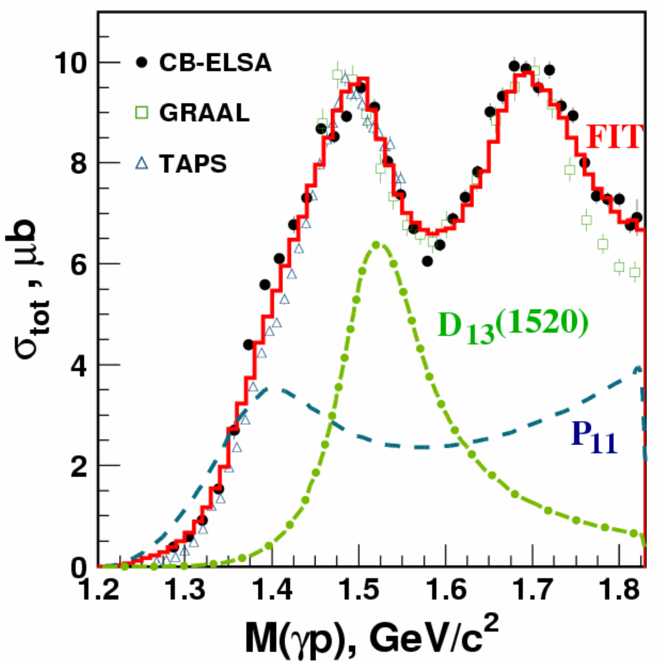
$$\gamma + p \rightarrow p + \pi^0 + \pi^0$$

-> Result report next year !!

Recent results and publications



M. Fuchs, U. Thoma



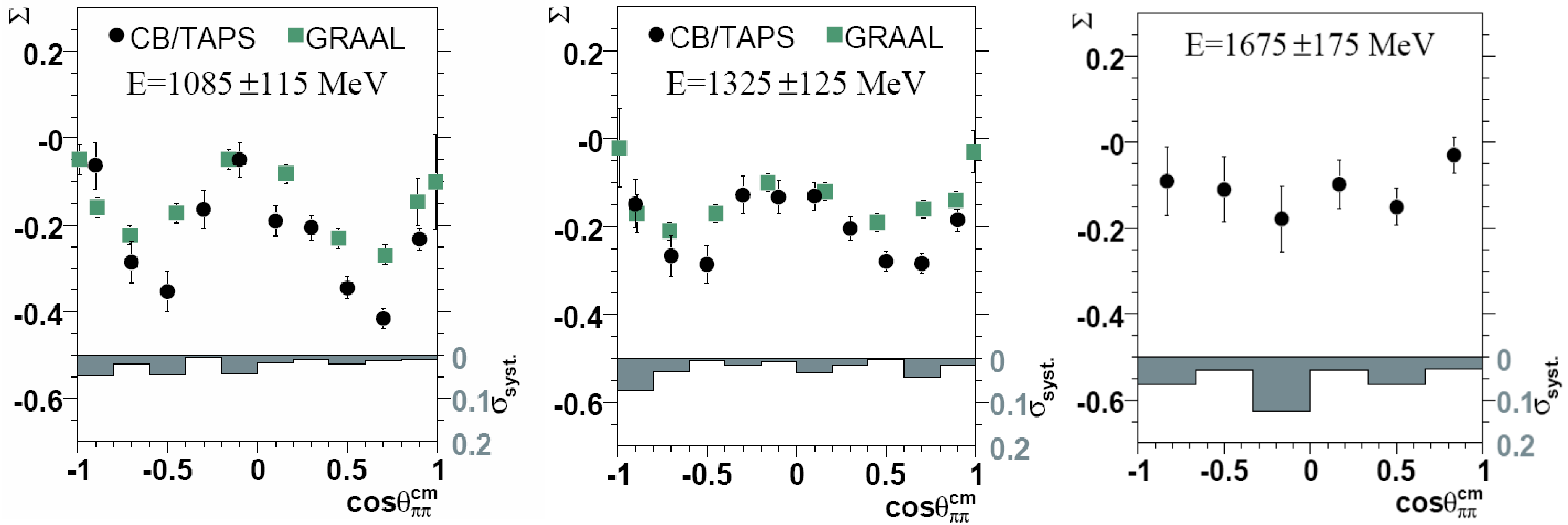
- Bonn-Gatchina PW-Analysis
- including additional data single meson production, $\pi^- p \rightarrow n\pi^0\pi^0$ (CB-BNL), πN –partial waves

- PWA -> P11(1440), P11(1850), D13(1520), D13(1700), D33(1700), P13(1720), + … t-, u- channel exchange, Born terms.

more details in
A2- Project

First results with linearly polarized photons

Preliminary results for photon asymmetry Σ : $\vec{\gamma} + p \rightarrow p + \pi^0 + \pi^0$



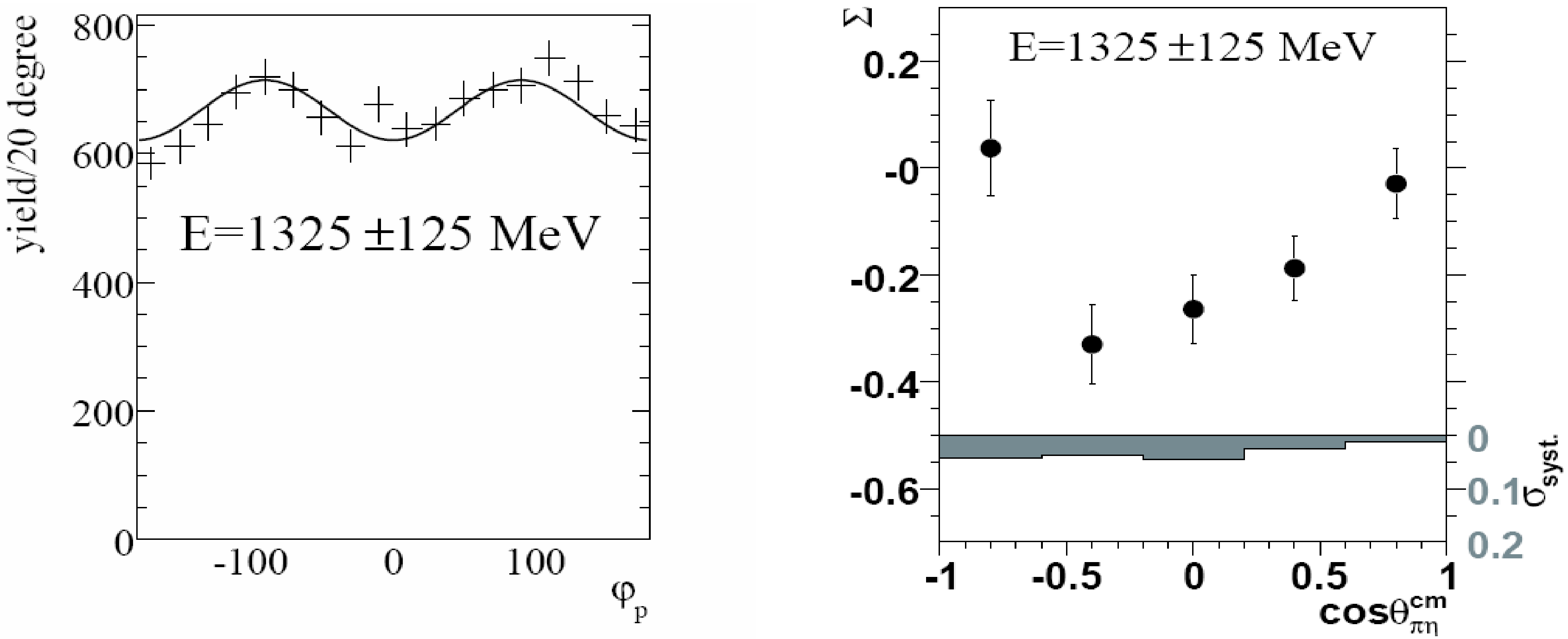
Data analysis in progress
- higher statistics (factor 2-3)
- higher energies ?

V. Sokhoyan , H. van Pee

-> Result report next year !!

First results with linearly polarized photons

Preliminary results for photon asymmetry Σ : $\vec{\gamma} + p \rightarrow p + \pi^0 + \eta$

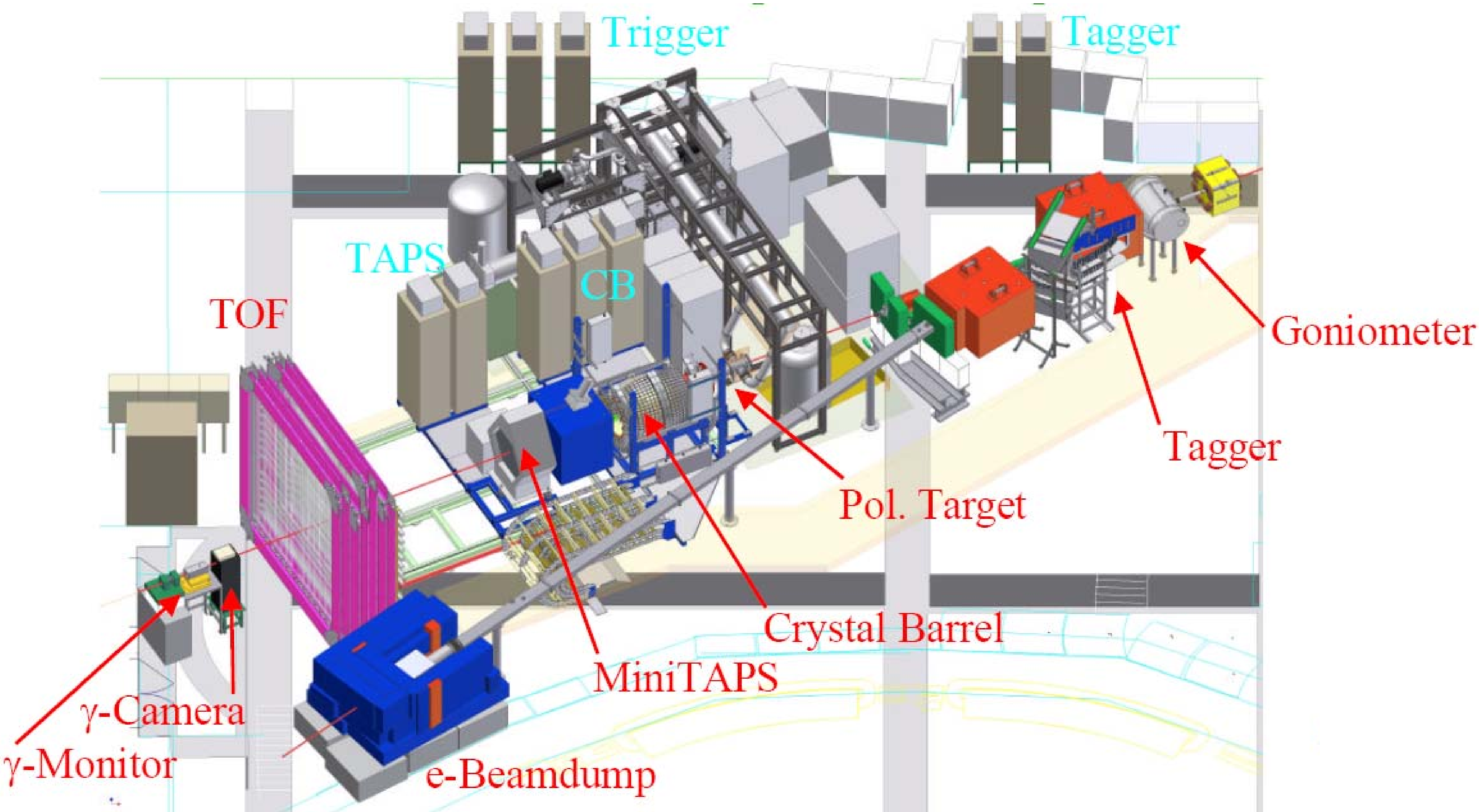


E. Gutz

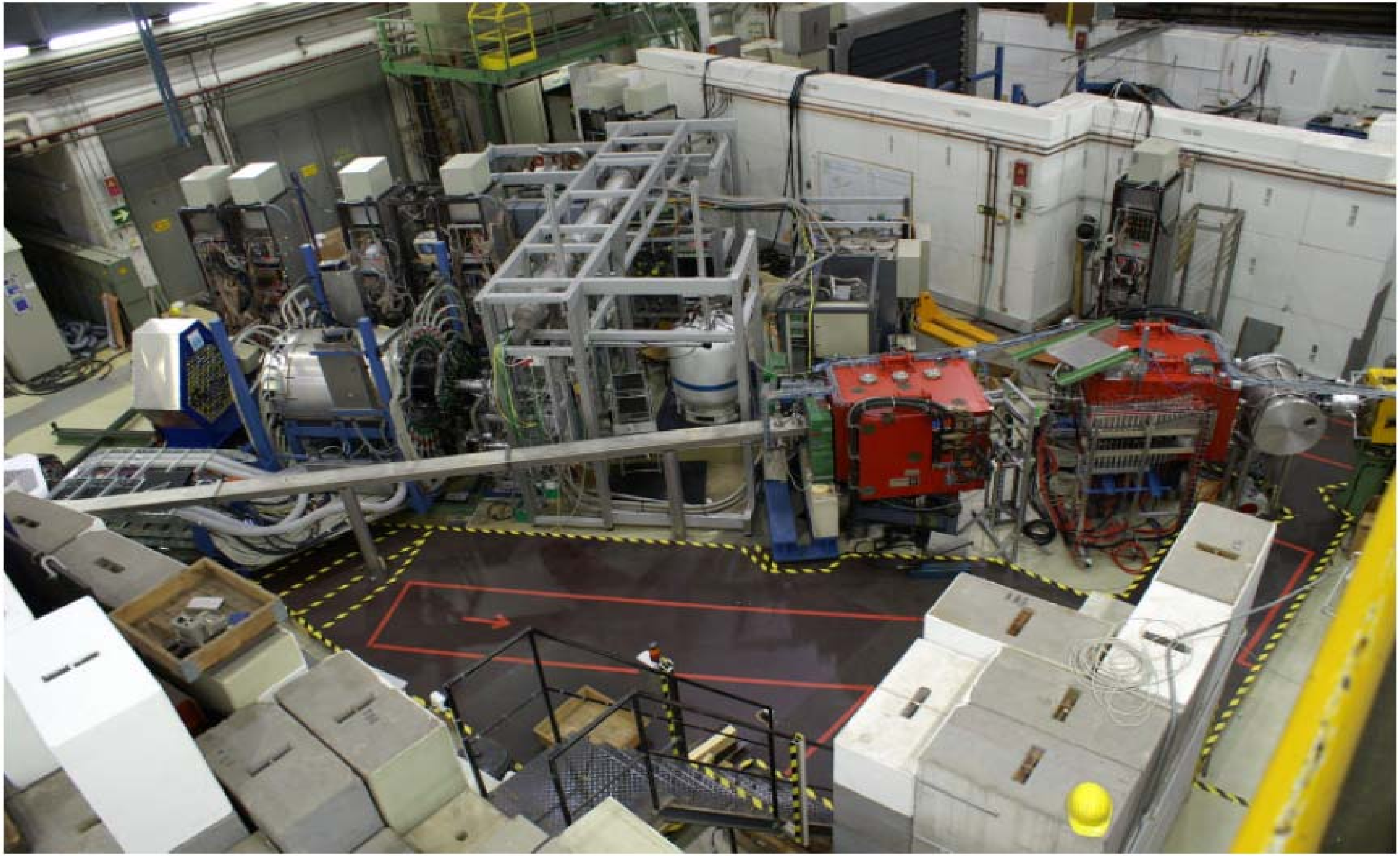
Data analysis in progress
- higher statistics
- more energy bins (1100 and 1600MeV)

-> Result report next year !!

New Crystal Barrel Set Up



New Crystal Barrel Set Up

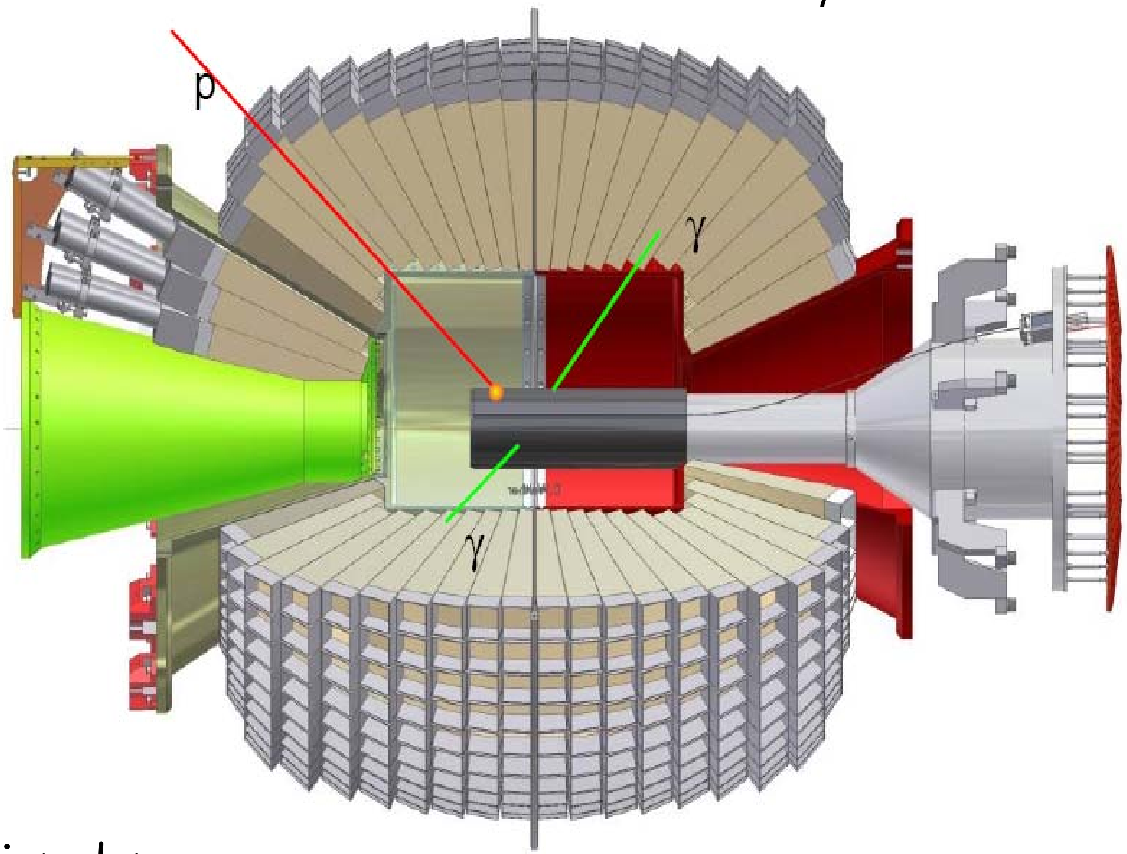


New Crystal Barrel Set Up

- Crystal Barrel detector
  1230 CsI crystals
- Inner-detector
  cylinder of 513 scintillating fibers
- forward detector (FWPlug)
  90 CsJ crystals with PM's, 12^0-30^0
- forward detector (MiniTAPS)
  216 BaF_2 , 1^0-12^0
- CO_2 Gas Cerenkov detector

$\pi^0 \rightarrow \gamma\gamma$ $\eta \rightarrow \gamma\gamma$

$\eta \rightarrow 3\pi^0$



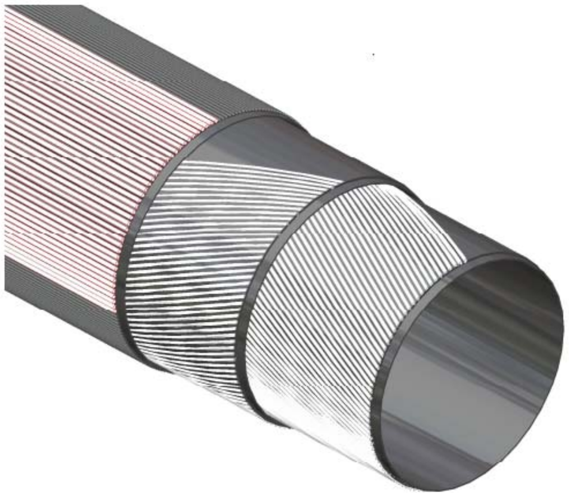
Status Crystal Barrel:
- Modification and installation done
- New rail system
- First tests with beam

D. Walther
H. Kalinowsky
M. Lang

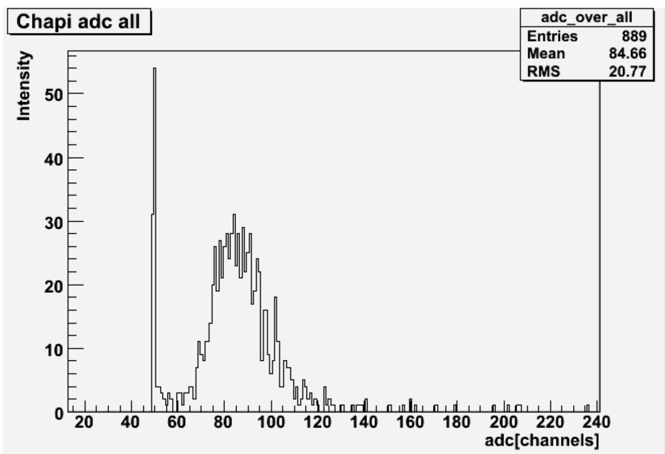
Inner detector

M. Grüner, I. Horn

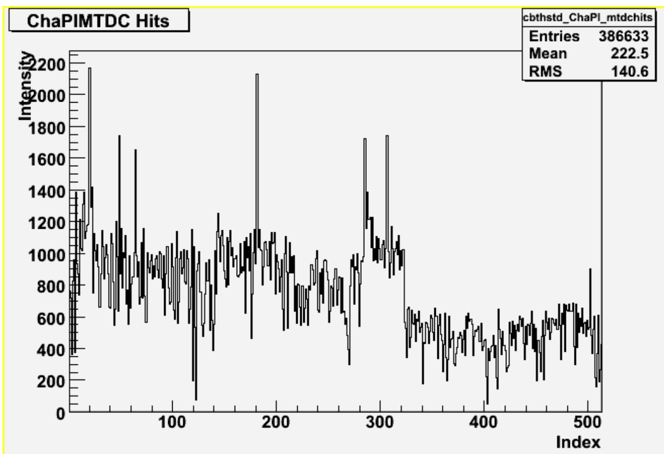
- Particle discrimination for CB
  (513 scintillating fibres in 3 layers)
- Included in first level trigger
  (2 out of 3 layers)
- Necessary modification done
  (to fit with polarized target)
- Installed and first tests with beam



ADC-Spectrum



Hit-Spectrum

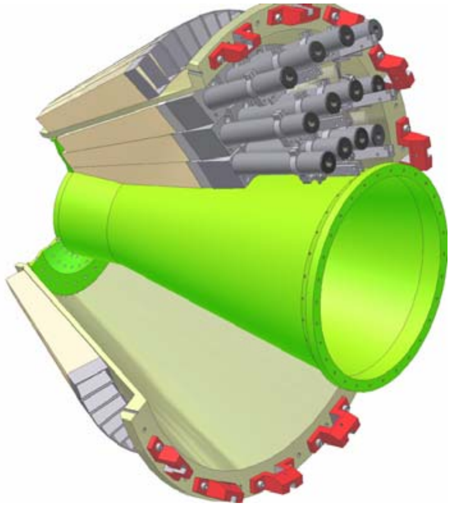


FWPlug: Crystals with PM-Readout

- All 90 crystals modified and installed (lightguide and photomultiplier)

- New first level cluster trigger

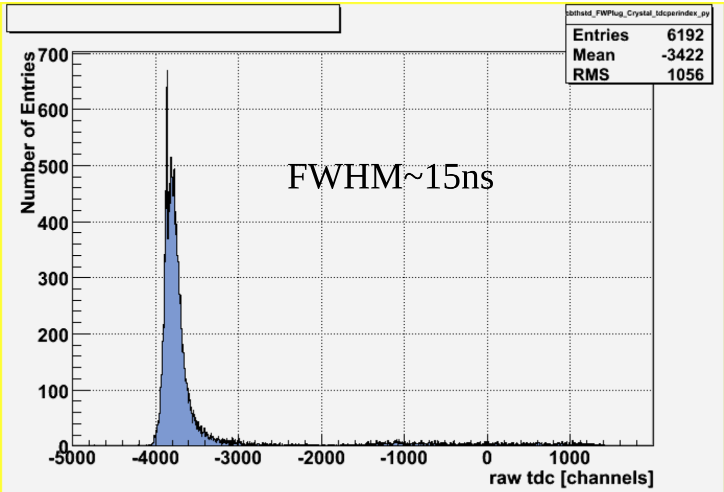
- First tests with beam



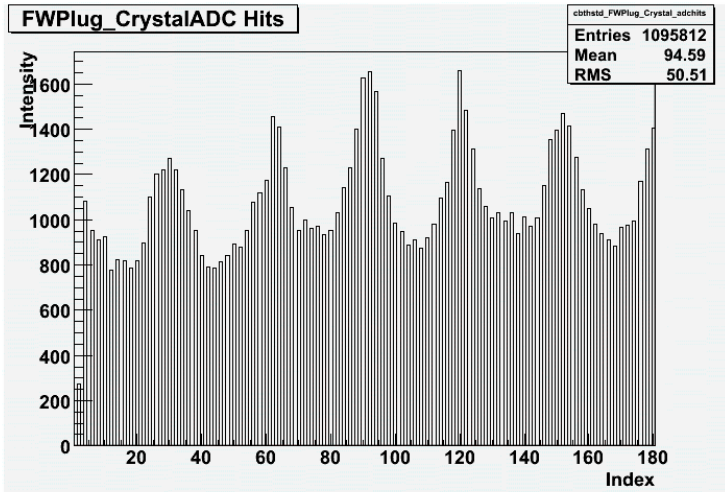
C. Funke

V. Sokhoyan , D. Bayadilov (HISKP, PNPI)

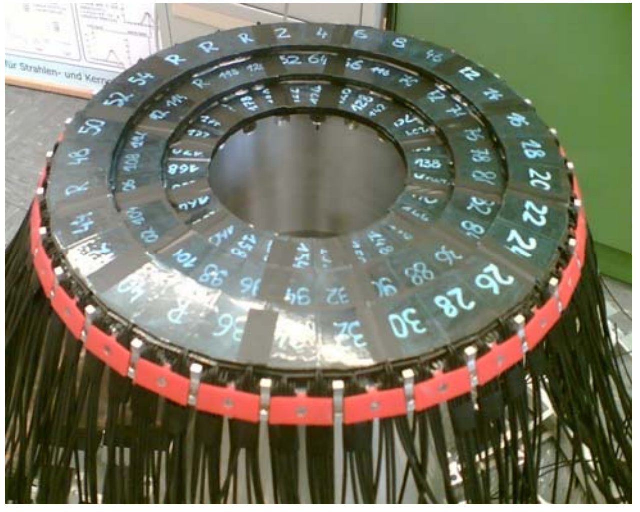
TDC-Spectrum



ADC-Spectrum

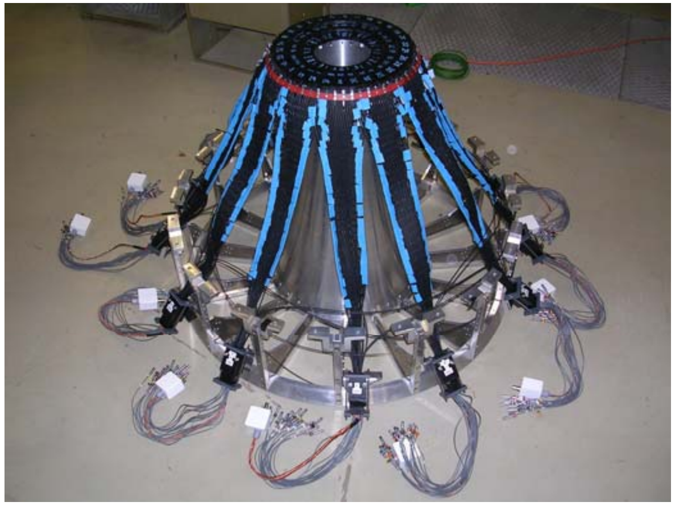


FWPlug: veto detectors

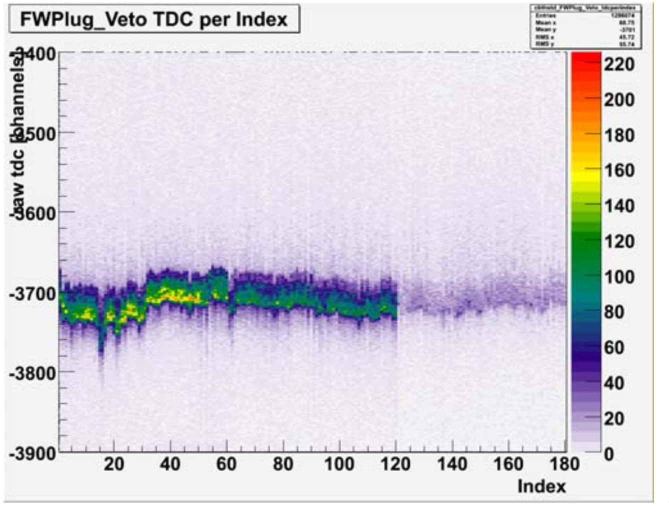


- Particle identification in FWPlug
- New frame and detectors installed
- First tests with beam

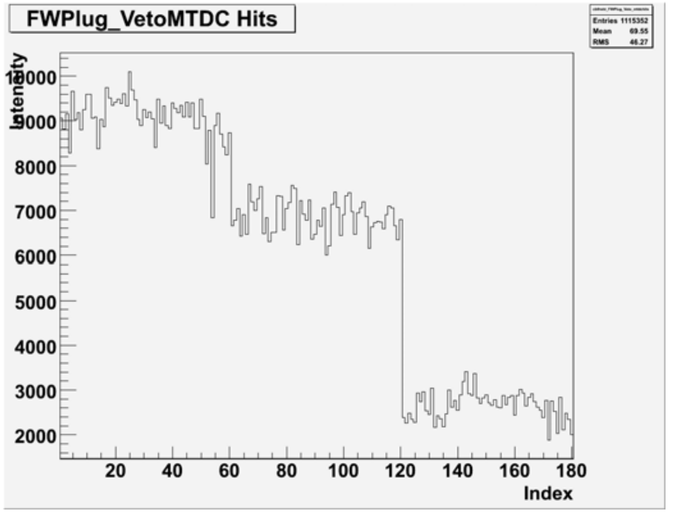
C. Wendel, Y. Beloglazov (PNPI+HISKP)



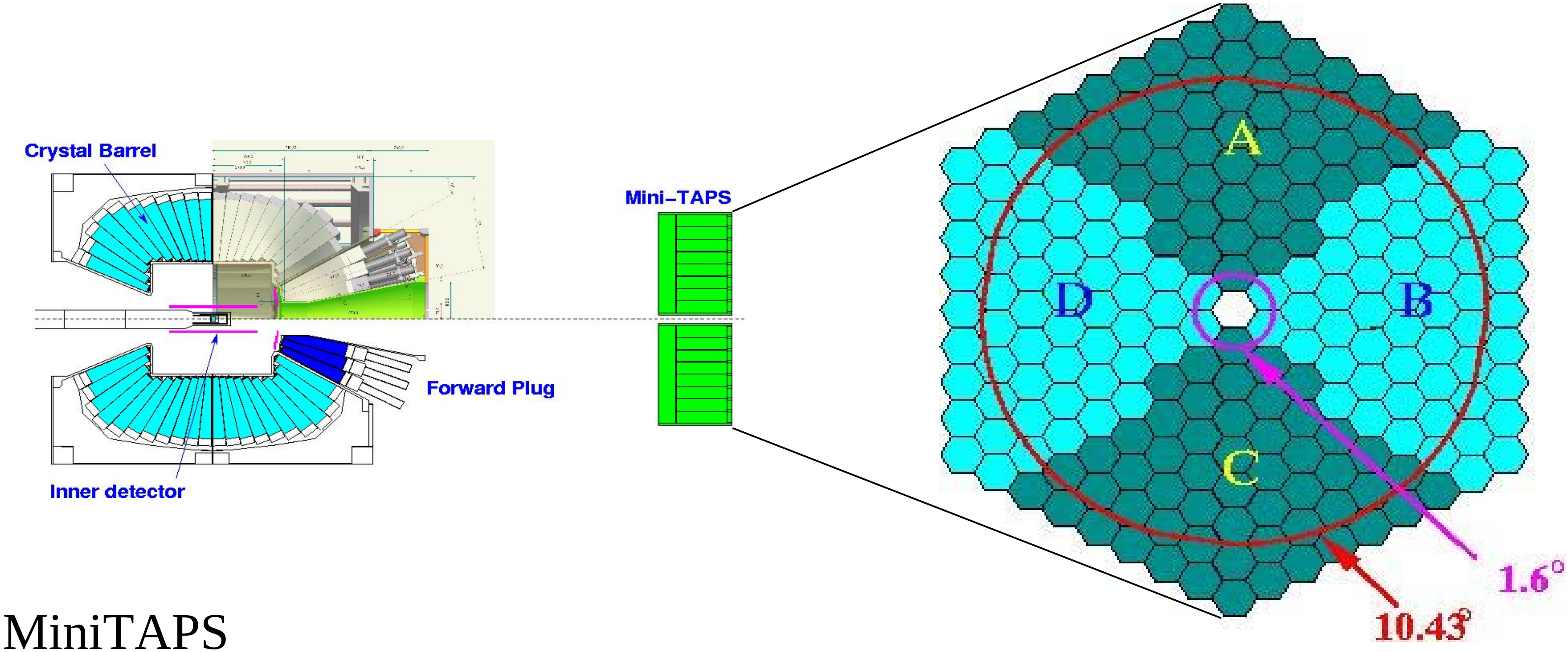
TDC-Spectra



Hit-Spectrum



MiniTAPS

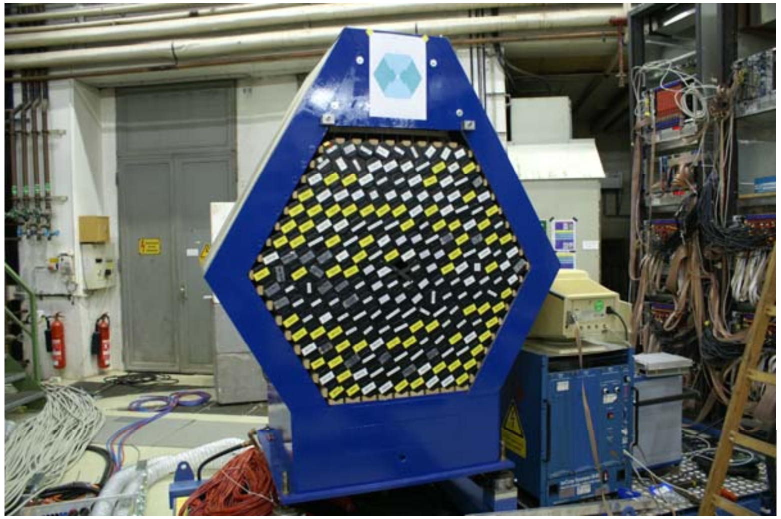


MiniTAPS

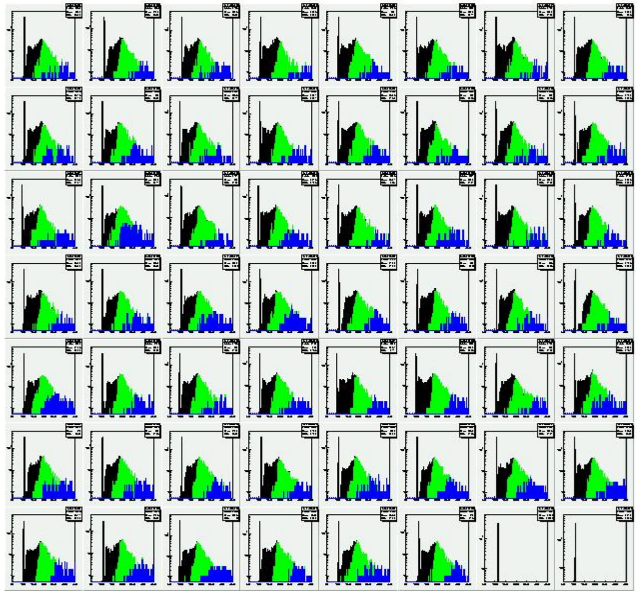
- consists of 216 modules
- covers solid angle between 1.6° and 10.43°
  $\Delta\theta \sim 3°$, $8° < \Delta\phi < 60°$

MiniTAPS

- 35 new BaF_2 detectors
- new readout electronics
- all BaF_2 detectors calibrated with cosmic muons
- the HV setting allows a dynamic range up to ~1.8 GeV photon energy
- calibration data collected for different LED-thresholds
- calibrated LED-thresholds at 40MeV [LED1] and 80 MeV [LED2]

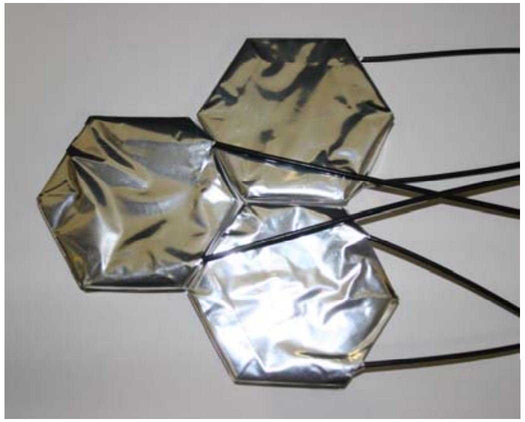


Threshold: ~9MeV (CFD)
Threshold: ~40 MeV (LED1)
Threshold: ~80 MeV (LED2)



P. Drexler
K. Makonyi

MiniTAPS Veto detectors



- readout on both sides
- fiber not glued
- polished end faces

-> factor 2 more light output

- new veto detector readout

- 8 channels per VME module
  (LED, ADC, TDC)

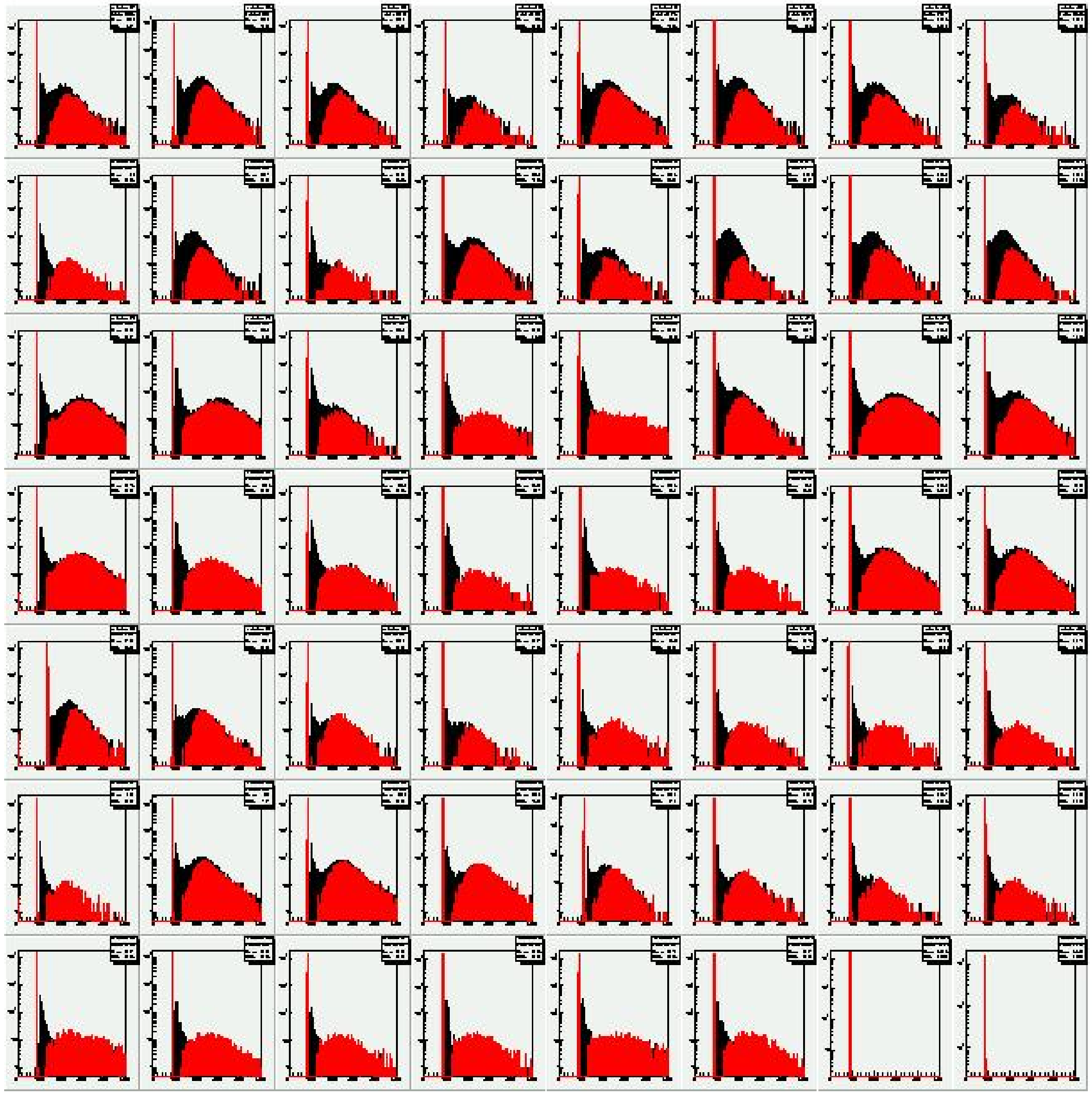
- similar to main BaF_2 – electronics

- stand alone readout working

P. Drexler

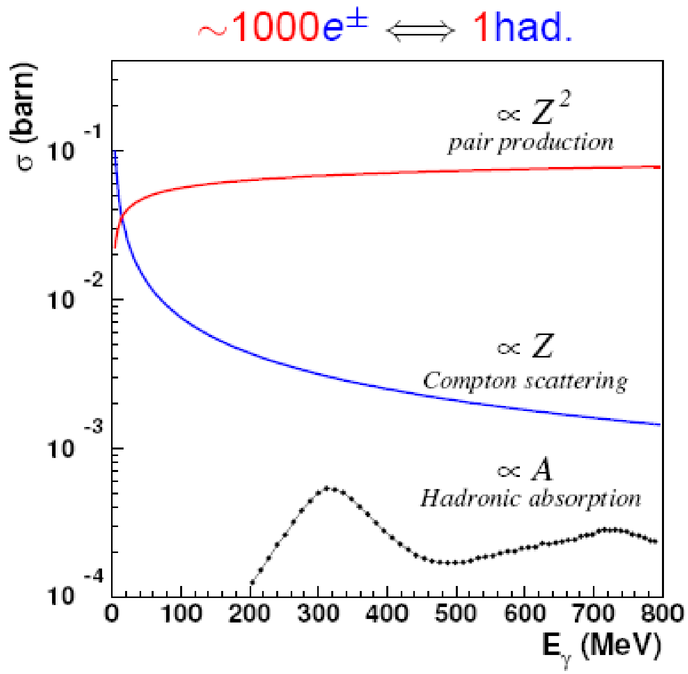
80 mV Threshold

240 mv Threshold



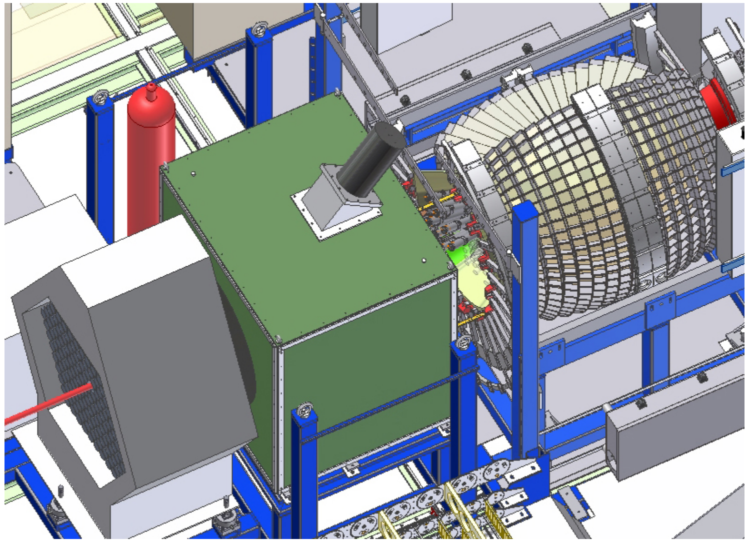
K. Makonyi

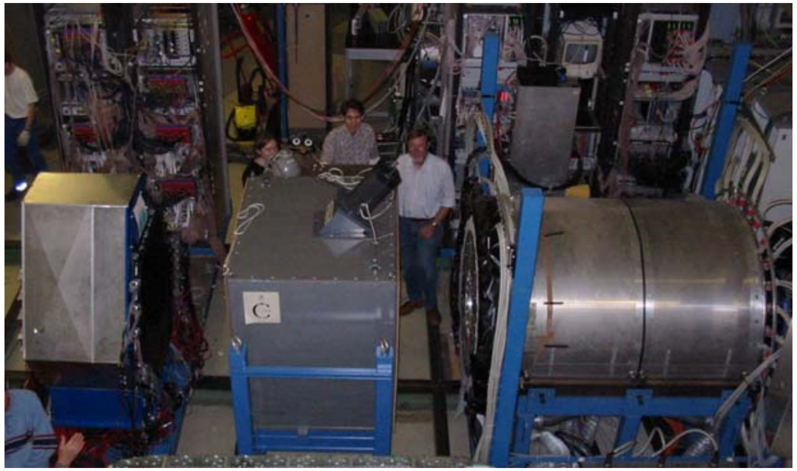
Gas Cerenkov Detector



Total cross sections on Hydrogen

- suppress electromagnetic background (for forward detector components)
- reduces first level trigger rate (trigger mainly on hadronic events)
- necessary modification done (Gent- and Pavia-group)
- first tests with beam



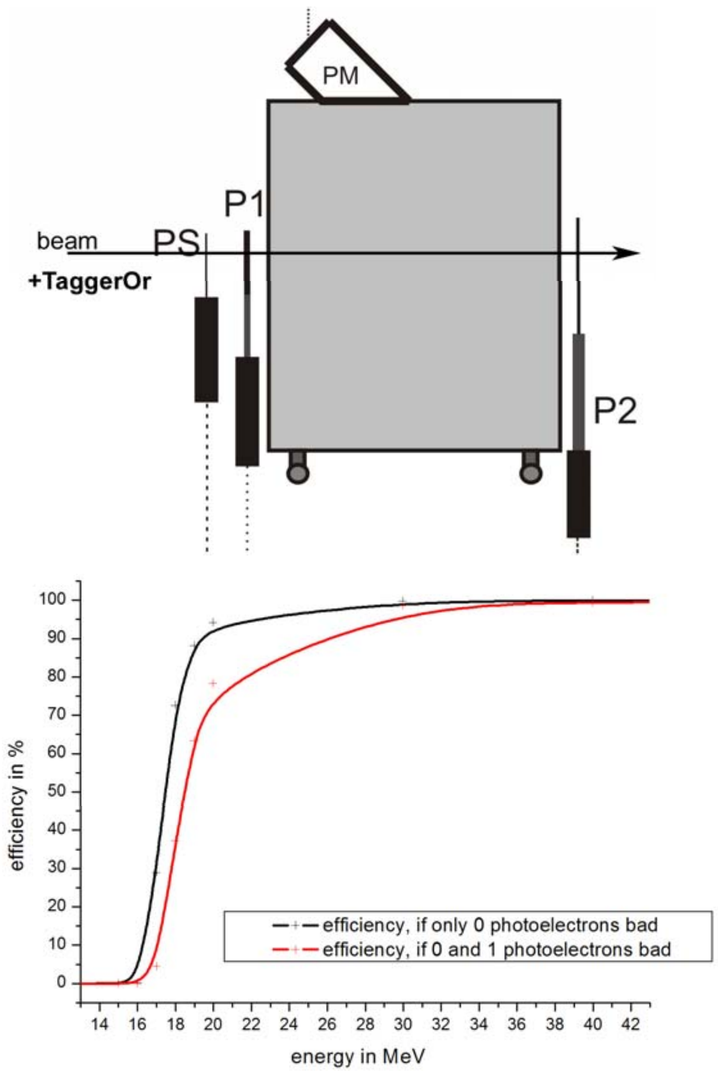


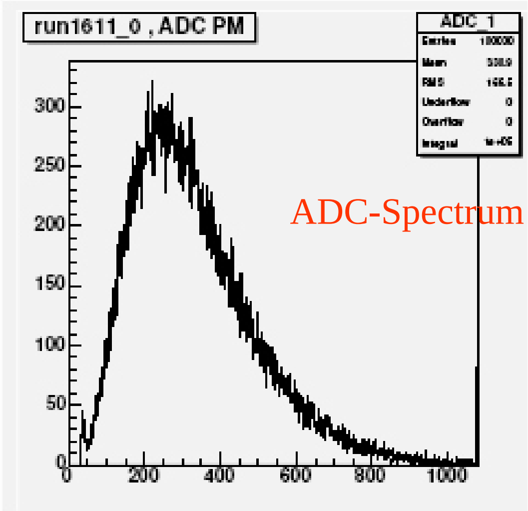
D. Kaiser

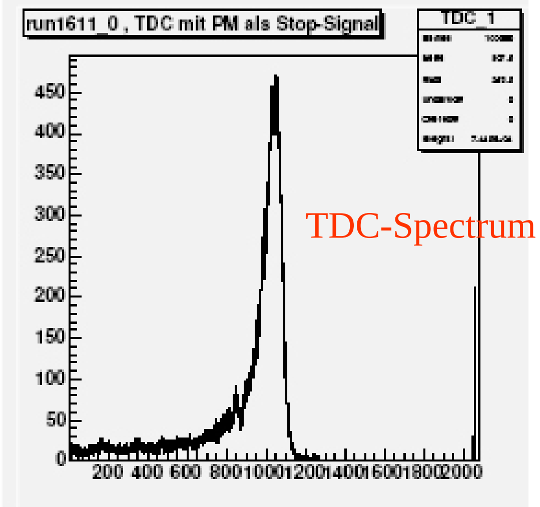
Gas Cerenkov Detector

First test beam time results: 99.7% efficiency

D. Kaiser







Trigger: P1+P2

Trigger, DAQ and Online/Offline

- Trigger: new FPGA based trigger modules build and tested
  - 1st and 2nd level trigger implemented
  - tests under experimental running conditions

A. Winnebeck

- Slow Control: control of HV, temperature, Crate power supplies, FACE discriminators, Goniometer, ….

A. Thiel

- Data acquisition system: New trigger control system implemented (optical TCS)
  - Readout of all major detector components working
  - in preparation: coupled readout mode CB with TAPS

P. Hoffmeister

- Online/Offline: Reconstruction code for all detector components implemented
  - online monitoring working
  - used already in the test beam times
  - absolute calibration prepared

Ch. Schmidt, A. Suele,
D. Piontek, J. Müller,
S. Boese, J. Junkersfeld

As important as hardware installation !
Advantage in analysis of new data !

Summary: New CB Set Up

- All major installations finished
- Electronics and readout of all detector components working
- Tests of all detector components with beam progressing

Last crucial steps :

- combined readout Crystal Barrel / TAPS
- second level trigger FACE (Bochum)
- tagging system
- polarized target

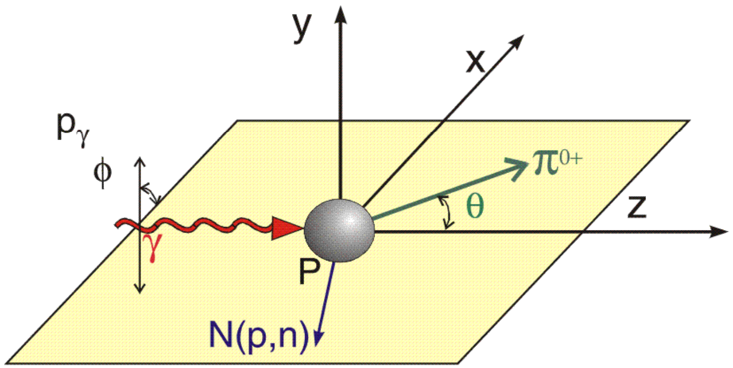
First round of double polarization experiments

$\vec{\gamma}\,\vec{p} \to p\,\pi^0$

Linearly polarized photons: p_γ^{Lin}

Circularly polarized photons: p_γ^{Cir}

Longitudionally polarized protons: p_z



$$\frac{d\sigma}{d\Omega}(\theta,\phi) = \frac{d\sigma}{d\Omega}(\theta)\left(1 - p_\gamma^{Lin}\Sigma \cdot \cos(2\phi) - p_\gamma^{Lin} p_z G \cdot \sin(2\phi) + p_\gamma^{Cir} p_z E\right)$$

G-measurement : linearly pol. photons and long. pol. Target

1.) Coherent peak at 600 MeV, $\vec{\gamma}\,\vec{p} \to p\,\pi^0$
interference between P33(1232) and P11(1440)

2.) Coherent peak at 1100 MeV, $\vec{\gamma}\,\vec{p} \to p\,\pi^0$ and $\vec{\gamma}\,\vec{p} \to p\,\eta$
interference between P13(1720) , P11(1710) and D13(1520)

3.) Coherent peak at 1700 MeV, $\vec{\gamma}\,\vec{p} \to p\,\pi^0$ and $\vec{\gamma}\,\vec{p} \to p\,\eta$
interference between P13(1720) , P11(1710) and D15(2070)

Observable G in pion-photoproduction

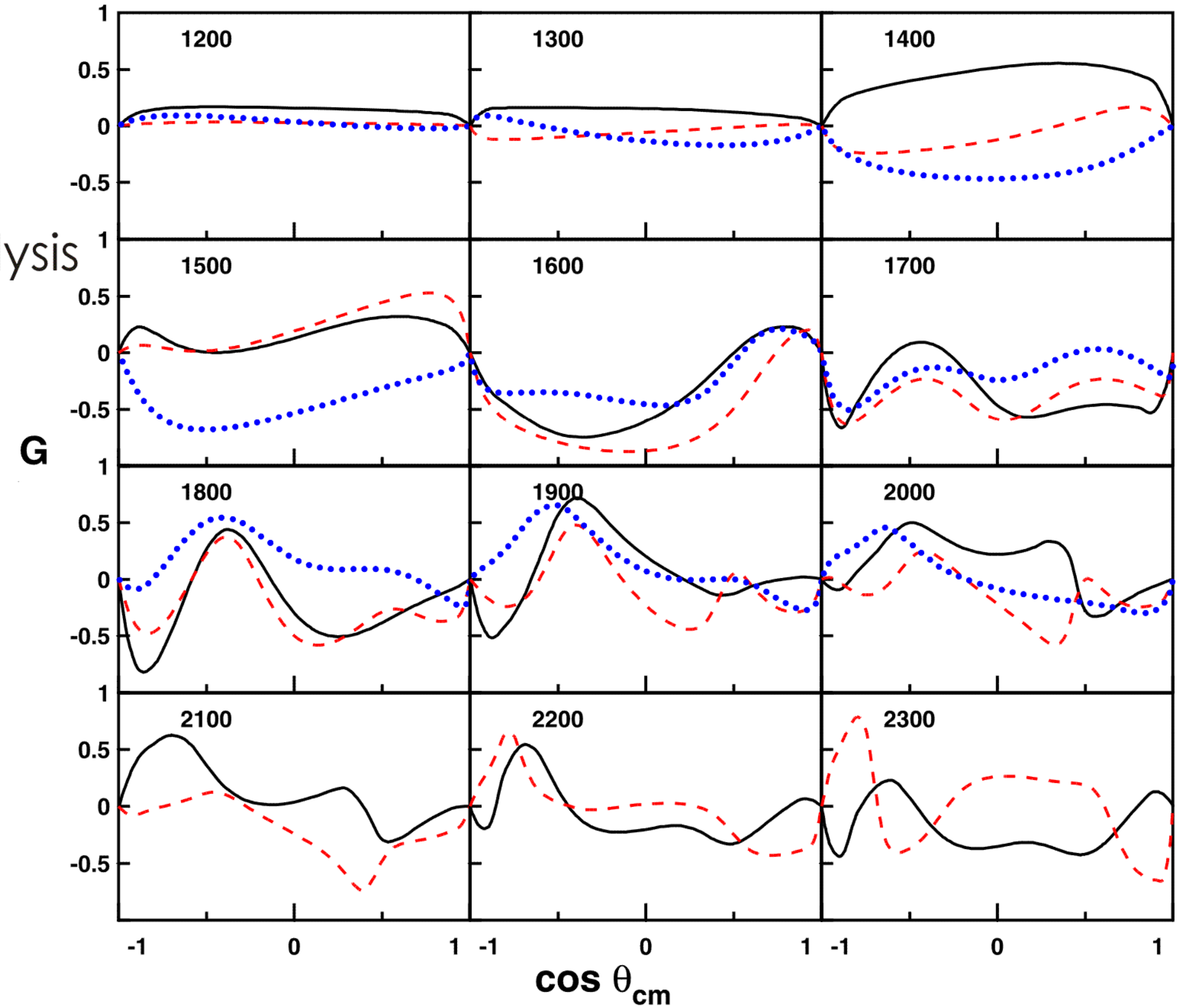
$\vec{\gamma}\ \vec{p} \rightarrow p\ \pi^0$

Partial wave analysis

MAID

SAID

BONN

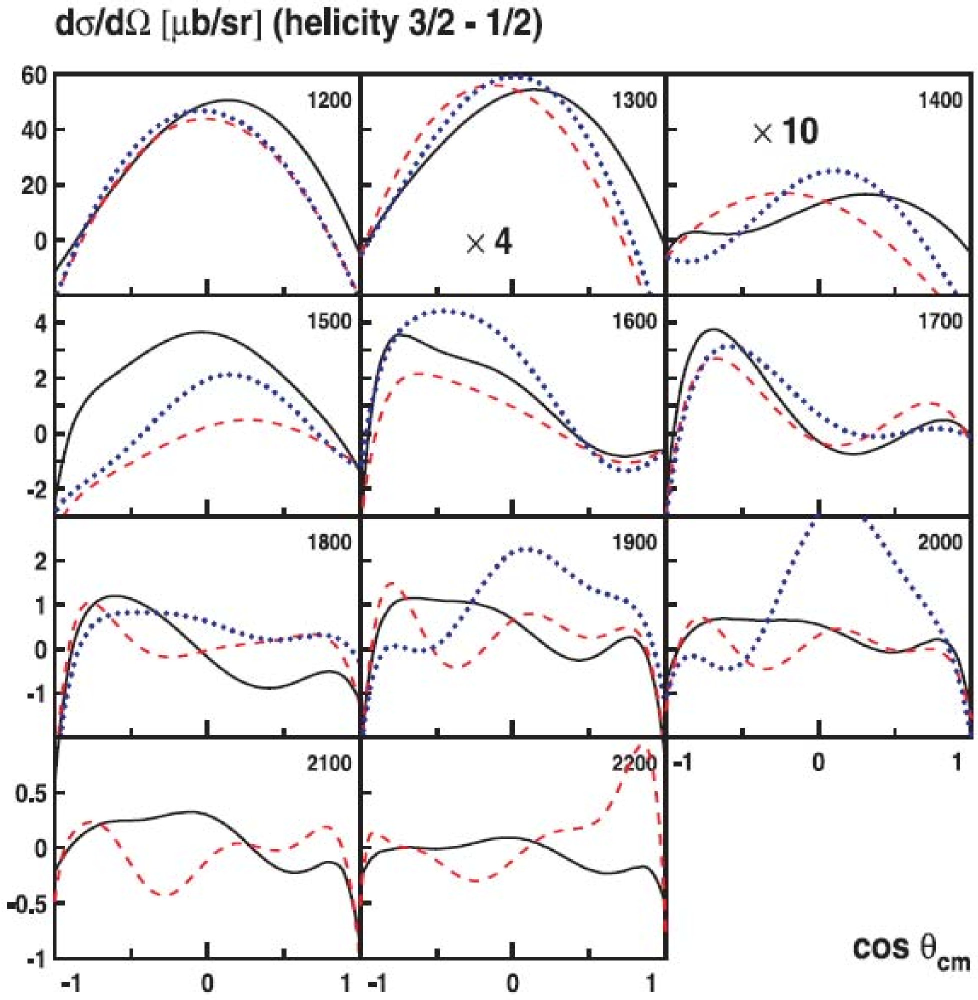


Observable E in pion-photoproduction

SAID/MAID/BONN

$$\frac{d\sigma_{(3/2-1/2)}}{d\Omega} = \frac{d\sigma_{3/2}}{d\Omega} - \frac{d\sigma_{1/2}}{d\Omega}$$

$$\frac{d\sigma_{tot}}{d\Omega} = \frac{1}{2}\left(\frac{d\sigma_{3/2}}{d\Omega} + \frac{d\sigma_{1/2}}{d\Omega}\right)$$



16 Polarization Observables in Meson Photoproduction

Photon		Target			Recoil			Target-Recoil			
					x'	y'	z'	x'	x'	z'	z'
		x	y	z				x	z	x	z
unpolarized	σ	0	T	0	0	P	0	$T_{x'}$	$-L_{x'}$	$T_{z'}$	$L_{z'}$
linearly polarized	$-\Sigma$	H	$(-P)$	$-G$	$O_{x'}$	$(-T)$	$O_{z'}$	$(-L_{z'})$	$(T_{z'})$	$(-L_{x'})$	$(-T_{x'})$
circularly polarized	0	F	0	$-E$	$-C_{x'}$	0	$-C_{z'}$	0	0	0	0

good experimental results only for :

differential cross section σ

beam asymmetry Σ

double pol. Observable E

Sensitive to the real part

$\Re e(P_1 P_2)$

new data important for :

target asymmetry T

recoil polarization P

double pol. Observable G

Sensitive to the imaginary part

$\Im m(P_1 P_2)$

transversal polarized target important

Complete experiment

- see talk A. Donnachie: 8 observable necessary for unique solution
  4 single and 4 double polarization observables

- Crystal Barrel with long. and trans. polarized target: 8 observables

  single polarization observables: σ, Σ, P, T
  double polarization observables: E, G, H, F

- additional constraints:

  1.) coupled channel analysis
  2.) energy dependence
  3.) angular momentum (l<10)

- example Δ(1232)-resonance:

  - two observable (σ, Σ) sufficient for "complete experiment"

  assumptions: only s- and p- waves fitted, higher partial waves in Born approximation, Watson Theorem

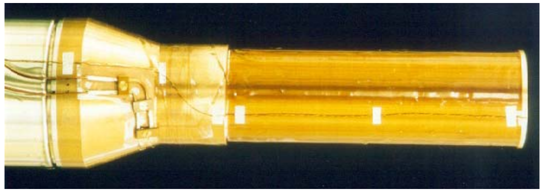
  without Watson Theorem: four observable (σ, Σ, P, T) sufficient for "complete experiment"

Future Plans

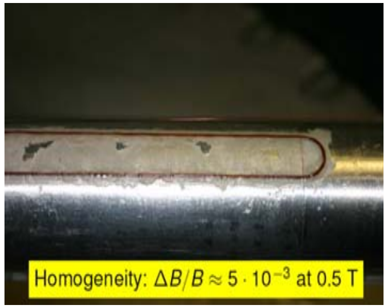
1.) Transverse polarized target , absolute necessary

- "complete experiment" <-> unique solution
- poor information on target asymmetry T even for single pion- and eta- photoproduction

-> new holding coil for transverse magnetic holding field



longitudinal polarization –> solonoid



transversal polarization –> race track coils

2.) Extension of trigger capabilities of the CB and faster readout

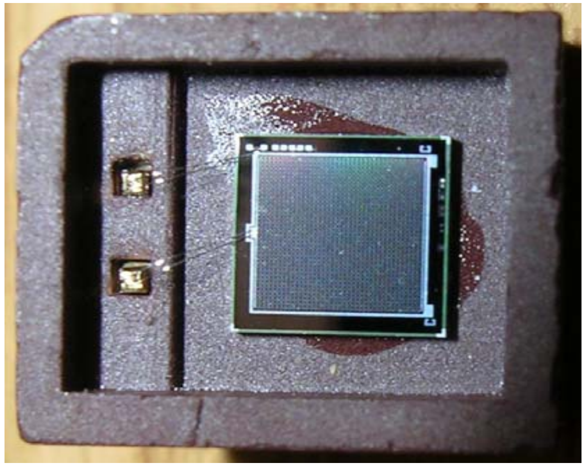
- at the moment: no timing information from Crystal Barrel, only second level trigger (FACE)

-> first success full tests done:
- Silicon Photomultipliers (Bonn)
- Avalanche Photodiodes (Giessen)

Future Plans

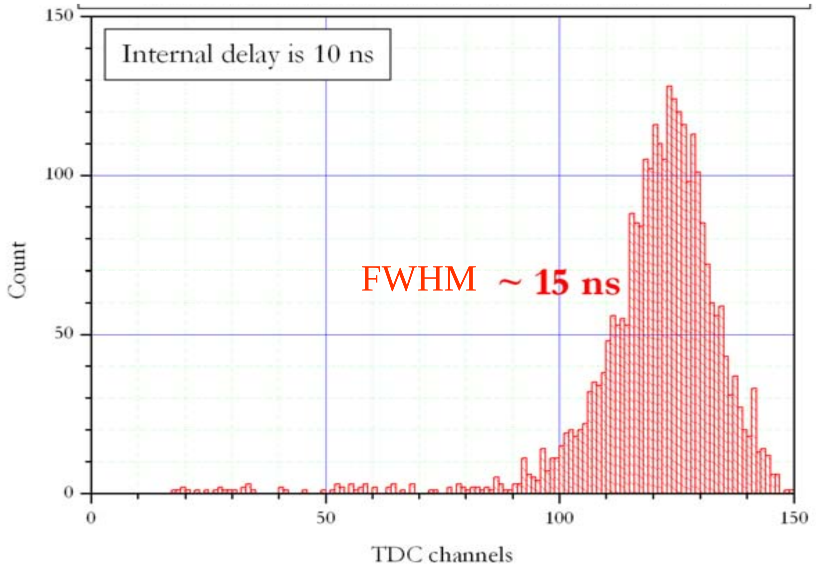
• Silicon Photomultiplier :

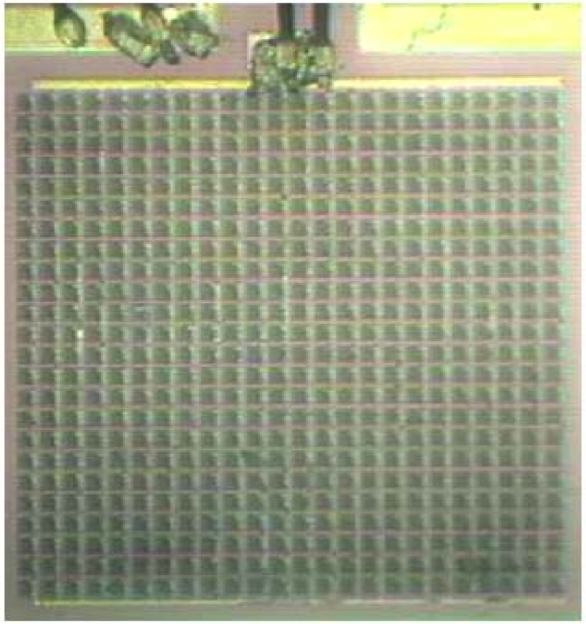
- Consists of many photodiodes
- Size 3x3mm^2 , 5625 pixels , pixel (30x30mm^2)
- Each pixel operates in Geiger mode
- Gain factor 10^6



M. Gottschall , D. Bayadilov (HISKP, PNPI)

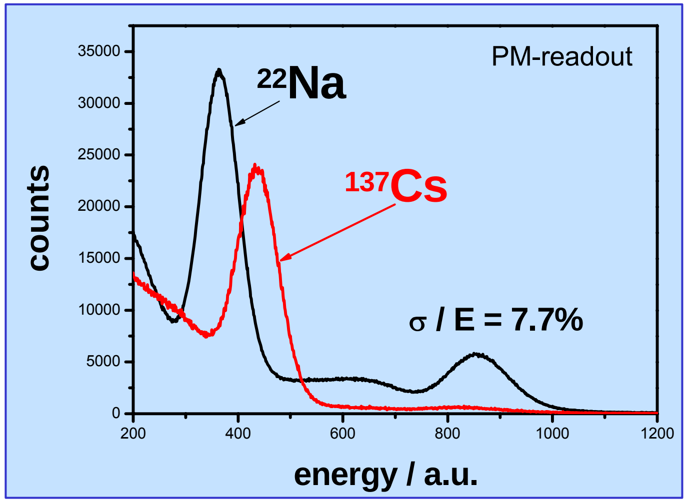
TDC-Spectrum





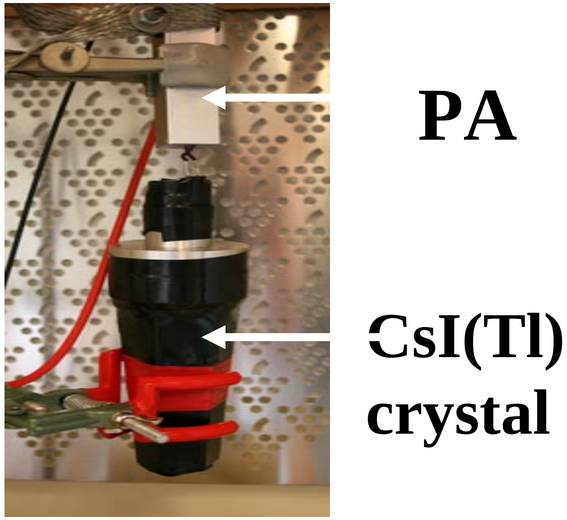
Future Plans

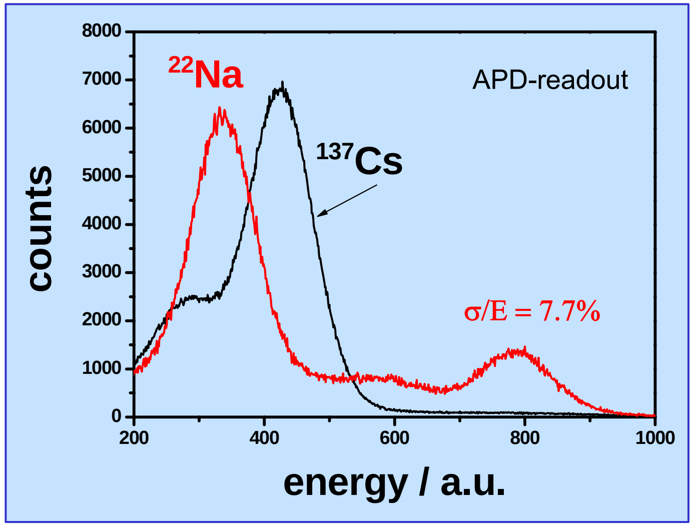
- Large Area Avalanche Photo-Diodes (LAAPD)
  - Size 5x5mm^2
  - Temperature sensitive



R. Novotny (Giessen)

test set-up:





Future Plans

3.) New tracking device inside the Crystal Barrel:

- Isospin separation
  channels with neutrals and charged particles
  $\gamma\, p \rightarrow n\, \pi^+\, \pi^0$

- Strangeness production
  $K^0 \rightarrow \pi^+\, \pi^-$, second vertex trigger possibility

- Dalitz decay $\eta' \rightarrow e^+\, e^-\, \gamma$ form factor

-> possible directions:

- two cylindrical silicon strip detectors,
  three silicon pad discs in forward directions close to target

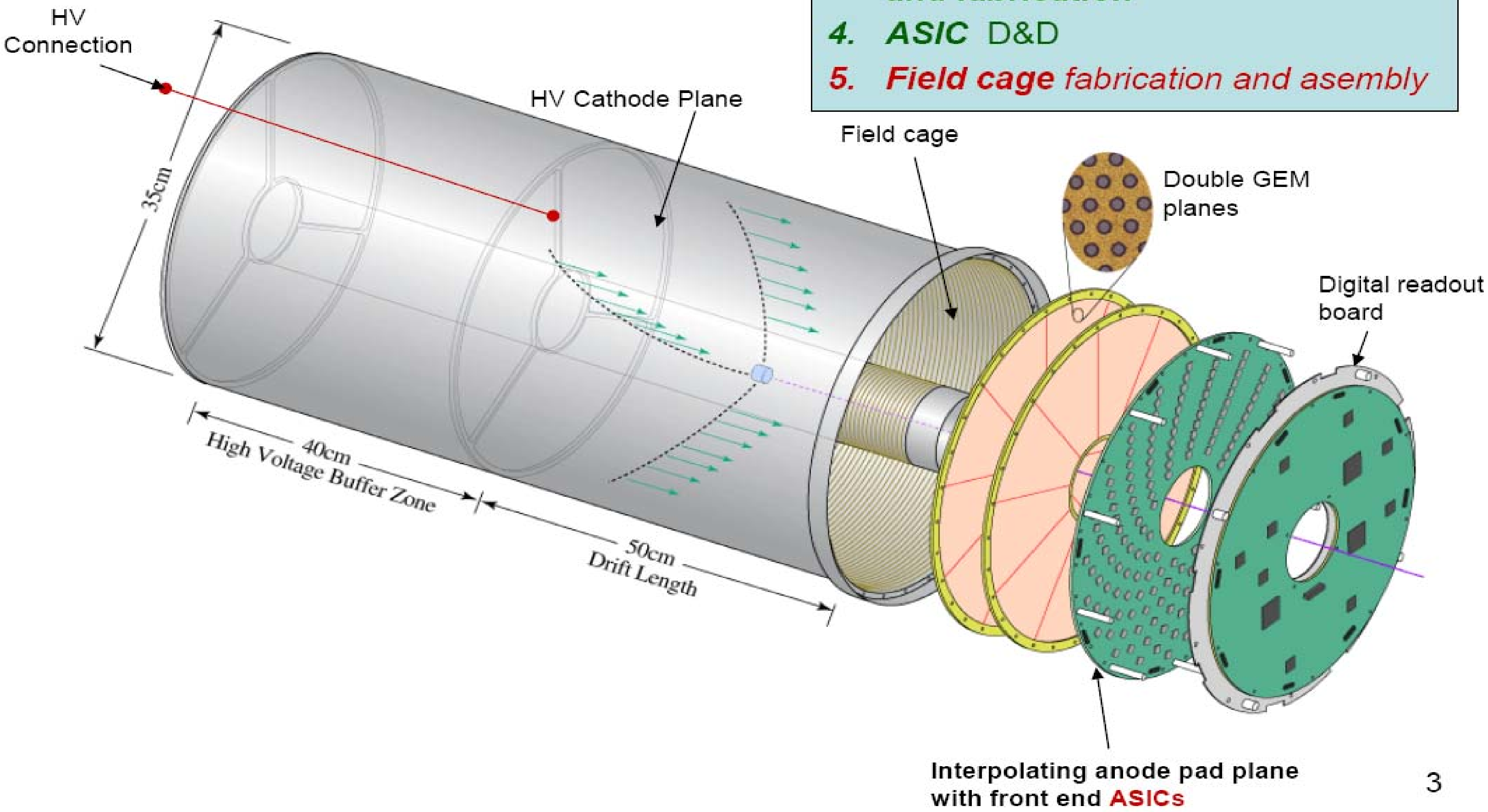
- first tests with existing old CB-strip detector beginning next year

- existing LEGS TPC ??

LEGS TPC

TPC Critical Technologies:

1. ***GEM*** *vs MWPC*
2. *Anode pad configuration -* ***chevron***
3. ***Anode pad – ASIC board topology and fabrication***
4. ***ASIC*** D&D
5. ***Field cage*** *fabrication and asembly*



Man power and finance issues

SFB-TR16 Personalmittel :	2006	2007
Bonn : 2 ∗ 0.75 BAT IIa	3 PhD-students: C. Funke, E. Gutz, C. Wendel	3 PhD-students C. Funke, E. Gutz, C. Wendel
Giessen : 1 ∗ BAT IIa, 1∗ 0.5 BAT IIa	1 PhD-students : K. Makonyi 1 Postdoc : H. van Pee	3 PhD-students R. Gregor, K. Makonyi, F. Hjelm

SFB-TR16 Sachmittel :	2006	2007
Bonn :	41.500,- Euro: VMIC's CPU CB-Trigger active analog-delay	29.000,- Euro: CB-Trigger
Giessen :	41.500,- Euro: CB-Trigger 27.200,- Euro: 5 TAPS crystals 21.760,- Euro: TAPS Veto-electronics	29.000,- Euro: CB-Trigger

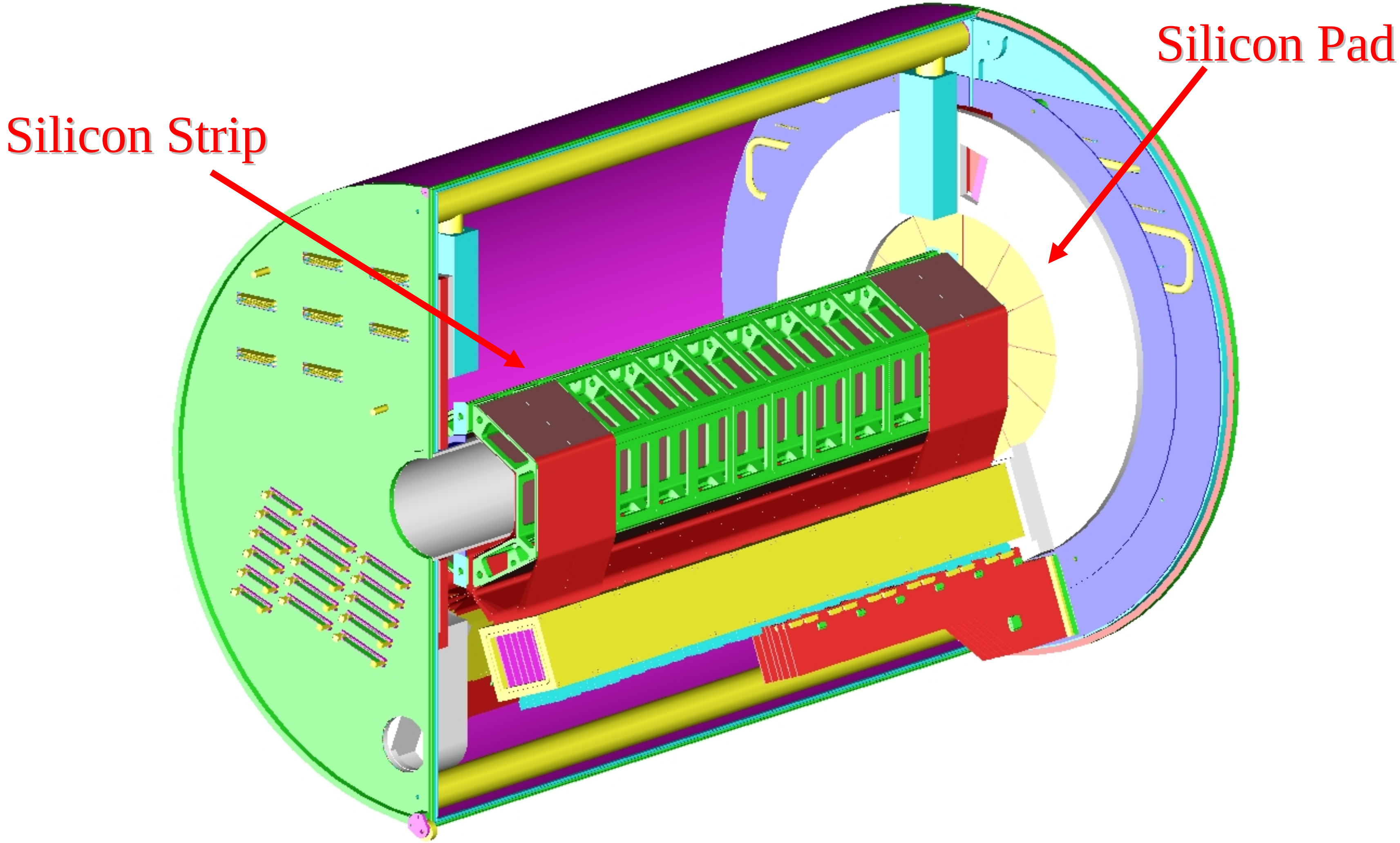
Thank you

Diploma – students: M. Gottschall, D. Kaiser, J. Müller, D. Piontek, A. Winnebeck,

PhD – students: S. Boese, C. Funke, M. Grüner, E. Gutz, P. Hoffmeister, K. Makonyi
V. Sokhoyan, A. Thiel, C. Wendel

Ersatzfolien

Multiplicity/Vertex Detector



	Refractive index n	Threshold energy $e^{\pm}$ (MeV)	Threshold energy π (GeV)
Air	1.0003	21.9	6.0
N_2	1.0003	20.4	5.7
CO_2	1.0004	17.9	4.9
C_4F_{10}	1.0014	9.7	2.6
C_4F_8	1.0013	10.0	2.7
Aerogel	1.0040	5.7	1.565
	M 1.0130	3.2	0.87
	M 1.0150	3.0	0.81
	B 1.0500	1.7	0.46
	1.2400	0.9	0.24

TABLE: UV transparent radiators.

LAAPS provide energy and time information

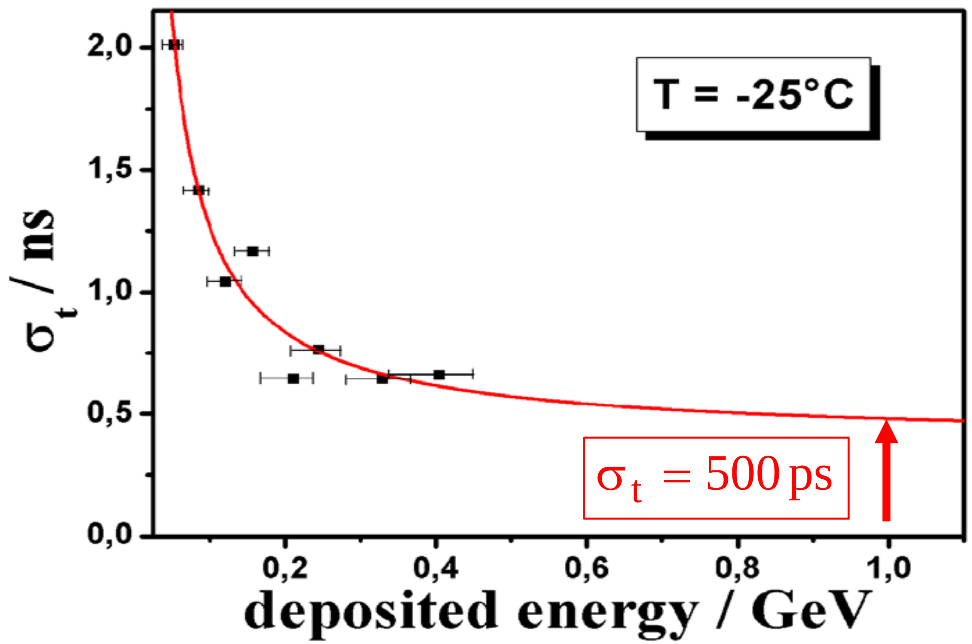
In case of CsI(Tl)

achievable time resolution
only limited by the
response of CsI(Tl) !

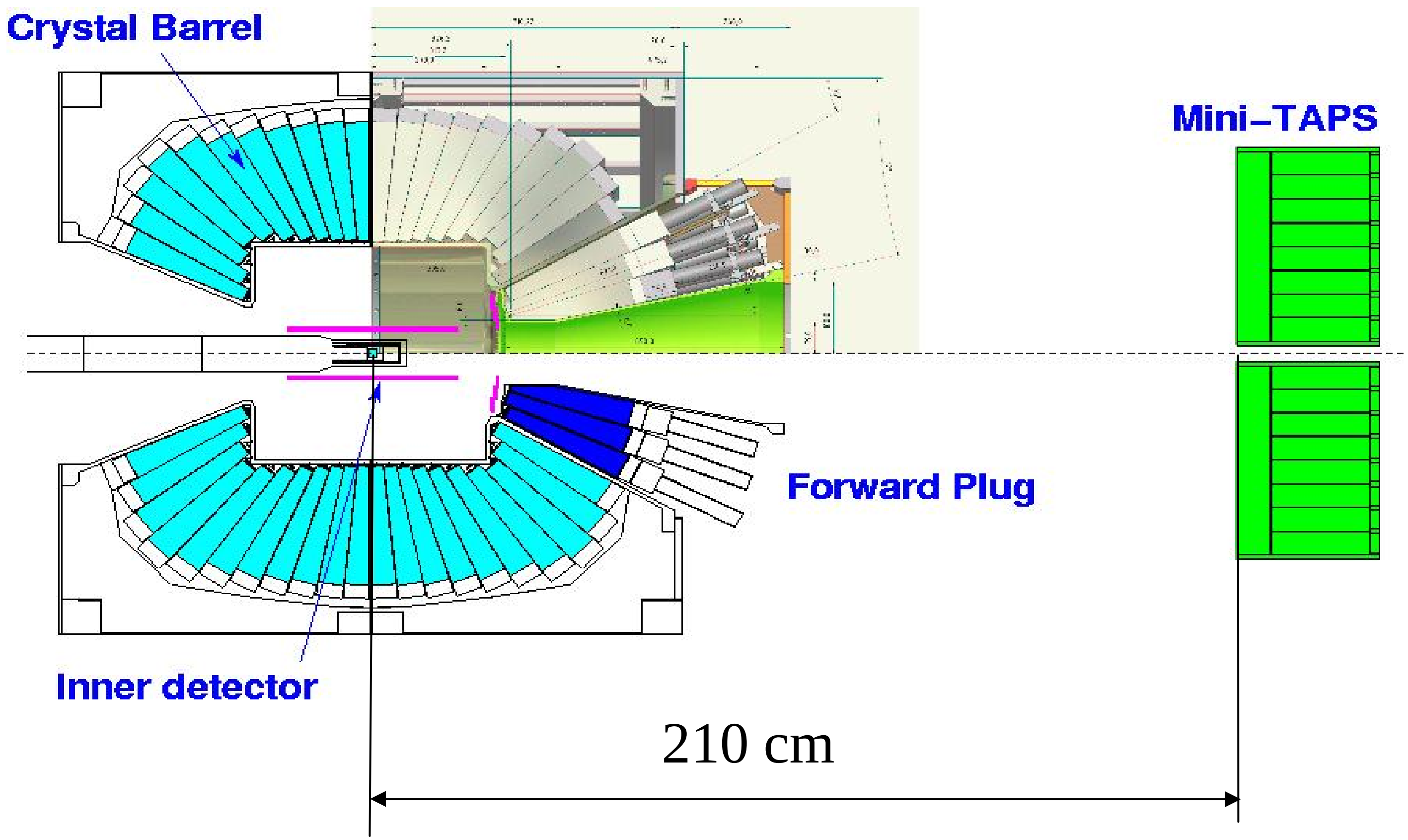
in case of fast scintillators,
such as $PbWO_4$,
time resolution < 1ns possible:

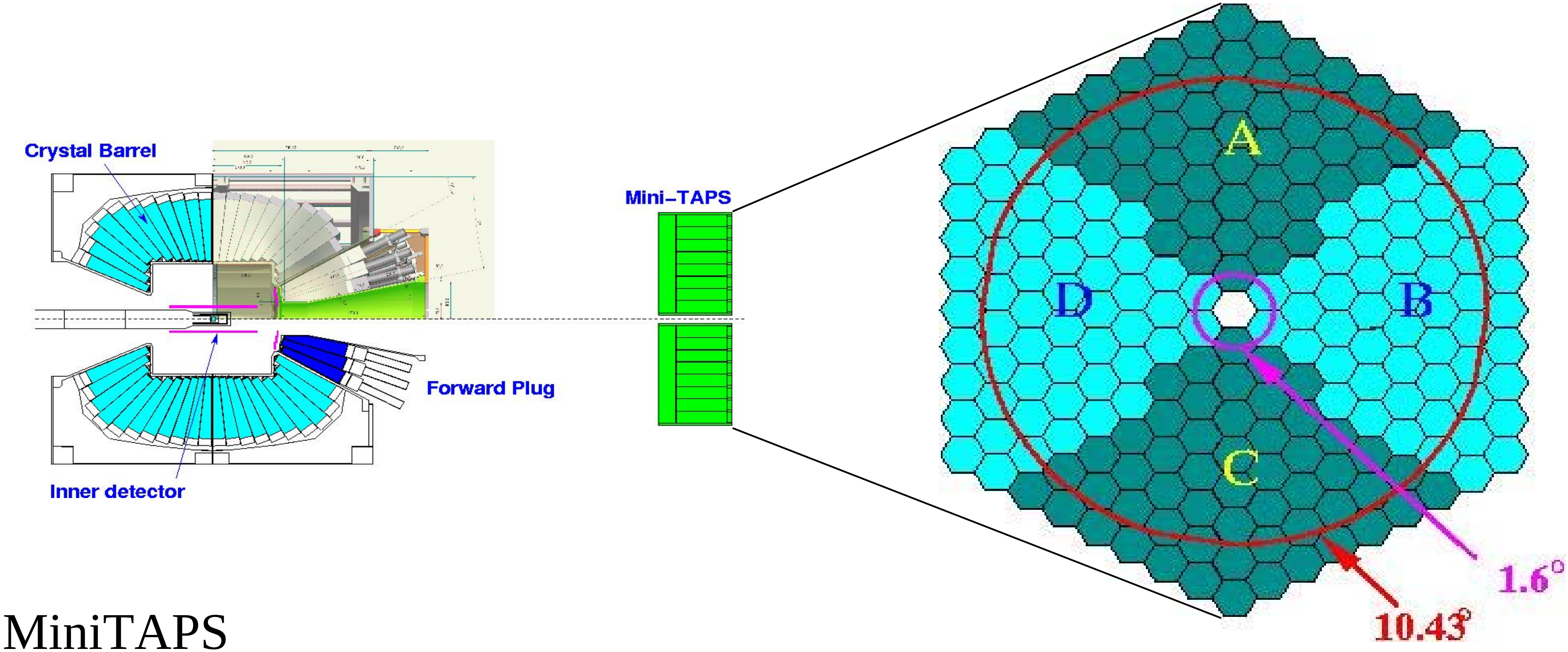
time resolution

central module versus *tagger*



TAPS set-up


Crystal Barrel
Mini–TAPS
Forward Plug
Inner detector
210 cm



MiniTAPS
- consists of 216 modules
- covers solid angle between 1.6° and 10.43°
  $\Delta\theta \sim 3°$, $8° < \Delta\phi < 60°$

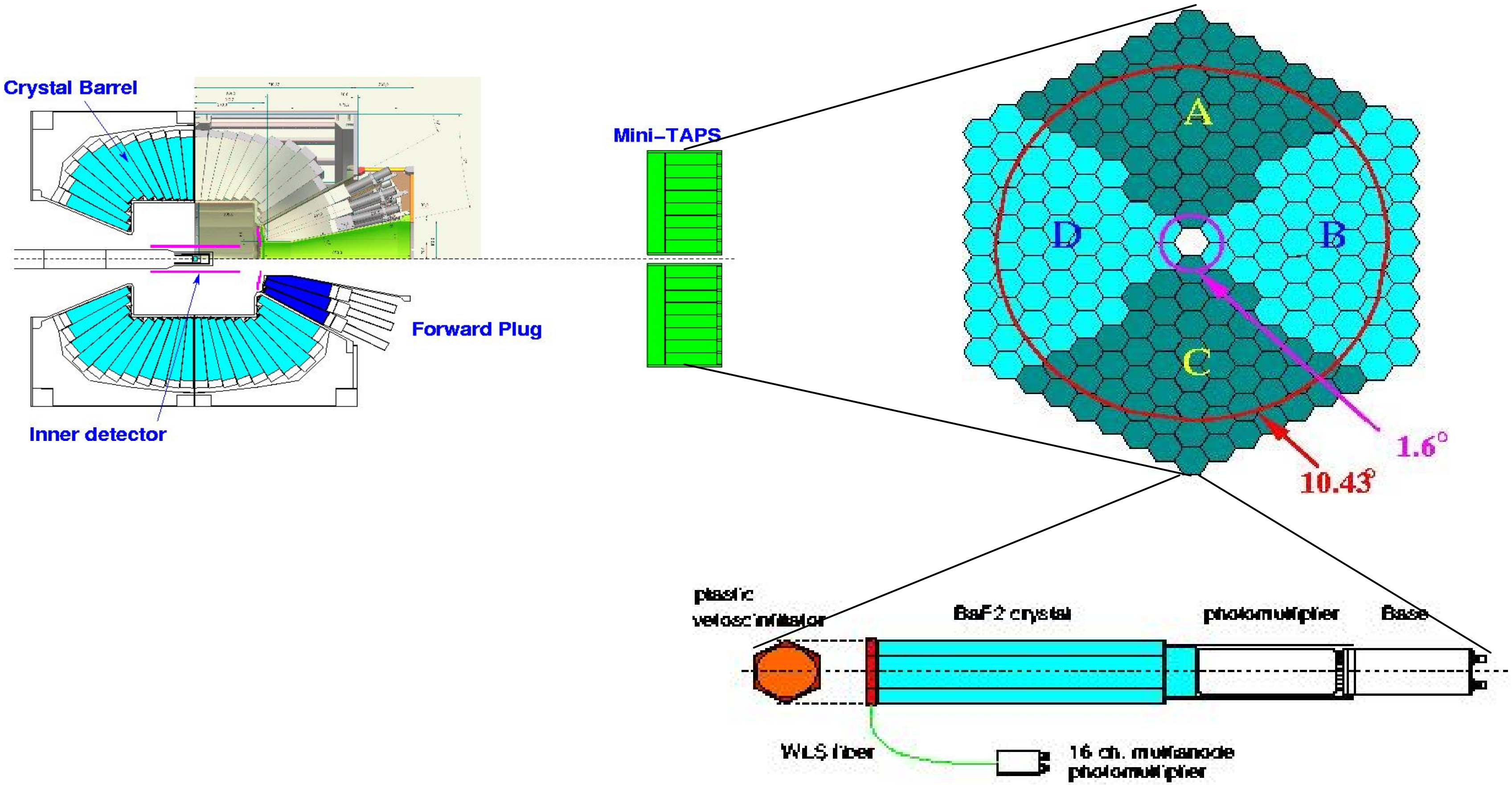
each telescope consists of:

BaF_2-crystal

$12\ X_o$, $\sigma/E \sim 2.5\%$ @ 1GeV

plastic scintillator veto

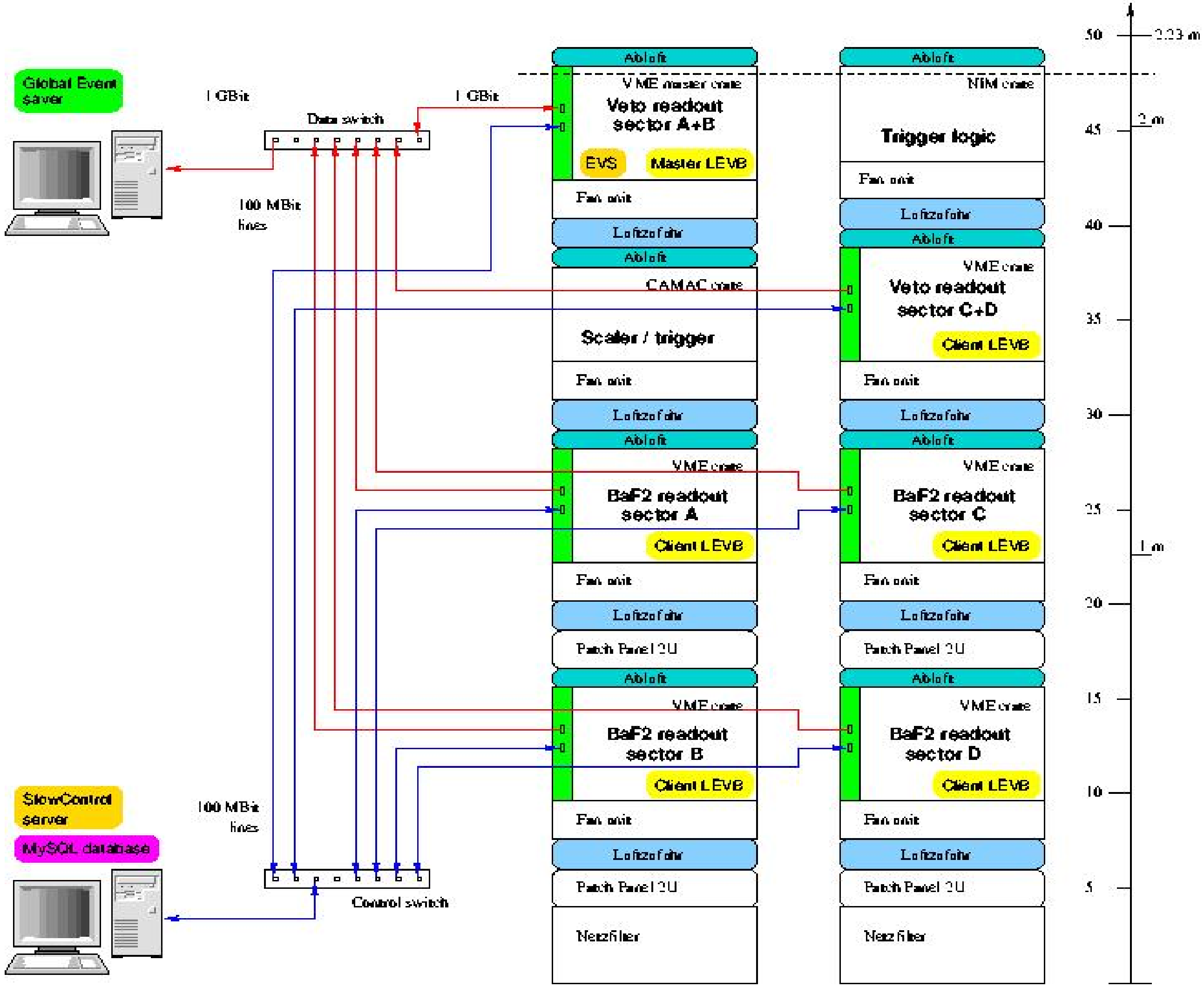
5mm thick



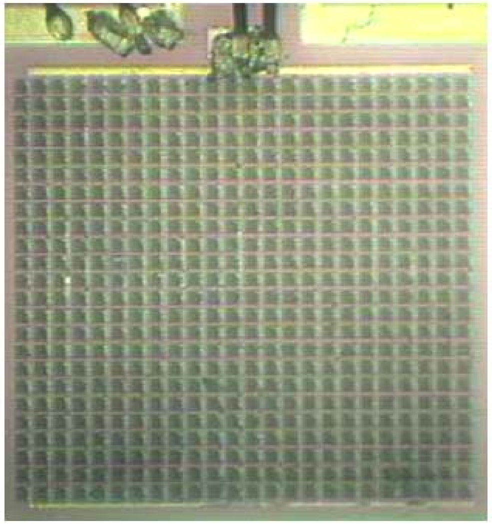
TAPS readout electronics

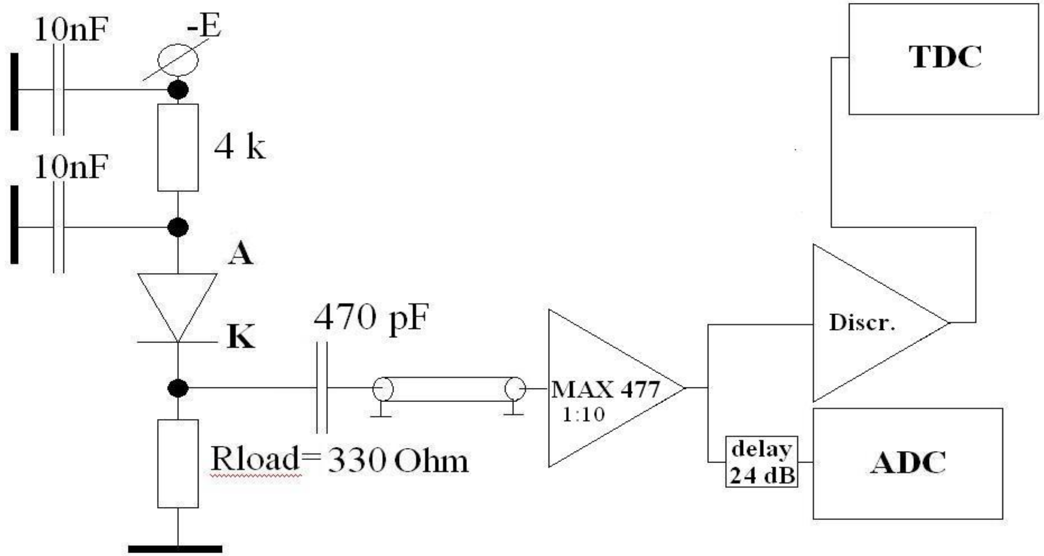
collected data sent via ethernet to the global event-server

Slowcontrol handles the actual setups by MySQL database



SiPM is a matrix of APD



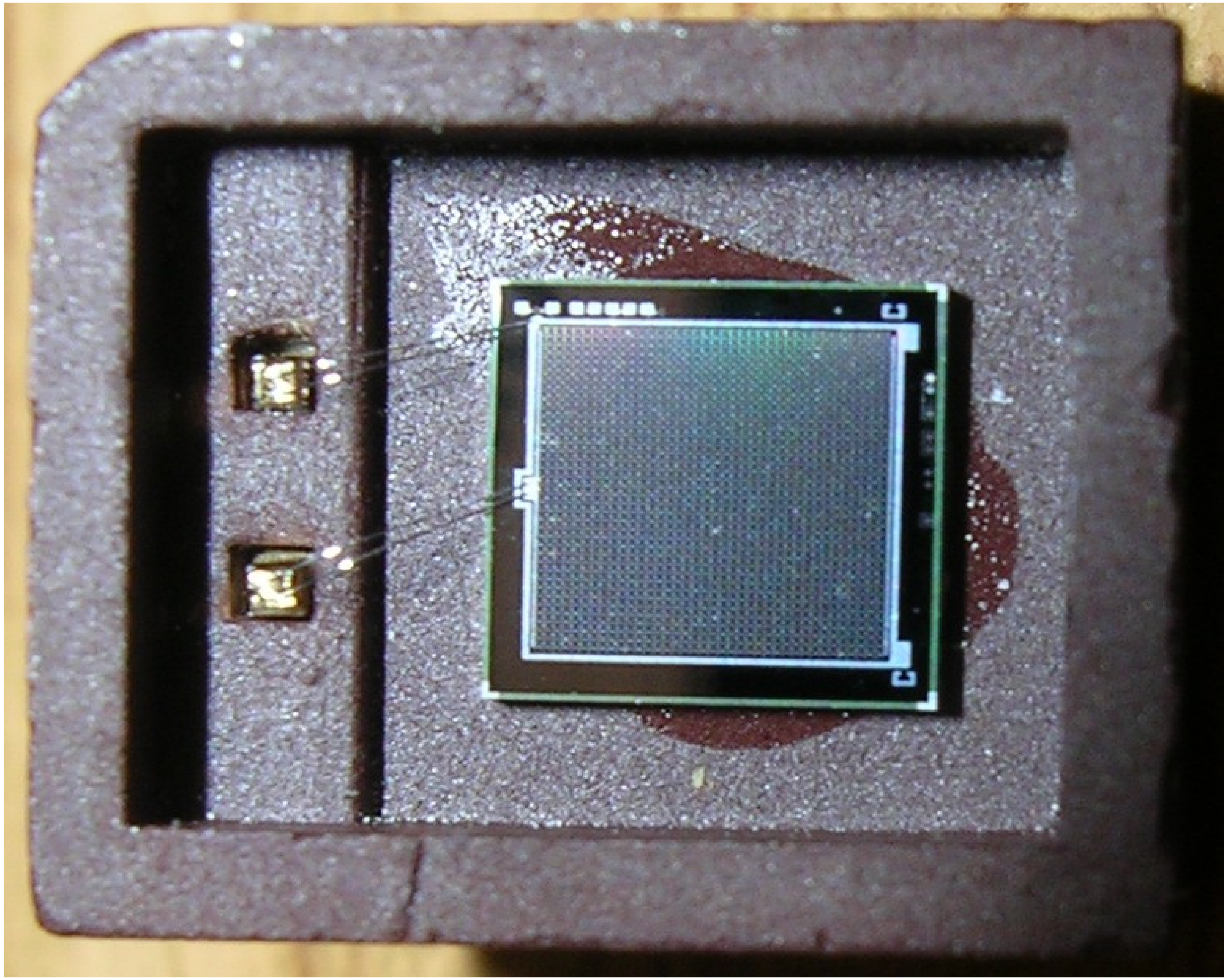


For each SiPM was used a power supply but with common R_{load}.

Supply voltage is about 27 V.

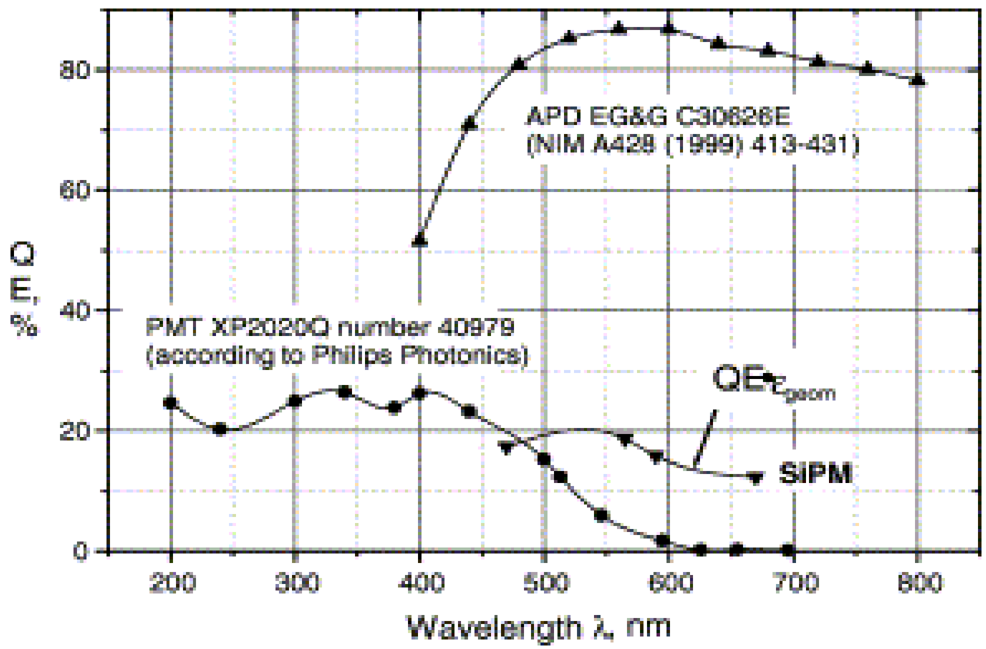
View of 3×3mm² SiPM

PULSAR enterprise



Characteristics

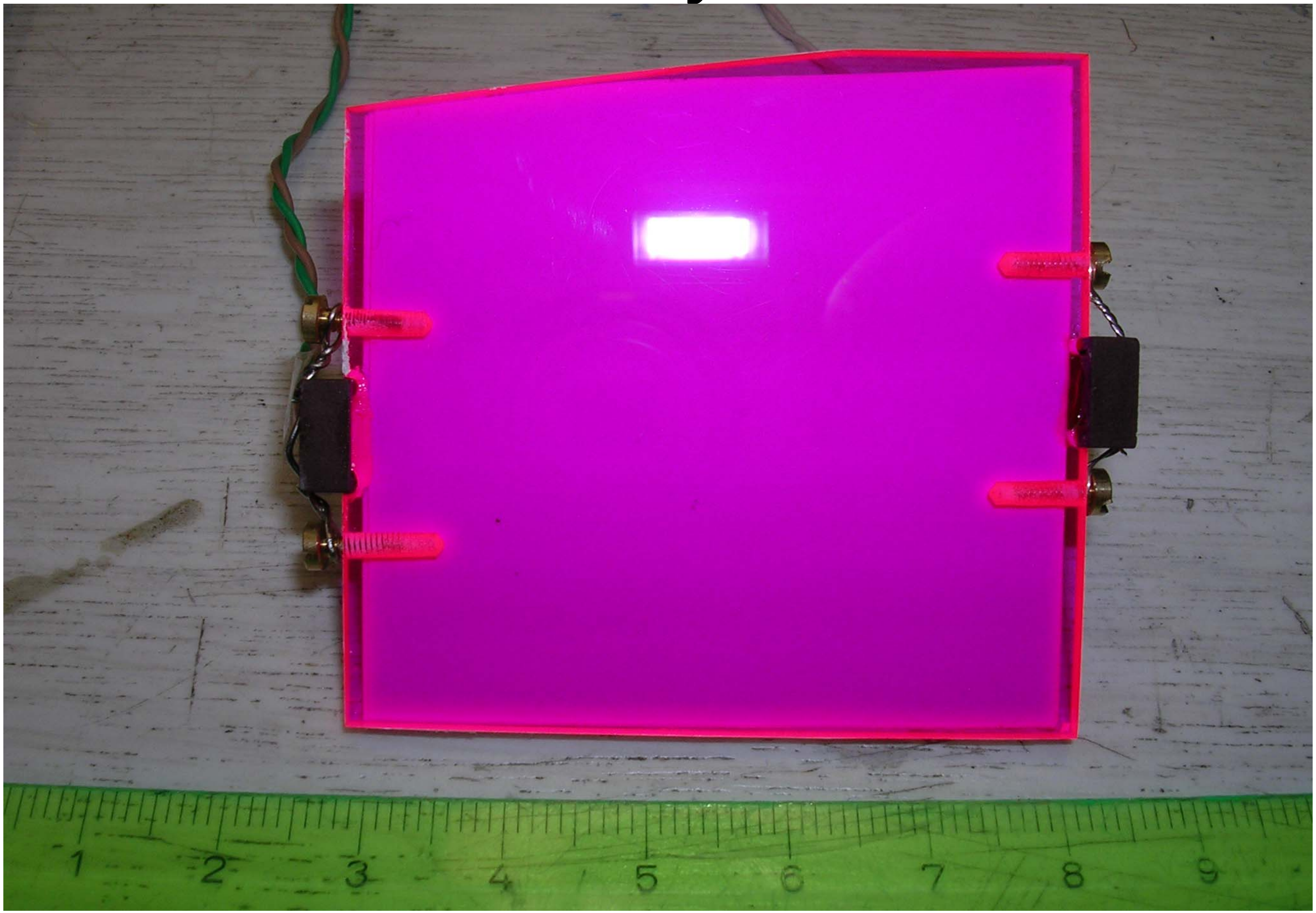
- ➔ Strong electric field (2-3) 10^5 V/cm
- ➔ Very short Geiger discharge development < 500 ps
- ➔ Pixel recovery time = (C_{pixel} R_{pixel}) ~ 20 ns
- ➔ Radiation stability like an usual semiconductor
- ➔ Exploitation period till now is 3 years



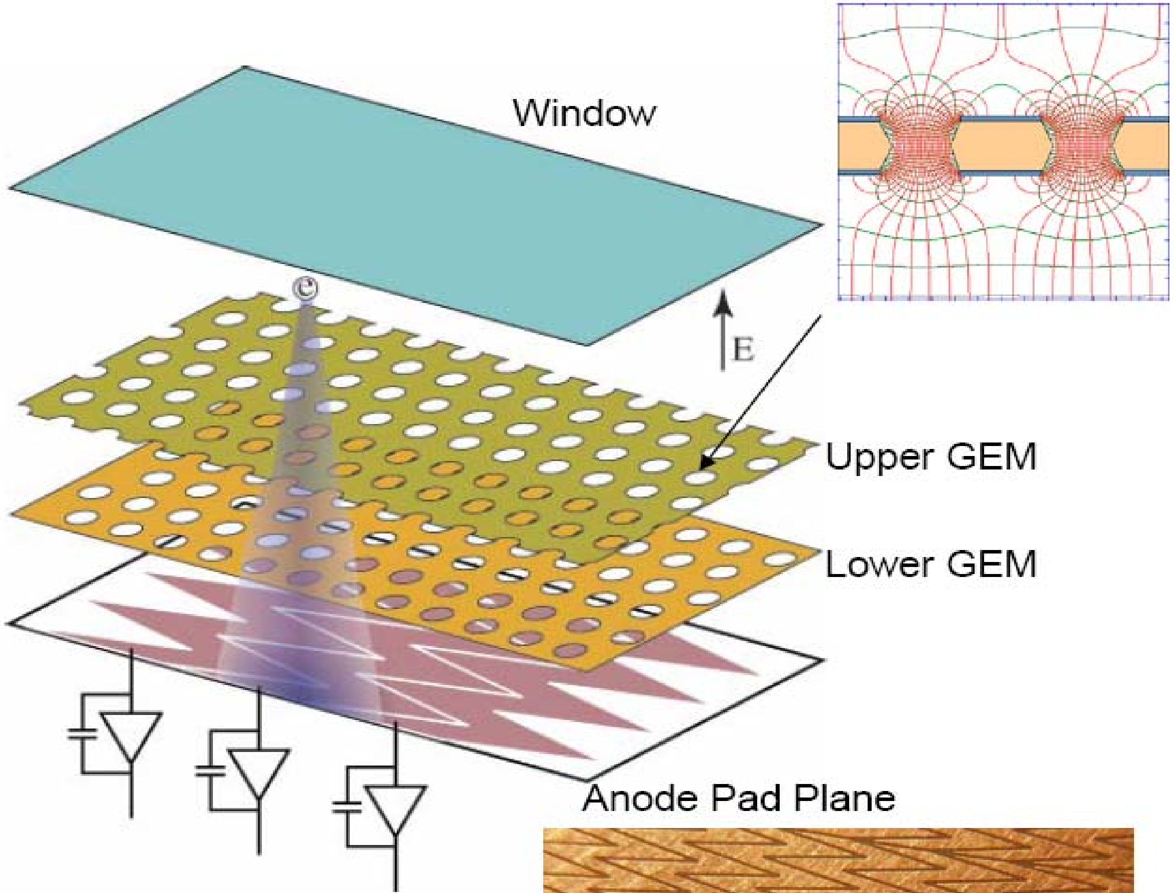
Photon detection efficiency (PDE):
- for SiPM the QE (~90%) is multiplied by Geiger efficiency (~60%) and by geometrical efficiency (sensitive/total area ~30%)
- highest efficiency for green light
  ➔ important when using with WLS fibers

Temperature and voltage dependence:
-1 °C ➔ +3% in Gain * PDE
+0.15 V ➔ +3% in Gain * PDE

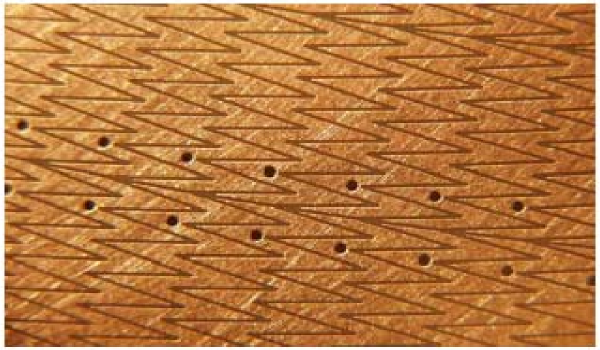
WLS viewed by two SiPM

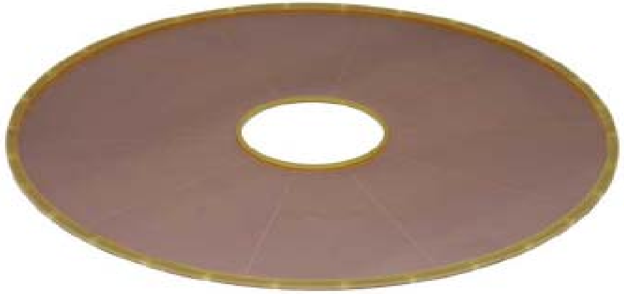


Interpolating Pad Readout for Gas Electron Multiplier (GEM)



Anode Pad Plane





Mounted GEM Foil on Frames

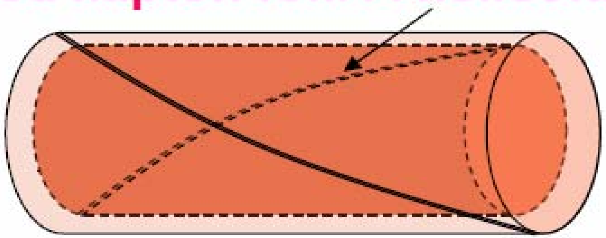
Prototype TPC with 10cm drift depth

GEM R&D reported by Bo Yu, et al. at IEEE NSS in Nov.2002

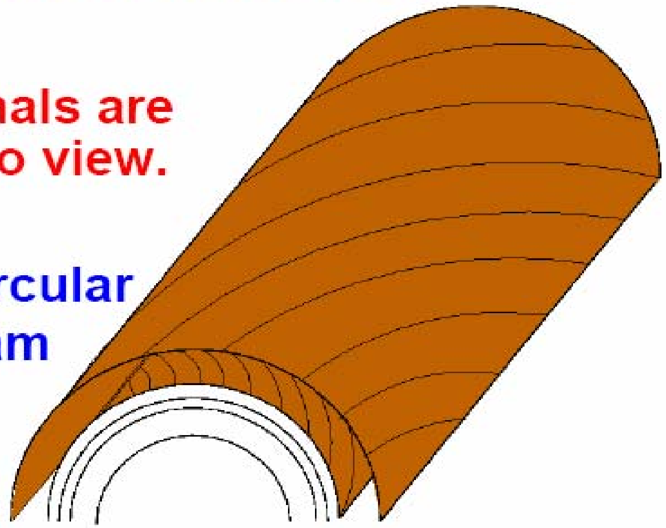
Cylindrical GEM development

LNF Detector Development Group
F.Anulli, G.Bencivenni,
D.Domenici, G.Felici, F.Murtas

- The basic cylindrical structure can be realized with the straw-tube technology
- The cylinder is obtained winding a parallelogram-shaped kapton foil. A helicoidal joint line (~3 mm wide) is left:



- Two consecutive cylindrical electrodes have opposite "helicity" in order to reduce the overlap of joint lines to only one point (~3x3 mm^2).
- A detector layer is composed by five concentric cylindrical structures: the cathode, the 3 GEM foils, the readout anode.
- Anode and GEM3-down (where only electron fast signals are present) are equipped with U-V strip readout for stereo view. Strip pitch is 400 μm.
- The cylindrical electrodes are glued at the ends on circular frames, by which the detector can be hung to the beam pipe, avoiding any internal support frame

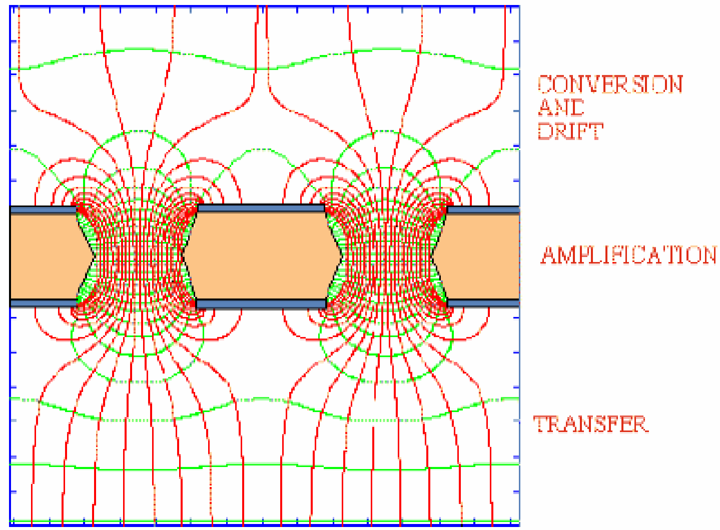


First prototype for mechanical test successfully produced

Principle of operation of a GEM detector

Courtesy of G.Bencivenni

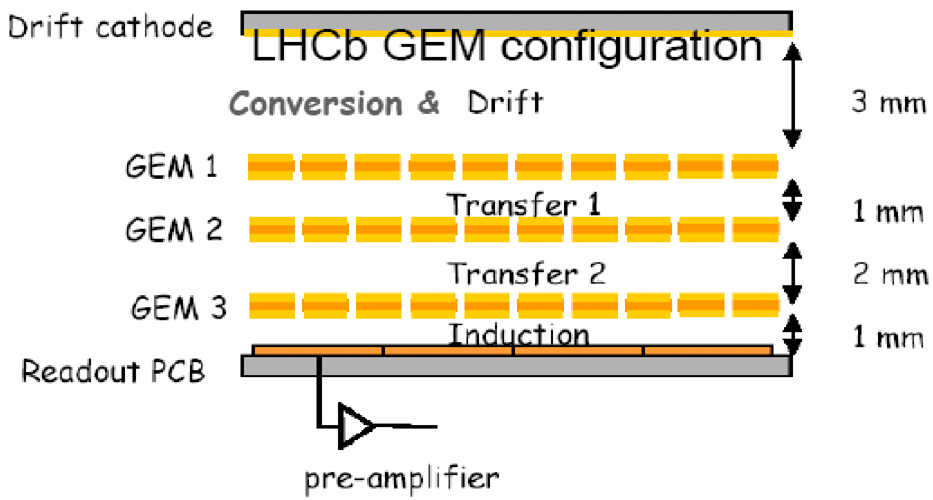
The GEM (Gas Electron Multiplier) (F.Sauli, NIM A386 (1997) 531) is a thin (50 μm) metal coated kapton foil, perforated by a high density of holes (70 μm diameter, pitch of 140 μm) → standard photo-lithographic technology.



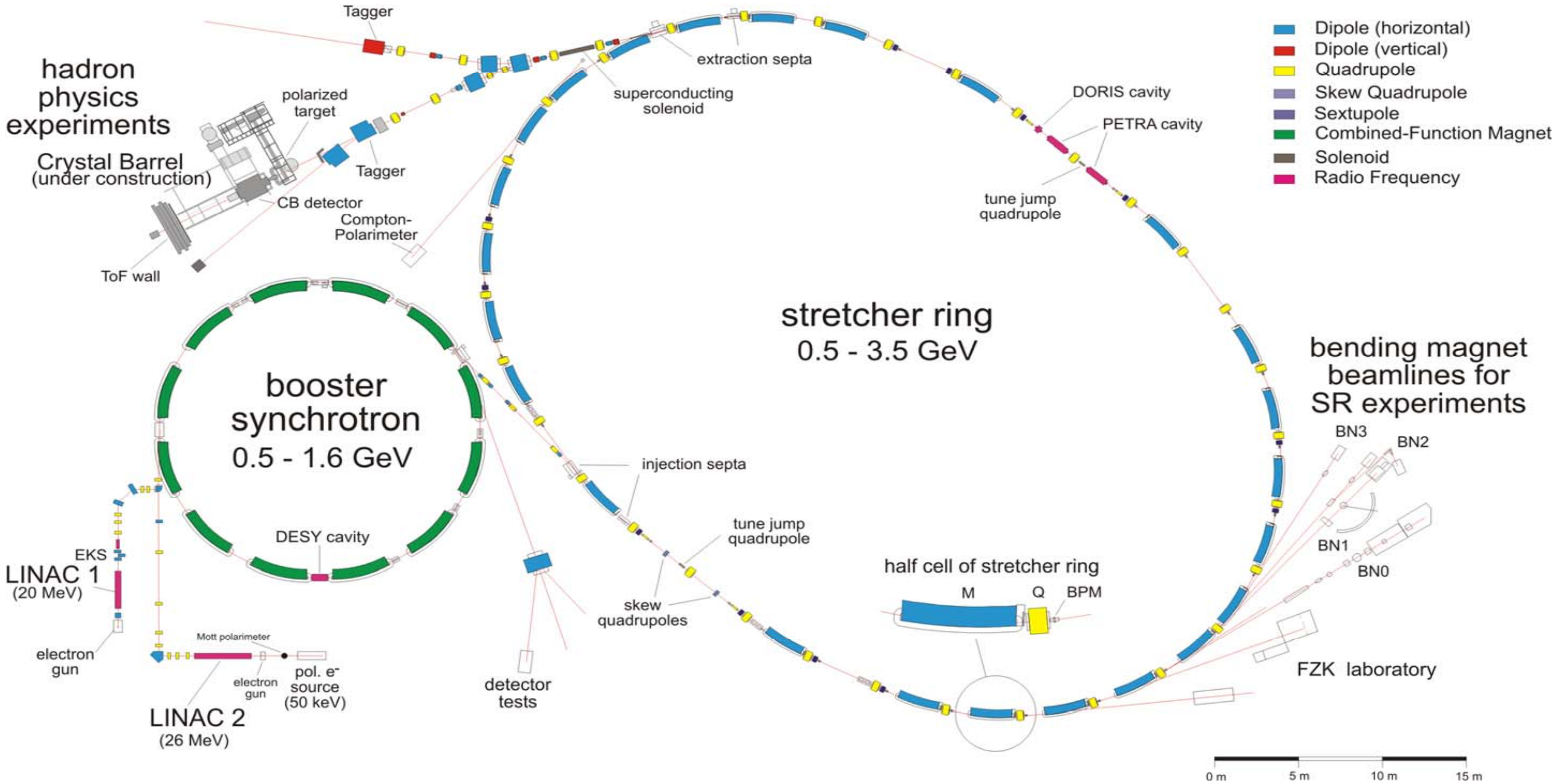
By applying 400-500 V between the two copper sides, an electric field as high as ~100 kV/cm is produced into the holes which act as multiplication channels for electrons produced in the gas by a ionizing particle.

Gains up to 1000 can be easily reached with a single GEM foil. Higher gains (and/or safer working conditions) are usually obtained by cascading two or three GEM foils.

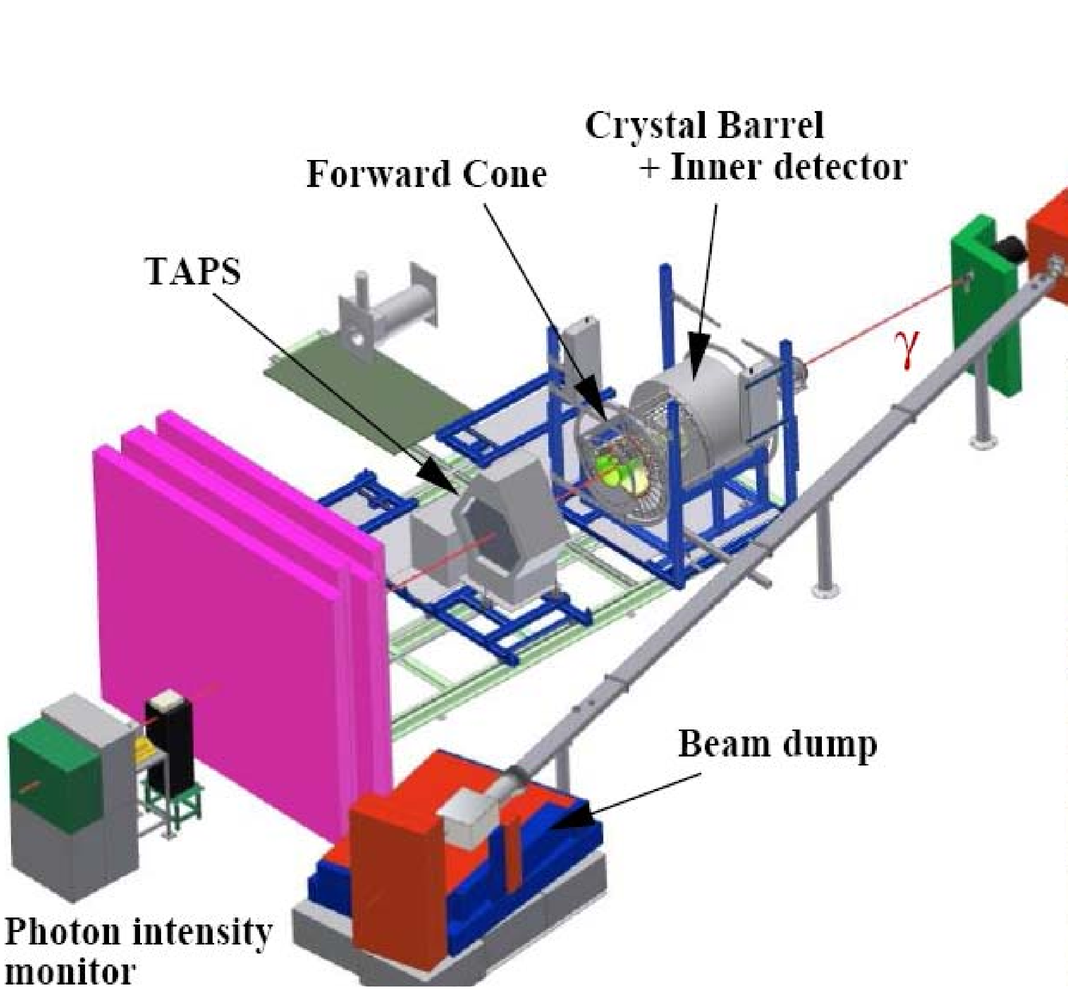
A Triple-GEM detector is built by inserting three GEM foils between two planar electrodes, which act as the cathode and the anode.

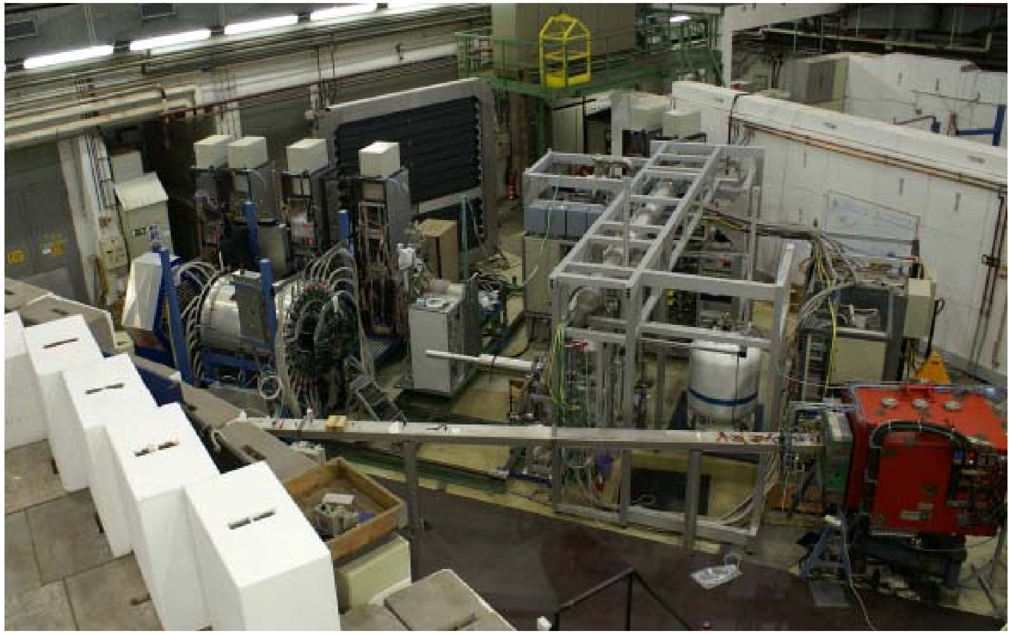


Electron Stretcher Accelerator (ELSA)

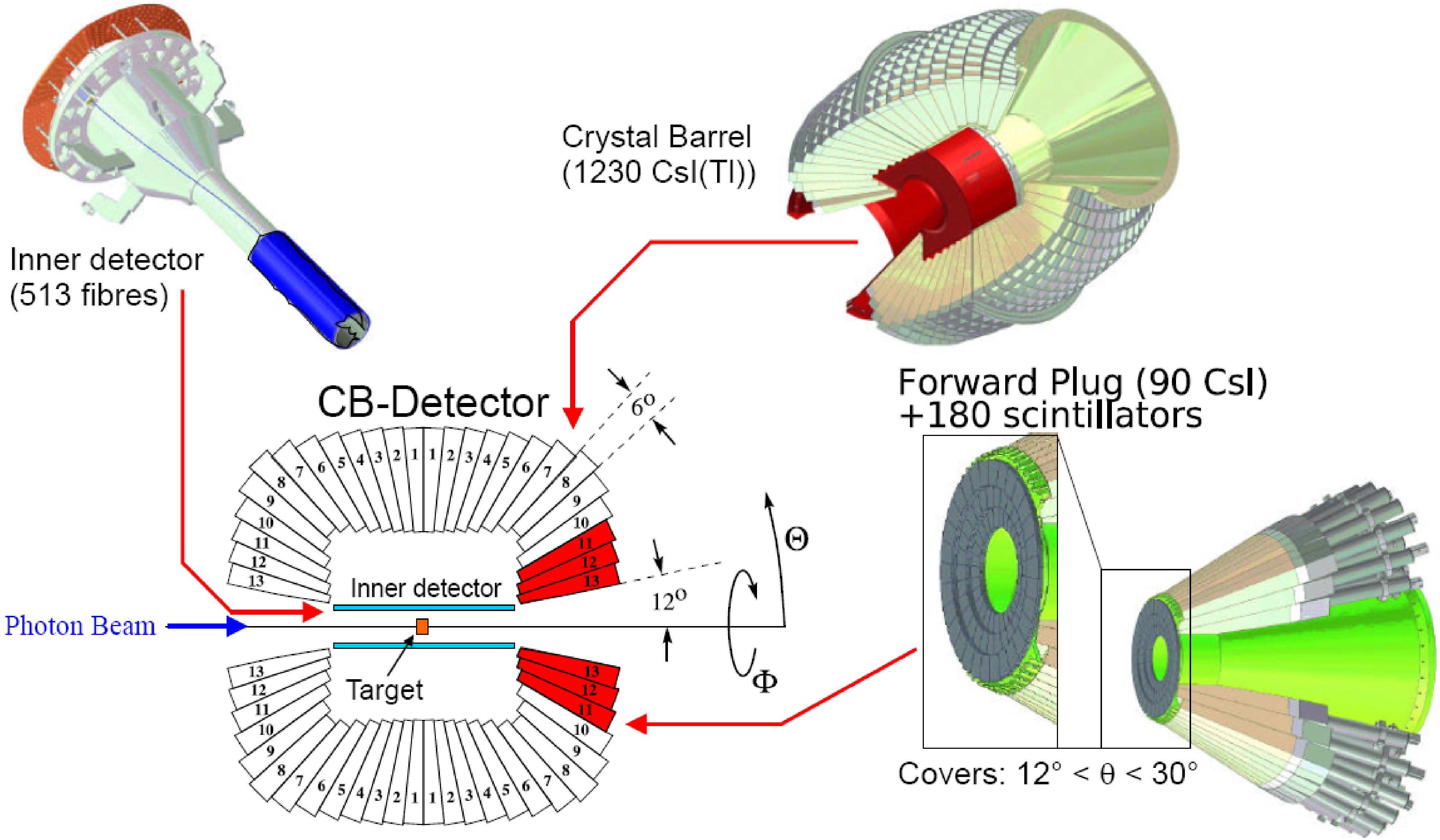


New Crystal Barrel Set Up





New Crystal Barrel Set Up



Single CsJ-Detector