L’esperimento PANDA
ed il rivelatore a pixel per il microvertice

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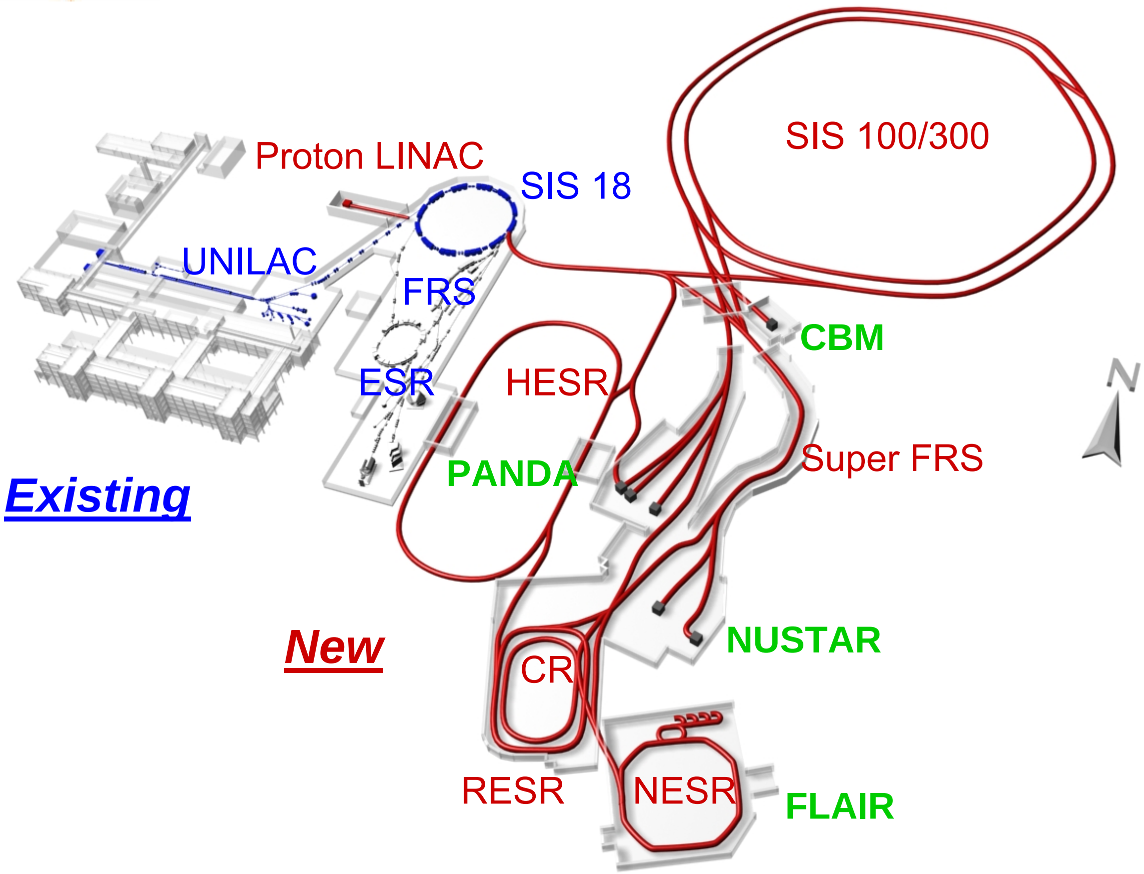
Scuola Nazionale "Rivelatori ed Elettronica per Fisica delle Alte Energie, Astrofisica, Applicazioni Spaziali e Fisica Medica“, 20-24 aprile 2009, LNL

Overview

- Introduction to FAIR and HESR
- The PANDA experiment
- The Micro Vertex Detector
- Prototypes for the Custom Pixel Detector

The future Facility FAIR in Darmstadt

FAIR **Facility for Antiproton and Ion Research**



Antiproton production

- Proton LINAC 50 MeV
- Accelerate p in SIS18 / 100
- Produce antiproton on Cu target
- Collect in CR, cool in RESR

Primary beams

- 10^{12}/s; 1.5 ÷ 2 GeV/u; $^{238}U^{28+}$
- Factor 100 ÷ 1000 over present intensity
- $2 \cdot 10^{13}$/s 30 GeV protons
- 10^{10}/s $^{238}U^{73+}$ up to 35 GeV/u
- 50 MeV new Proton LINAC

Secondary beams

- Broad range of radioactive beams up to 1.5 ÷ 2 GeV/u
- Intensity up to factor 10000 over present
- Antiprotons 1.5 ÷ 15 GeV/c

Storage and Cooler Rings

- 10^{11} stored and cooled 0.8 ÷ 14.5 GeV antiprotons

Parallel operations

- Up to 4 different independent experiments

HESR-High Energy Storage Ring

Circumference = 574 m

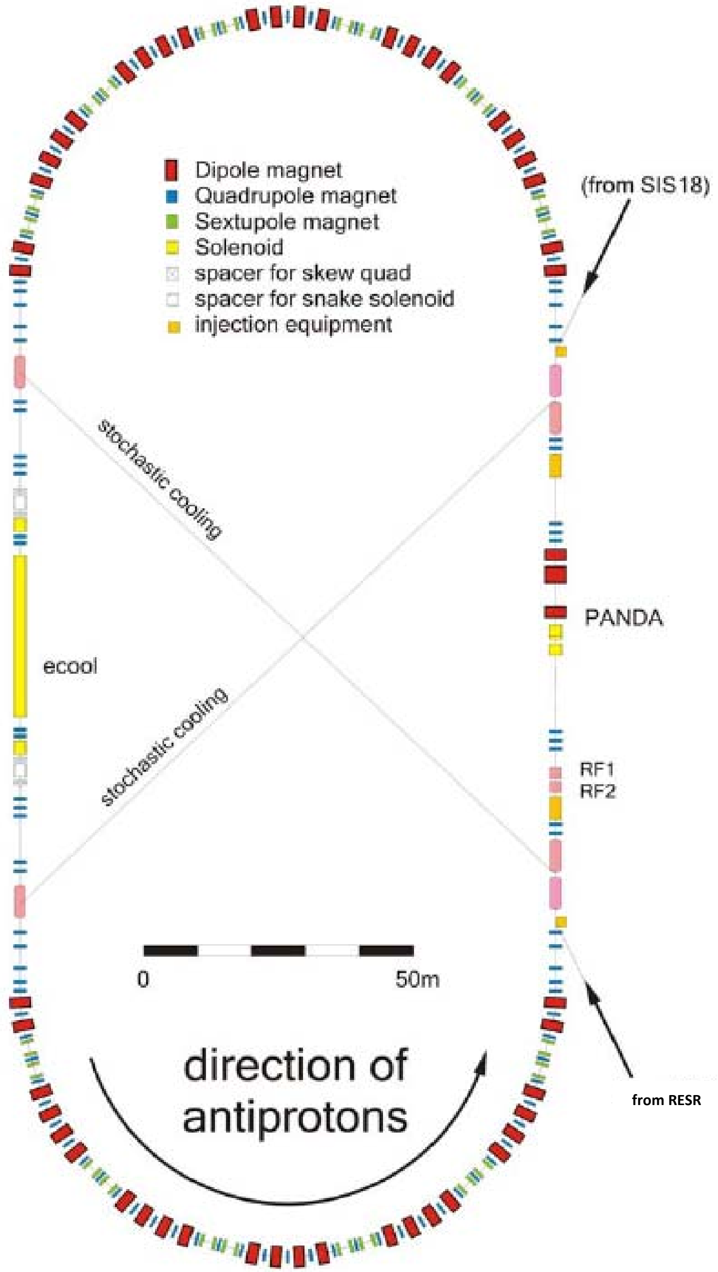
P_{beam} = 1.5 ÷ 15 GeV/c

$N_{stored} \lesssim 10^{11}$ antip

Internal thick Target = $4 \cdot 10^{15}$ cm^{-2}

Beam lifetime > 30 min

- **High resolution mode**
  - $\delta p/p \sim 4 \cdot 10^{-5}$
  - Momentum range = 1.5 ÷ 8.9 GeV/c
  - Electron cooling ≤ 8.9 GeV/c
  - Antiprotons number = 10^{10}
  - Peak luminosity = $2 \cdot 10^{31}$ cm^{-2}s^{-1}
- **High luminosity mode**
  - $\delta p/p \sim 4 \cdot 10^{-4}$
  - Momentum range = 1.5 ÷ 15 GeV/c
  - Stochastic cooling ≥ 8.9 GeV/c
  - Antiprotons number = 10^{11}
  - Peak luminosity = $2 \cdot 10^{32}$ cm^{-2}s^{-1}



PANDA experiment

D. Calvo

The PANDA Collaboration

About 400 physicists from 53 institutions in 16 countries

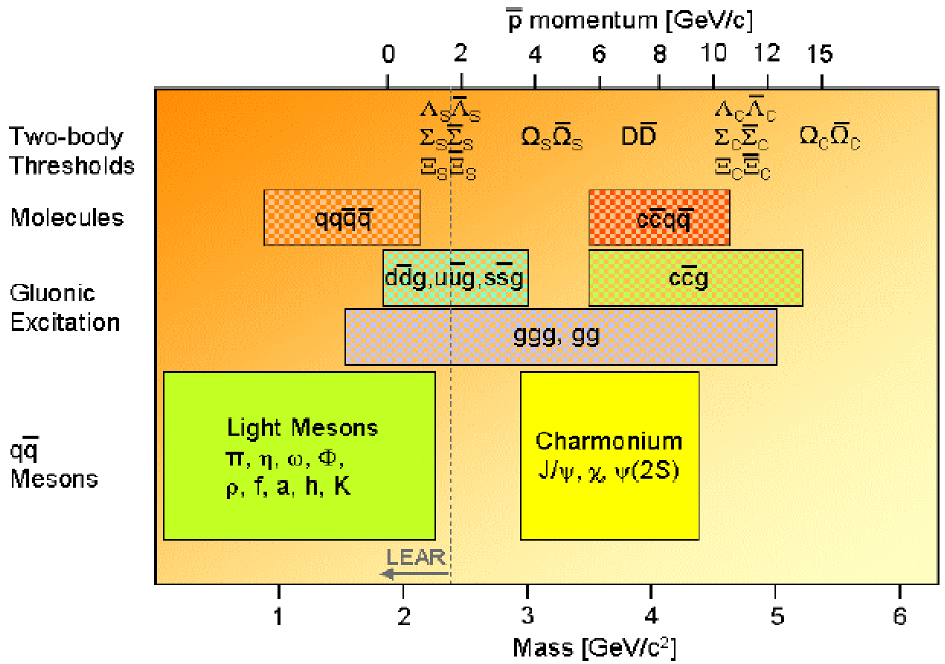
U Basel
IHEP Beijing
U Bochum
IIT Bombay
U Bonn
IFIN-HH Bucharest
U & INFN Brescia
U & INFN Catania
JU Cracow
TU Cracow
IFJ PAN Cracow
GSI Darmstadt
TU Dresden
JINR Dubna
(LIT,LPP,VBLHE)
U Edinburgh
U Erlangen
NWU Evanston

U & INFN Ferrara
U Frankfurt
LNF-INFN Frascati
U & INFN Genova
U Glasgow
U Gießen
KVI Groningen
IKP Jülich I + II
U Katowice
IMP Lanzhou
U Lund
U Mainz
U Minsk
ITEP Moscow
MPEI Moscow
TU München
U Münster
BINP Novosibirsk

IPN Orsay
U & INFN Pavia
IHEP Protvino
PNPI Gatchina
U of Silesia
U Stockholm
KTH Stockholm
U & INFN Torino
Politechnico di Torino
U Piemonte Orientale, Torino
U & INFN Trieste
U Tübingen
TSL Uppsala
U Uppsala
U Valencia
SMI Vienna
SINS Warsaw
TU Warsaw

Antiproton physics program in PANDA

- Charmonium (cc) spectroscopy: precision measurements of mass, width, decay branches of all charmonium states, especially for extracting information on qq models of mesons.
- Search for gluonic excitations (charmed hybrids, glueballs) in the charmonium mass range (3 – 5 GeV/c^2).
- Search for modifications of meson properties in the nuclear medium
- Precision γ-ray spectroscopy of single and double hypernuclei for extracting information on their structure and on the hyperon-nucleon and hyperon-hyperon interaction.
- Inverted DVCS to extract parton distributions proton form-factors at large Q^2 up to 25 GeV^2/c^4 D-meson decay spectroscopy BR and decay dalitz plots CP-Violation in the D/Λ sector



Strange and charmed candidates for identification by means of their delayed decays

particle	lifetime	decay length $c\tau$	decay channel (fraction)
K^0_S	895.3(6) ps	2.6842 cm	$\pi^+\pi^-$ $((68.95 \pm 0.14)\%)$
$D^\pm$	1.040(7) ps	311.8 μm	e^+anything + c.c. $((17.2 \pm 1.9)\%)$
			K^-anything + c.c. $((27.5 \pm 2.4)\%)$
			K^+anything + c.c. $((5.5 \pm 1.6)\%)$
			$\overline{K}^0$anything + K^0anything $((61 \pm 8)\%)$
			e.g. $K^-\pi^+\pi^+$ + c.c. $((9.2 \pm 0.6)\%)$
			$\overline{K}^0\pi^+\pi^+\pi^-$ + c.c. $((7.1 \pm 1.0)\%)$
D^0	410.3(15) fs	123.0 μm	e^+anything + c.c. $((6.87 \pm 0.28)\%)$
			μ^+anything + c.c. $((6.5 \pm 0.8)\%)$
			K^-anything + c.c. $((53 \pm 4)\%)$
			K^+anything + c.c. $((3.4 \pm 0.4)\%)$
			$\overline{K}^0$anything + K^0anything $((53 \pm 4)\%)$
			e.g. $\overline{K}^0K^+K^-$ $((1.03 \pm 0.10)\%)$
			$K^-\pi^+\pi^+\pi^-$ + c.c. $((7.46 \pm 0.31)\%)$
			$\overline{K}^0\pi^+\pi^-\pi^0$ + c.c. $((10.9 \pm 1.3)\%)$
$D^\pm_s$	490(9) fs	147.0 μm	e^+anything/c.c. $(\approx 8\%)$
			K^-anything + c.c. $(\approx 13\%)$
			K^+anything + c.c. $(\approx 20\%)$
			$\overline{K}^0$anything + K^0anything $(\approx 39\%)$
			e.g. $K^+K^-\pi^+$ + c.c. $(4.4 \pm 1.2)\%$

Strange and charmed candidates for identification by means of their delayed decays

Λ	26.32(20) ps	7.69 cm	$p\pi^-$ $((63.9 \pm 0.5)\%)$
Σ^+	80.18(26) ps	2.404 cm	$p\pi^0$ $((51.57 \pm 0.30)\%)$
			$n\pi^+$ $((48.31 \pm 0.30)\%)$
Σ^-	147.9(11) ps	4.434 cm	$n\pi^-$ $((99.848 \pm 0.005)\%)$
Ξ^-	163.9(15) ps	4.91 cm	$\Lambda\pi^-$ $((99.887 \pm 0.035)\%)$
Ω^-	82.1(11) ps	2.461 cm	ΛK^- $((67.8 \pm 0.7)\%)$
			$\Xi^0\pi^-$ $((23.6 \pm 0.7)\%)$
			$\Xi^-\pi^0$ $((8.6 \pm 0.4)\%)$
Λ_c^+	200(6) fs	59.9 μm	$p\overline{K}^0$ $((2.3 \pm 0.6\%)$
			$pK^-\pi^+$ $((5.0 \pm 1.3\%)$
			$\Lambda\pi^+\pi^+\pi^-$ $((3.3 \pm 1.0\%)$
			$\Sigma^0 + \pi^+\pi^-$ $((3.6 \pm 1.0\%)$
Ξ_c^0	112(13) fs	33.6 μm	$\Xi^-\pi^+$$(not\ known)$

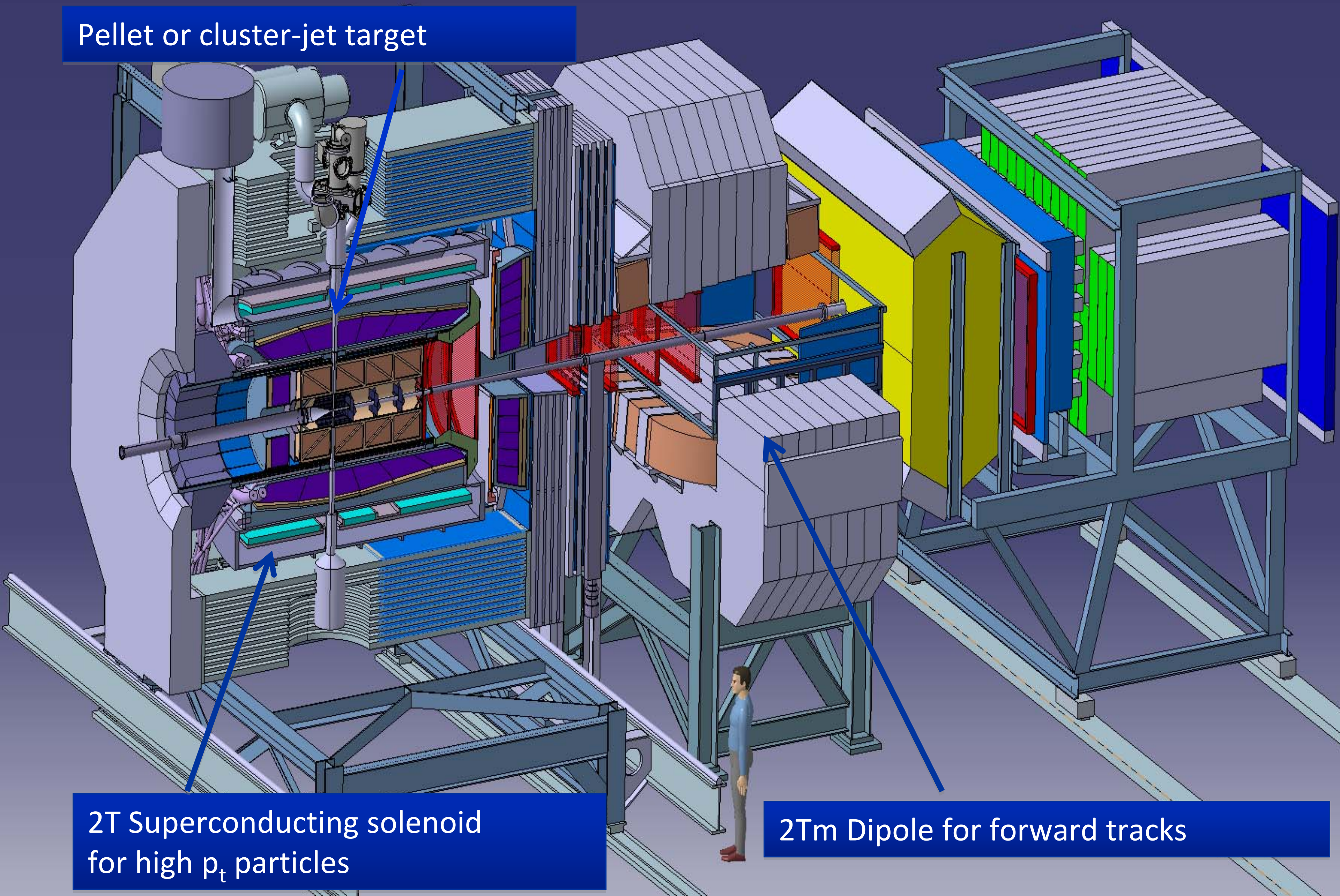
Production rates $(1\text{-}2(\mathrm{fb})^{-1}/\mathrm{y})$

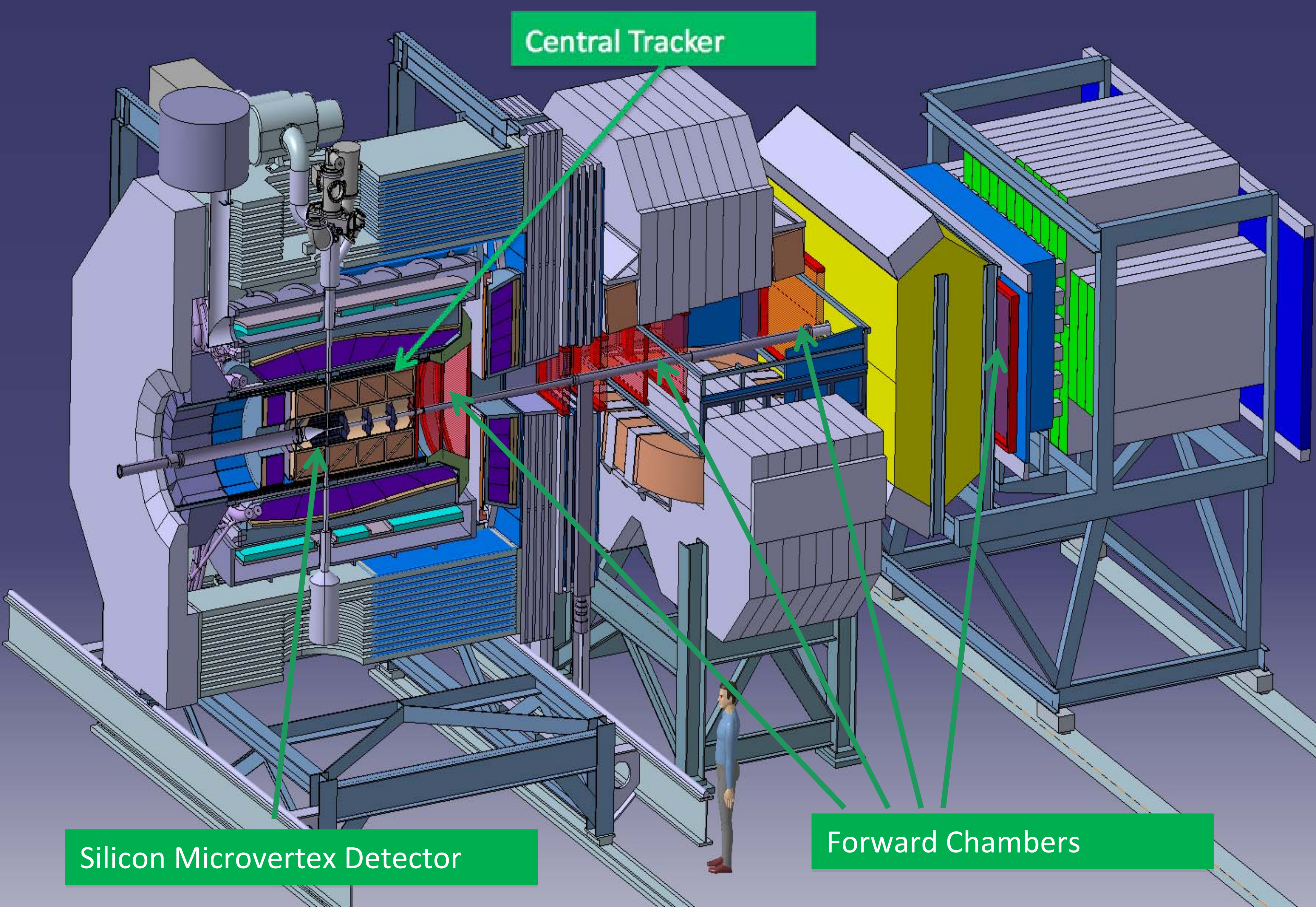
Final State	cross section	# rec. events/y
$\eta_c \to K_S^0 K^{\pm} \pi^{\mp}$	$10\,nb$	10^7
$\Lambda\overline{\Lambda}$	$50\,\mu b$	10^{10}
$\Xi\overline{\Xi}(\to_{\Lambda\Lambda} A)$	$2\,\mu b$	$10^8(10^5)$
$\psi(3770) \to D\overline{D}$	$3\,nb$	10^7
$J/\psi(\to e^+e^-, \mu^+\mu^-)$	$630\,nb$	10^9
$\chi_2(\to J/\psi + \gamma)$	$3.7\,nb$	10^7
$\Lambda_c\overline{\Lambda}_c$	$20\,nb$	10^7
$\Omega_c\overline{\Omega}_c$	$0.1\,nb$	10^5
$\sigma_T(p\overline{p})$	$70\,mb$	

Key elements : Low multiplicity events
Possibility to trigger on defined final states

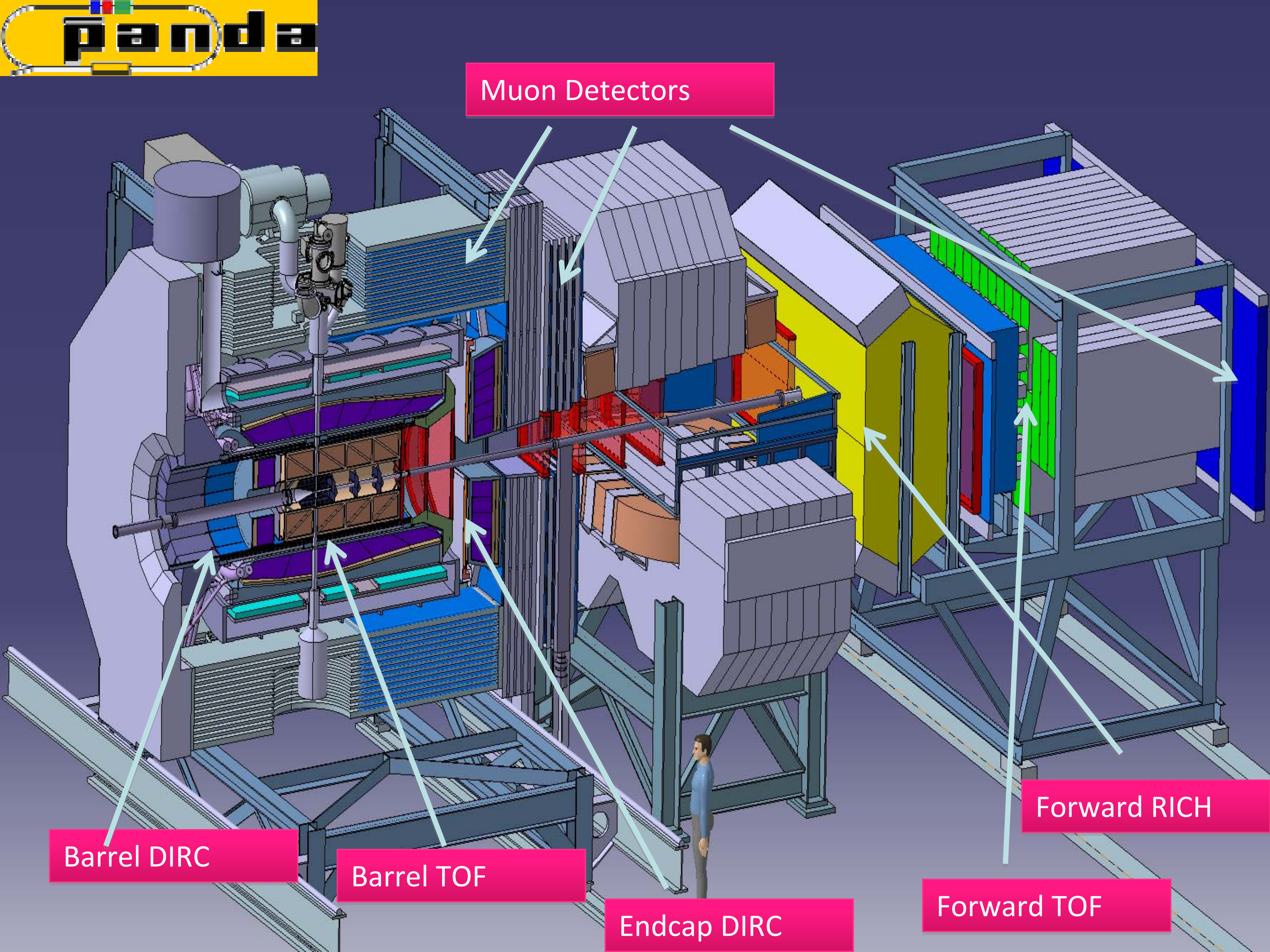
Multi-purpose Detector requirements

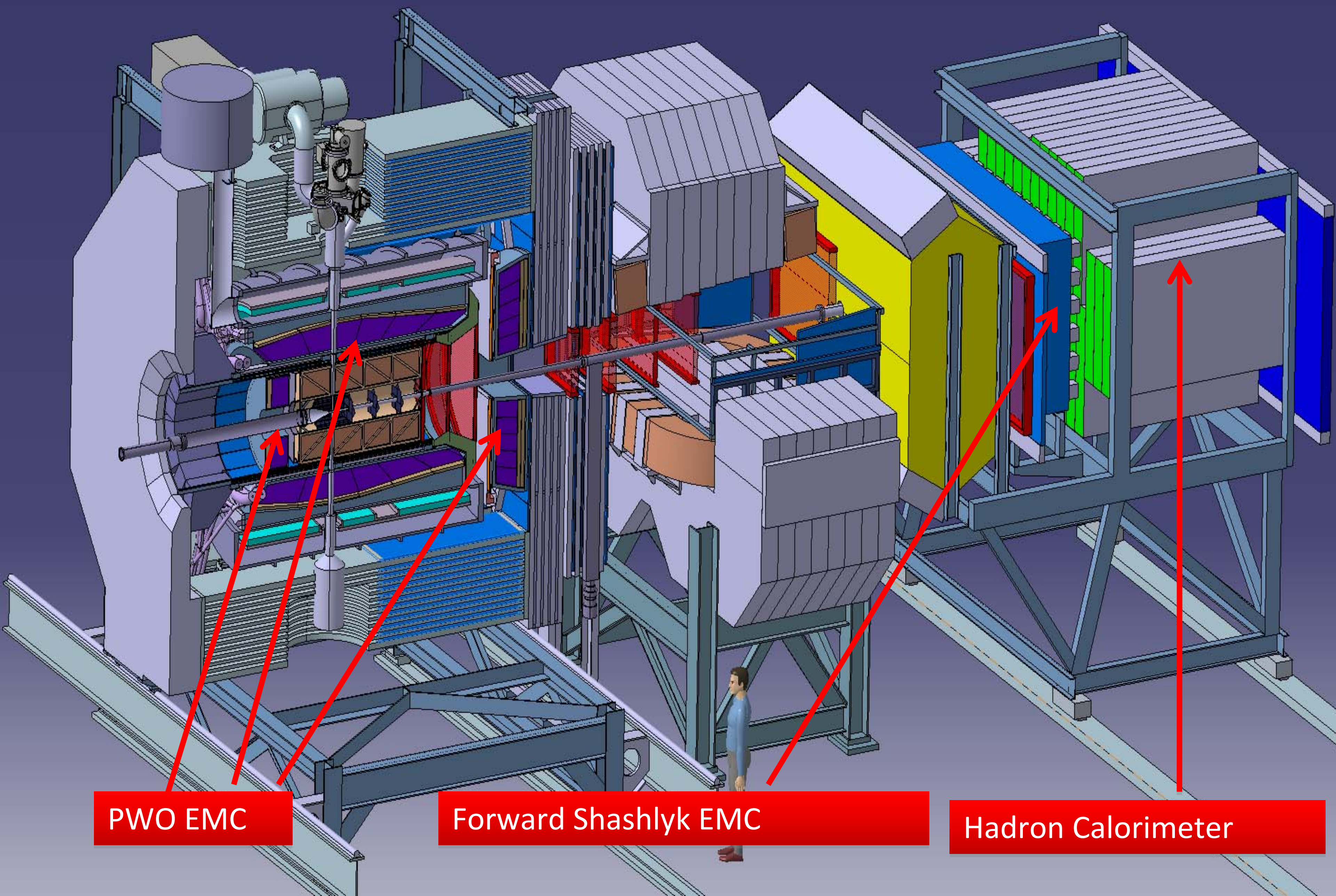
- Nearly 4π solid angle
- High rate capabilities ($2 \cdot 10^7$ annihilations /s)
- Efficient event selection
  - Continuous readout
- Moment resolution (1%)
- Vertex info for D, K^0_s, L (c_τ = 317 μm for D^{+-})
  - good tracking
- Good PID (γ, e, m, π, k, p)
  - Cherenkov, tof, dE/dx
- γ-detection 1 MeV ÷ 10 GeV
  - Crystal Calorimeter
- Modular design (hypernuclear experiments)


Pellet or cluster-jet target
2T Superconducting solenoid for high p_t particles
2Tm Dipole for forward tracks

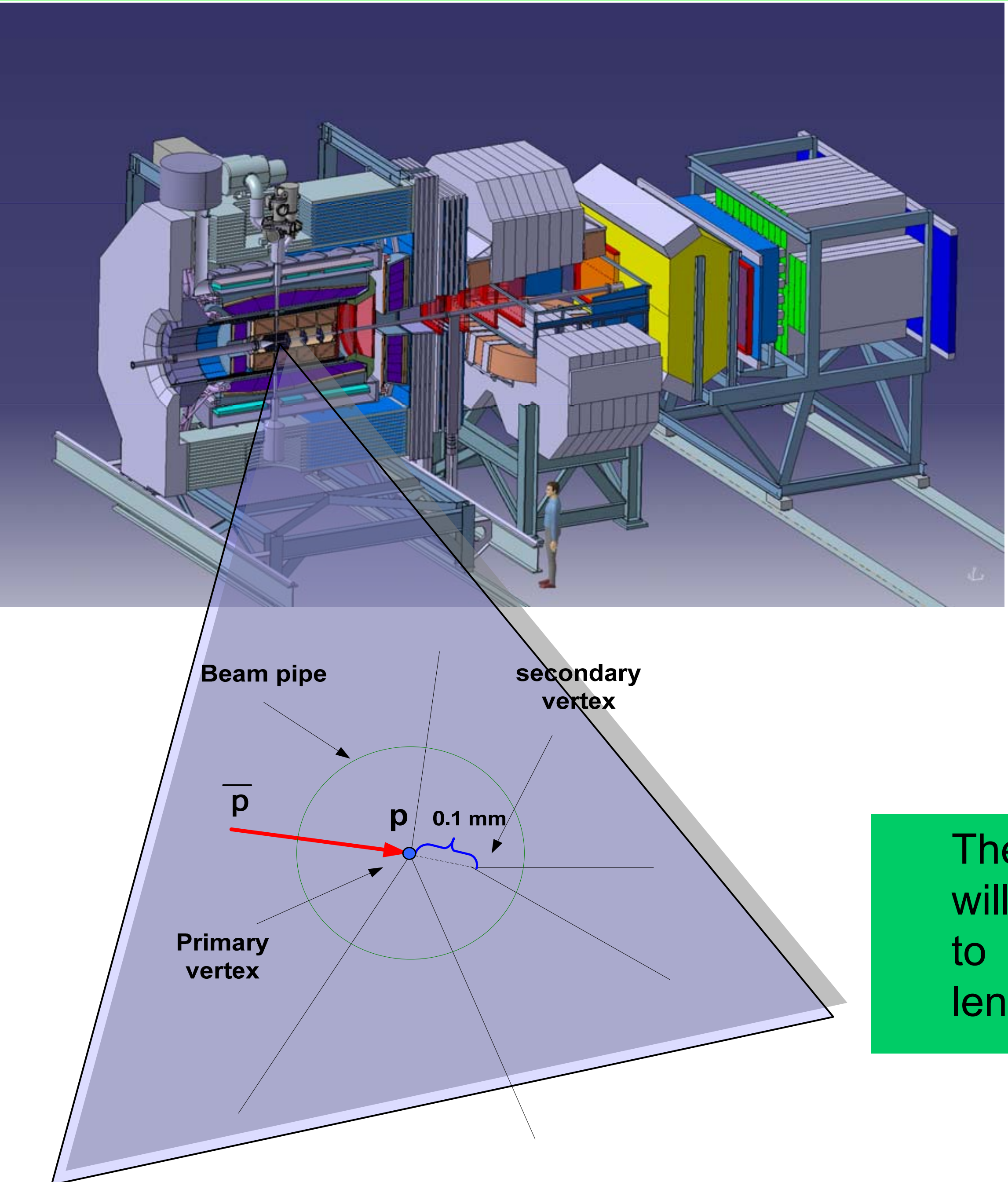


Central Tracker
Silicon Microvertex Detector
Forward Chambers


panda
Muon Detectors
Forward RICH
Barrel DIRC
Barrel TOF
Endcap DIRC
Forward TOF


PWO EMC
Forward Shashlyk EMC
Hadron Calorimeter

MVD requirements



Benchmark experiments that require optimum performance of the vertex tracking

reaction channel	detected particle
$\overline{p}p \rightarrow \phi\phi$	$2K^+ \, 2K^-$
$\overline{p}p \rightarrow \eta_c$	$K^\pm \, \pi^\mp \, K^0_S$
$\overline{p}p \rightarrow \psi(3770)$	$D\overline{D}$
	$\rightarrow K$'s and π's
$\overline{p}A \rightarrow D\overline{D}\, X$	D

The most serious challenge will be D identification due to the very short decay lengths of these mesons

MVD requirements

- Good spatial resolution in r-phi
  Momentum measurement of pions from D* decays

- Good spatial resolution specially in z
  - Vertexing, D-tagging

- Good time resolution
  - 20 ns (at 50 MHz clock) with $2 \cdot 10^7$ ann/s

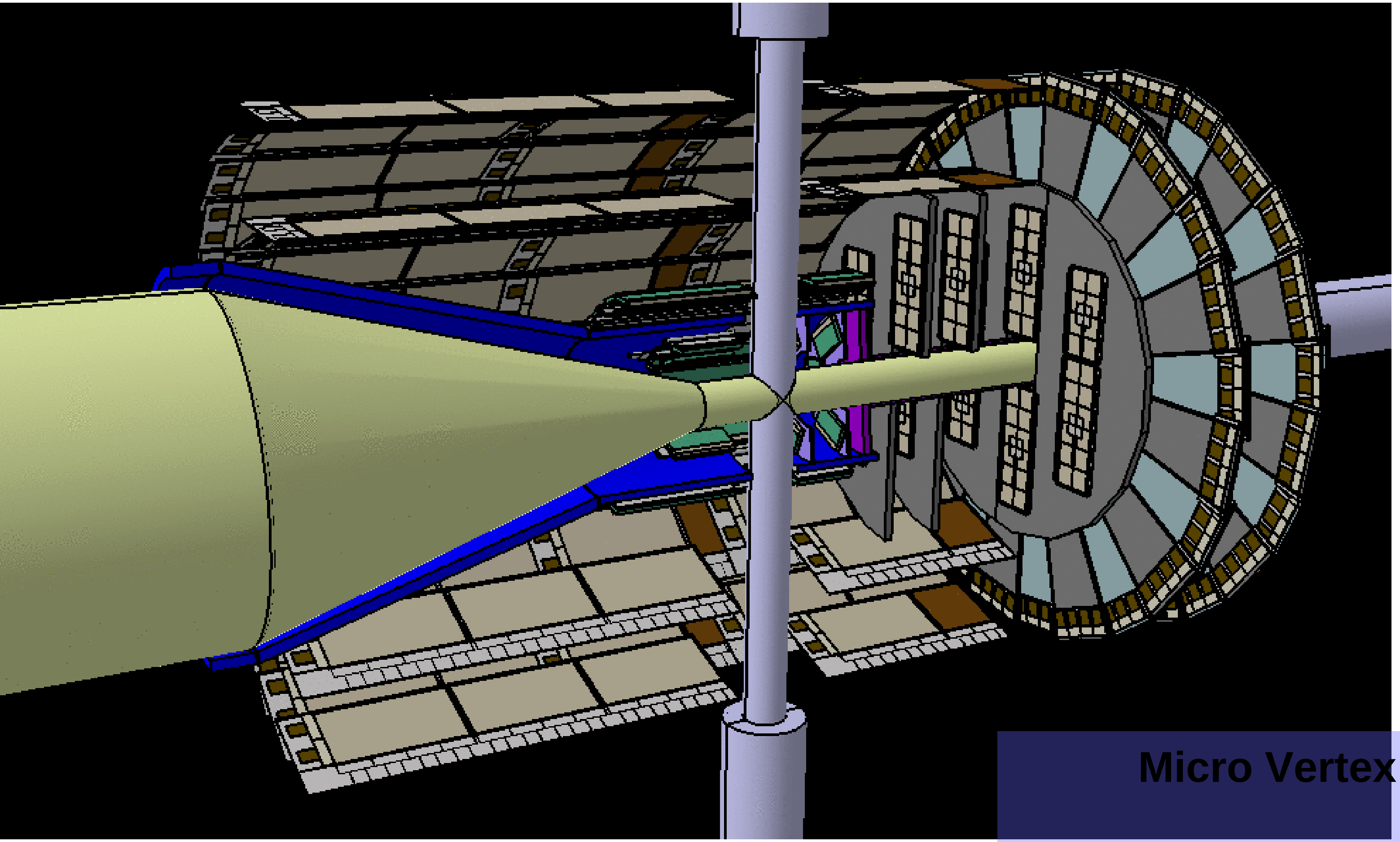
- Triggerless readout
  - No first level hardware trigger, clock at 50 MHz

- Amplitude measurement
  - Improvement of resolution with dE/dx to improve particle ID

- Low material budget
  - low momentum particles (starting from some hundreds of MeV/c) (<1% X_0 for each layer)

- Radiation hardness (~$4 \cdot 10^{14}$ $n_{1MeV\ eq}$ /cm^2)
  - Depends on target material

MVD layout

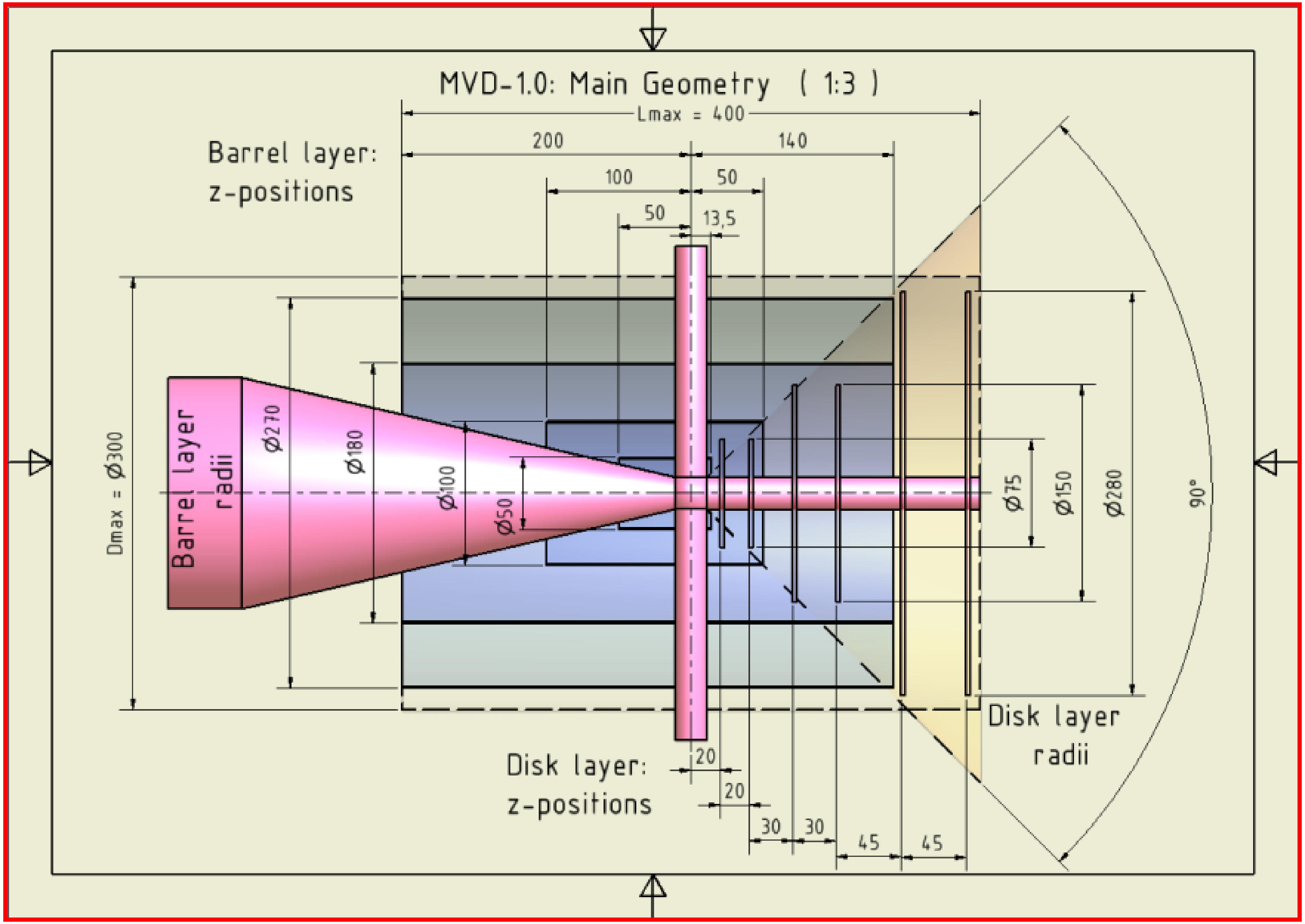


Micro Vertex Detector

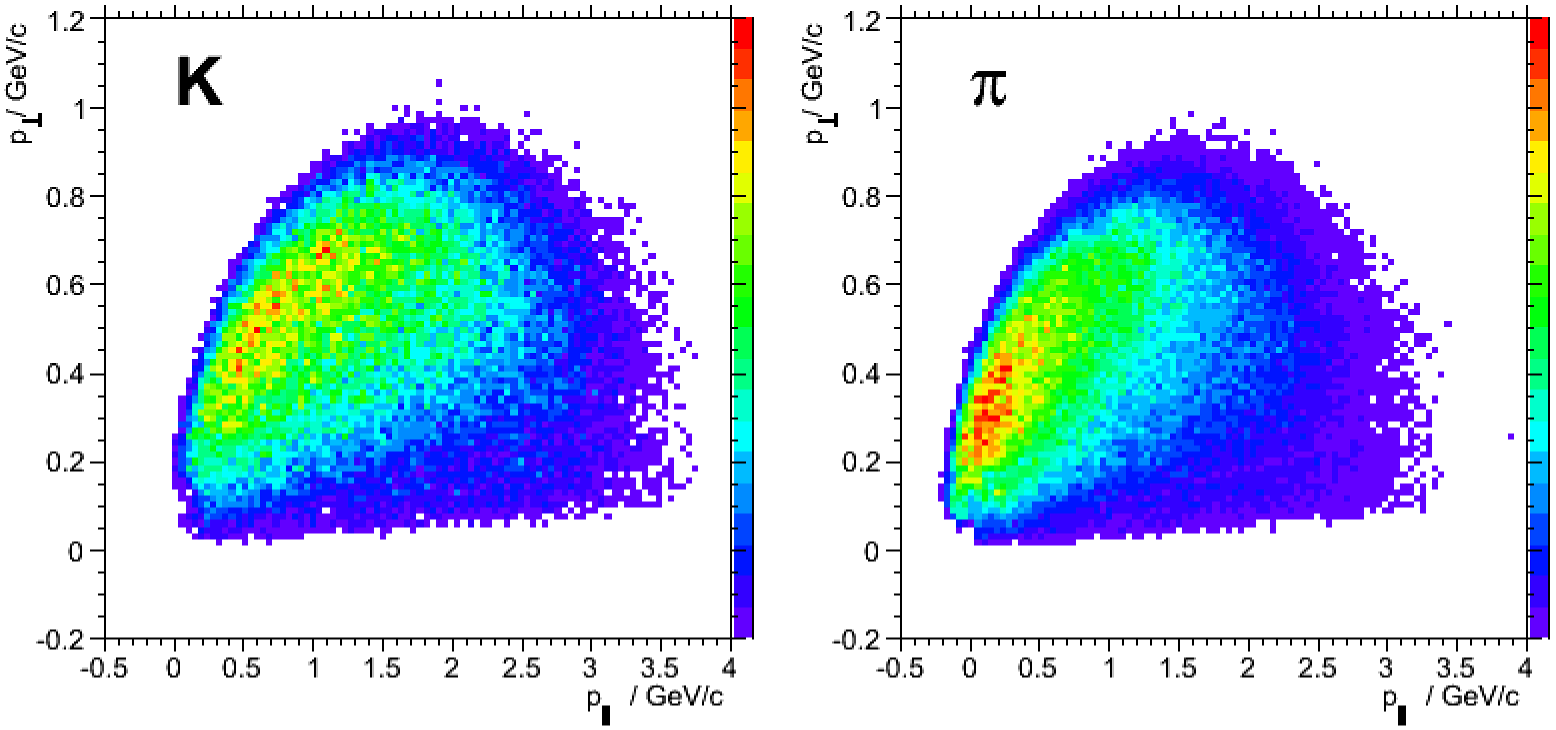
4 barrels
Inner layers: hybrid pixels
Outer layers: double sided strips

and 6 forward disks
4 disks: hybrid pixels
2 disks: pixel and strips mixed

MVD geometry

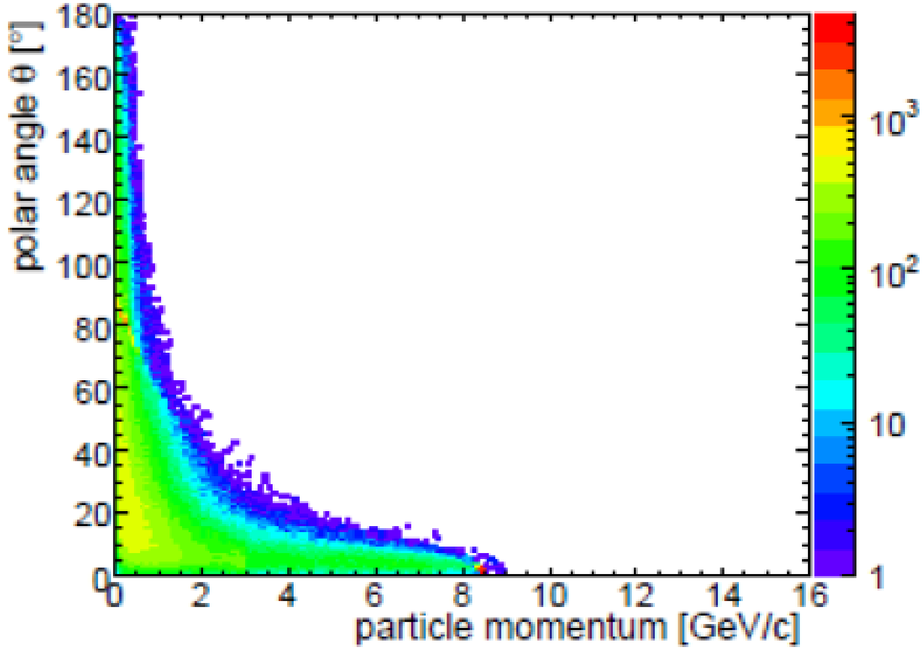


Kaon and pion momentum distribution from D decay



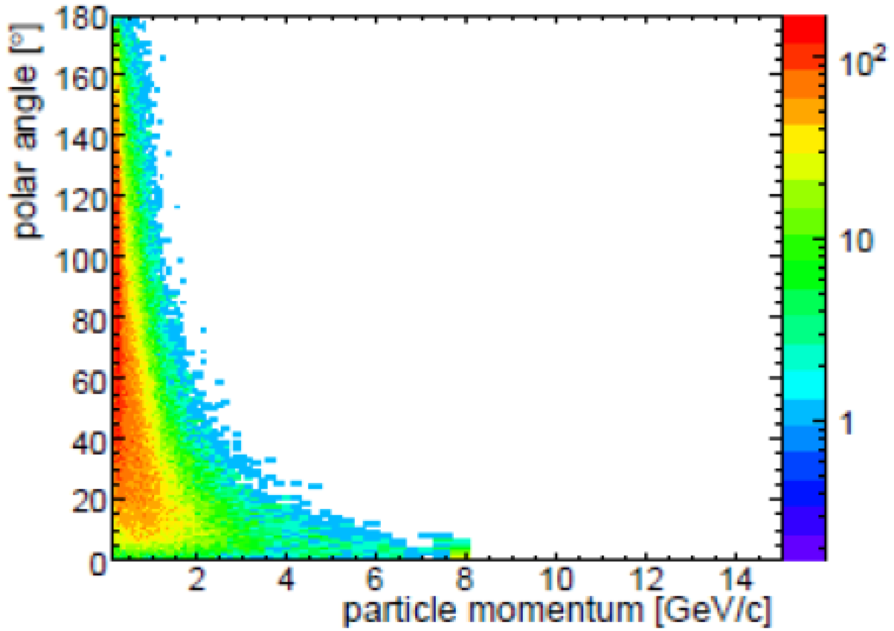
Transverse vs. longitudinal momentum of k and π from the reaction antipp→DantiD at the beam momentum of 6.7 GeV/c. The detected charged particles are produced in the decay of the D mesons via $D^{+-} \rightarrow K^{-+} \pi^{+} \pi^{-}$

Momentum distribution

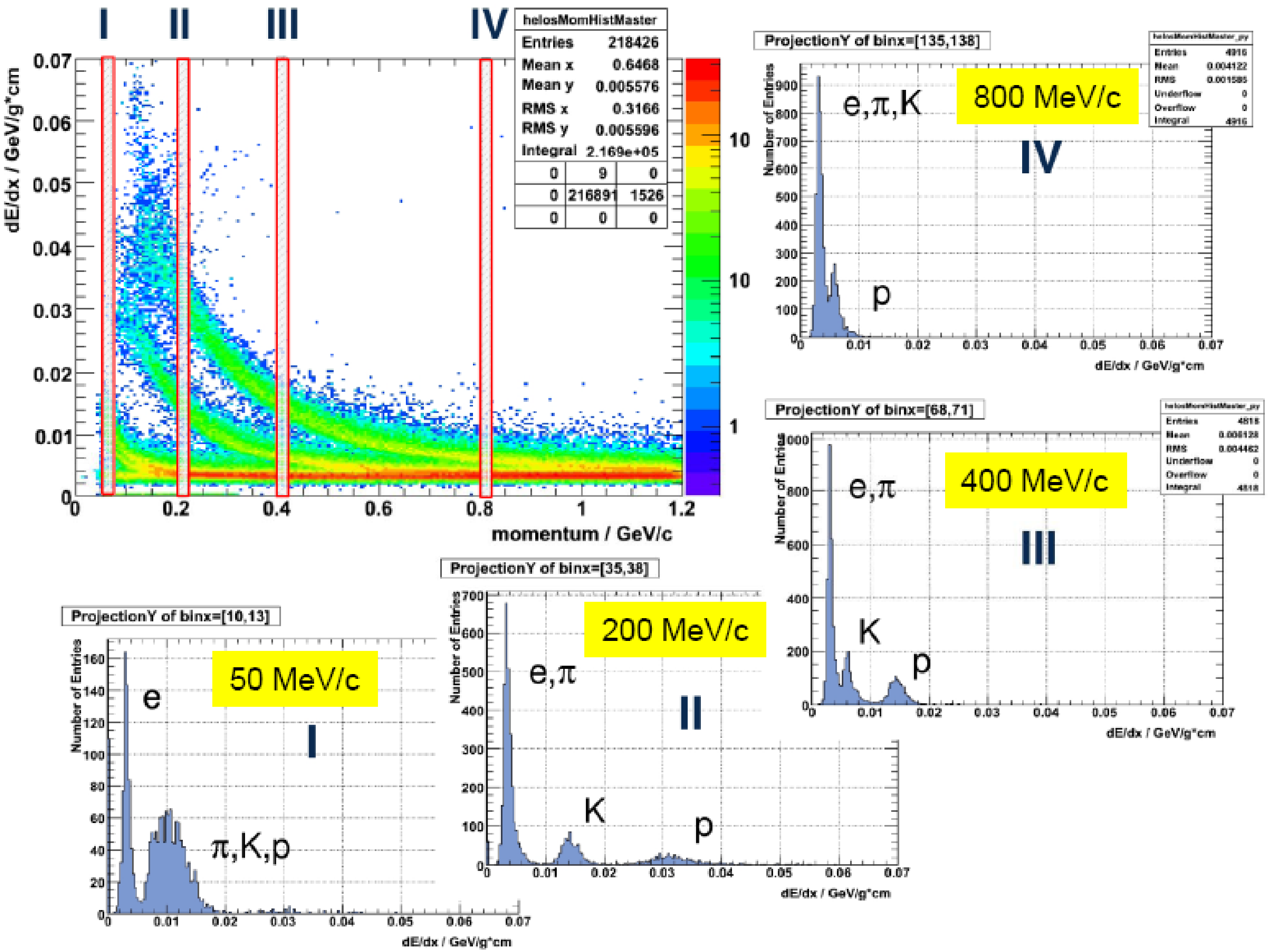


antipp @8 GeV/c

antipAu @8 GeV/c

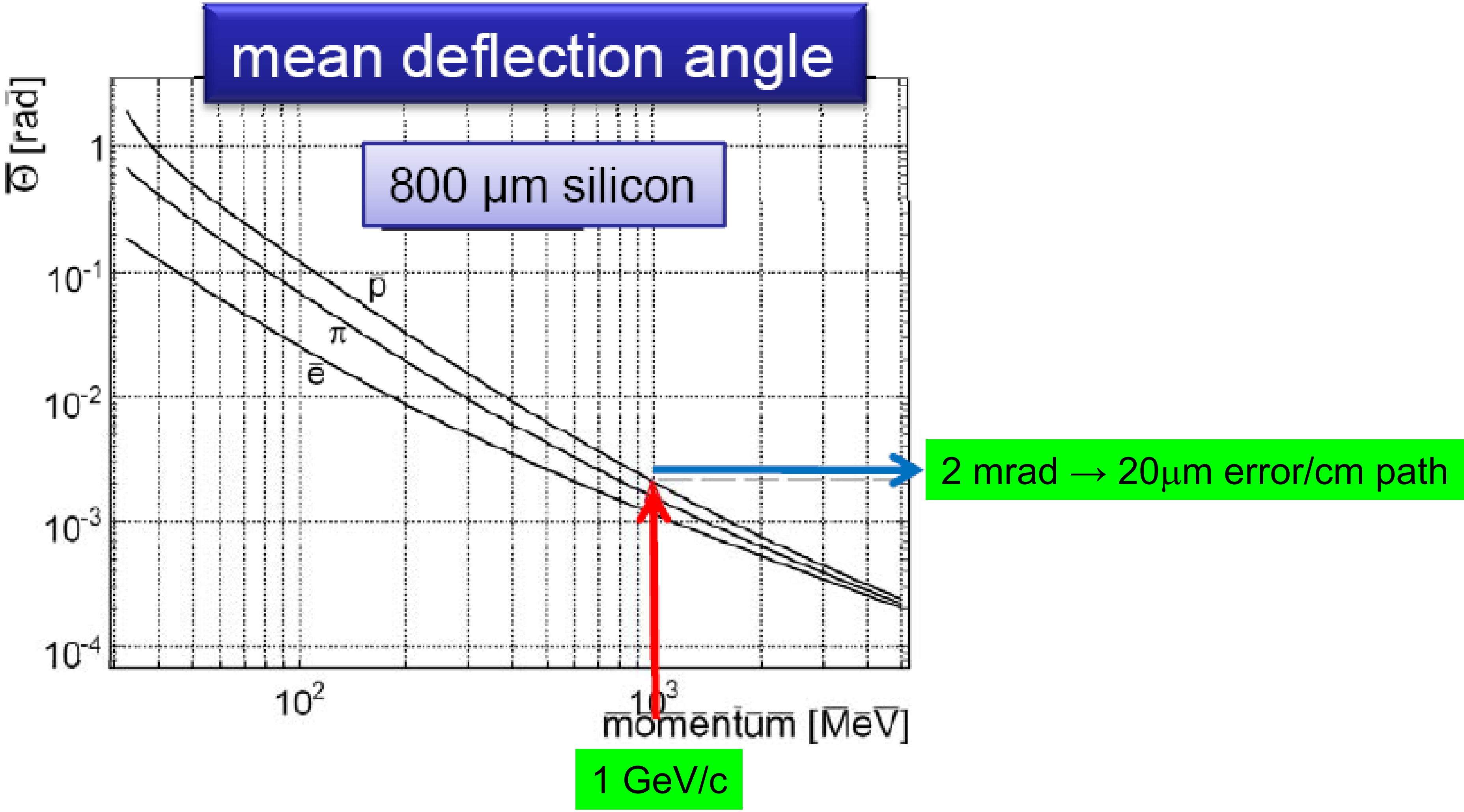


PID with MVD



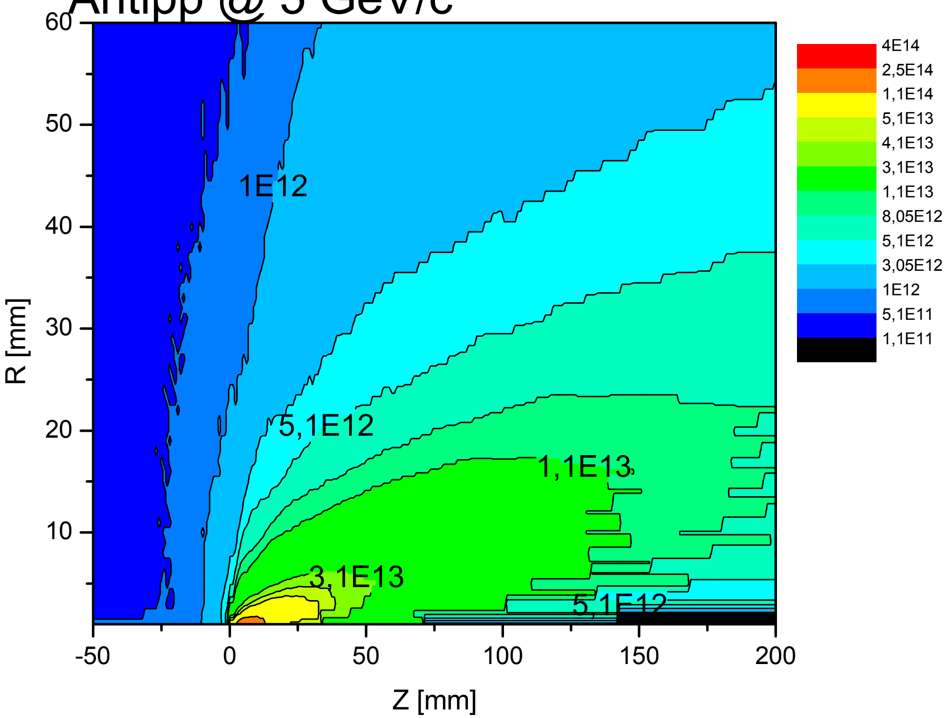
I
II
III
IV
helosMomHistMaster
Entries 218426
Mean x 0.6468
Mean y 0.005576
RMS x 0.3166
RMS y 0.005596
Integral 2.169e+05
dE/dx / GeV/g*cm
momentum / GeV/c
ProjectionY of binx=[135,138]
e,π,K
800 MeV/c
p
ProjectionY of binx=[68,71]
e,π
400 MeV/c
K
p
ProjectionY of binx=[35,38]
200 MeV/c
e,π
K
p
ProjectionY of binx=[10,13]
50 MeV/c
e
π,K,p
Number of Entries
dE/dx / GeV/g*cm

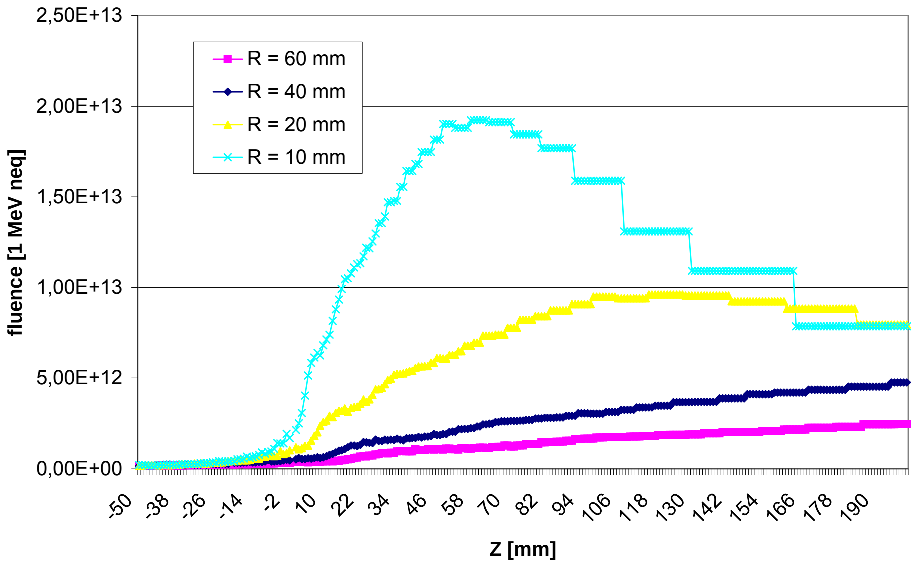
Multiple scattering

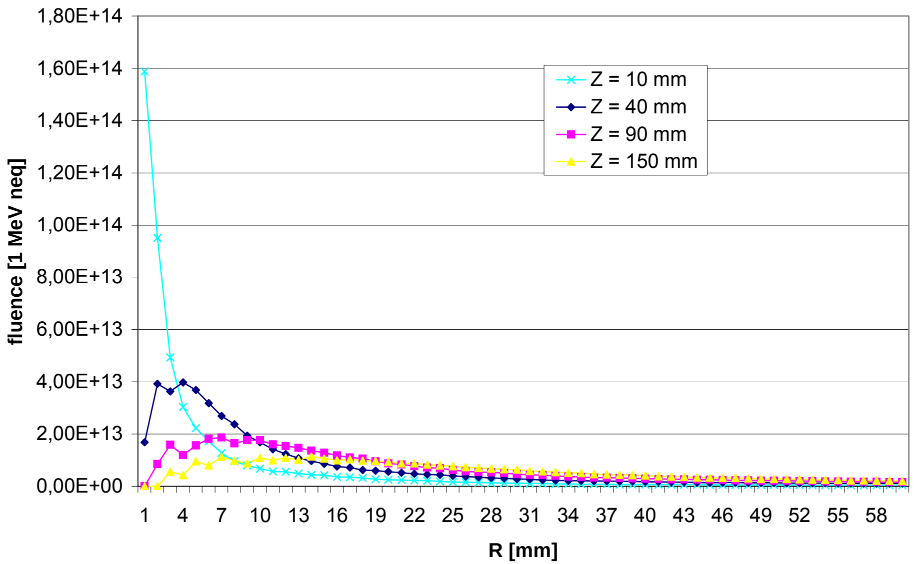


Radiation load I

Antipp @ 5 GeV/c

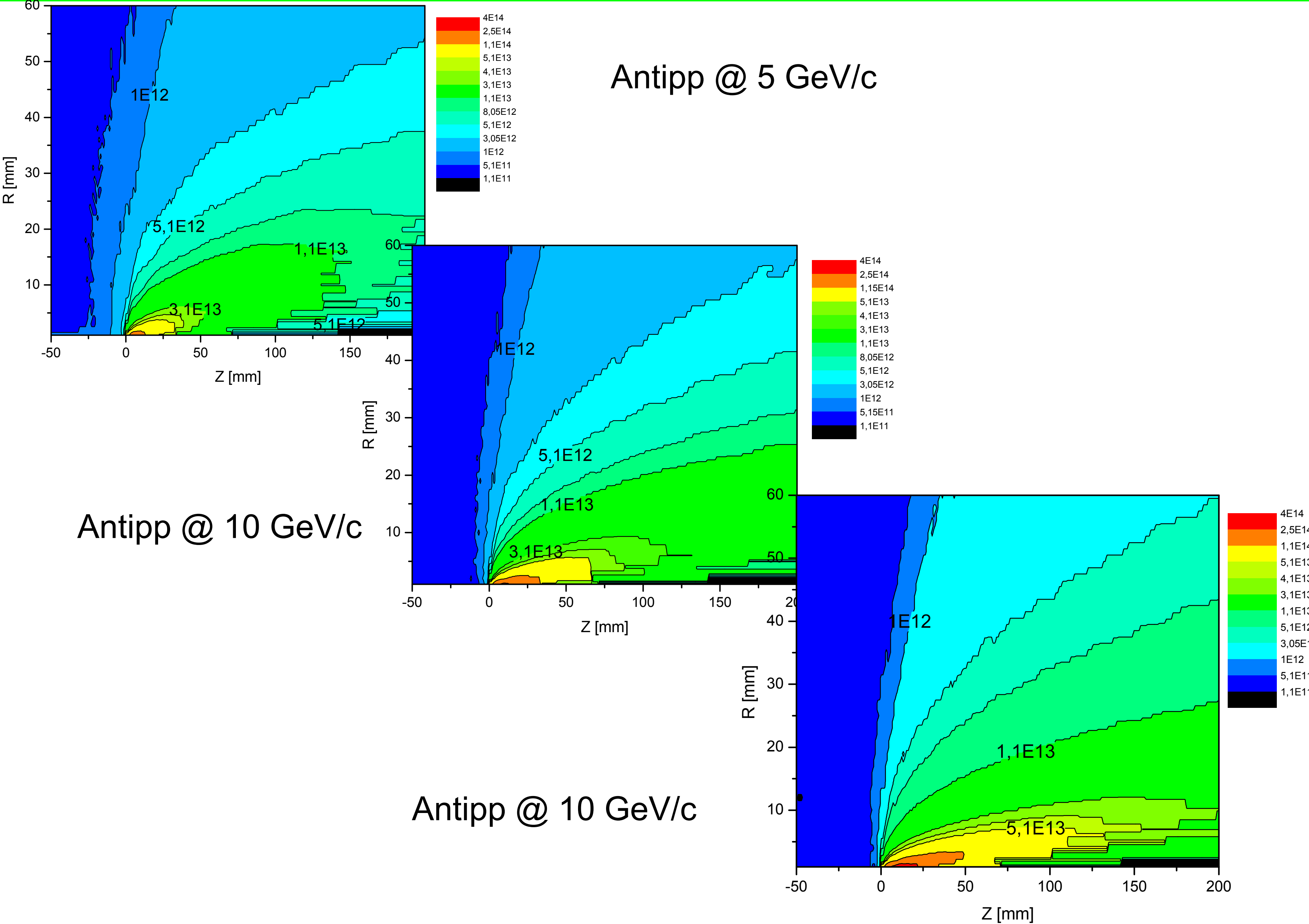






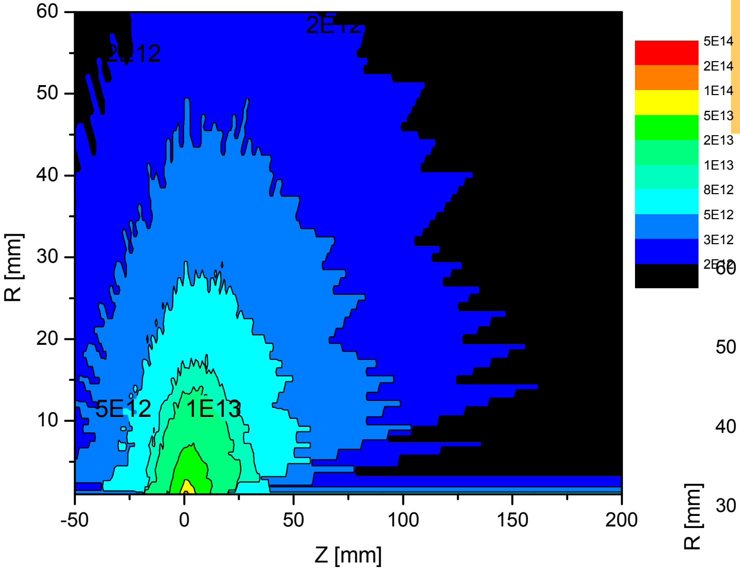
- particles are peaked in forward direction
- radial distribution ~1/R^2
- nearly no damage in backward parts of the MVD
- annual fluence well below 10^{13}n/cm^2 for all relevant parts

Radiation load II

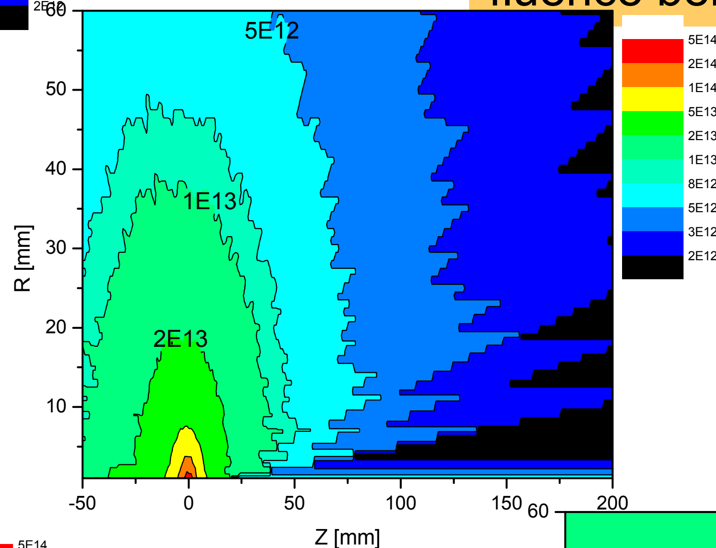


Radiation load III

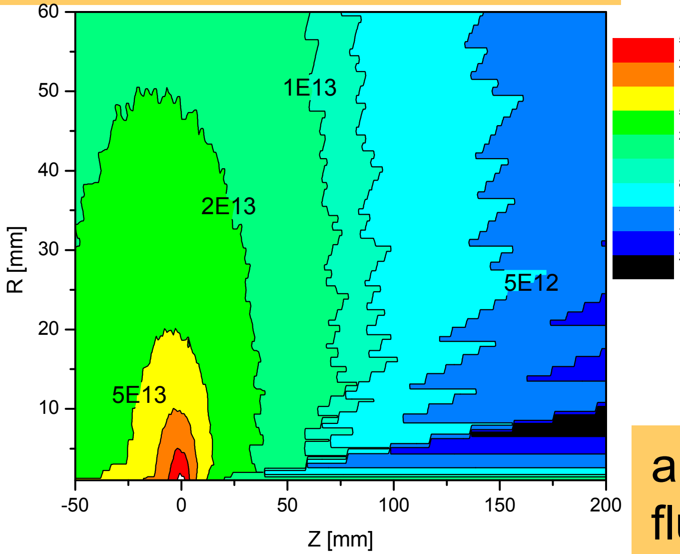
antipC @ 4.05 GeV/c
fluence below $1 \times 10^{13} n/cm^2$



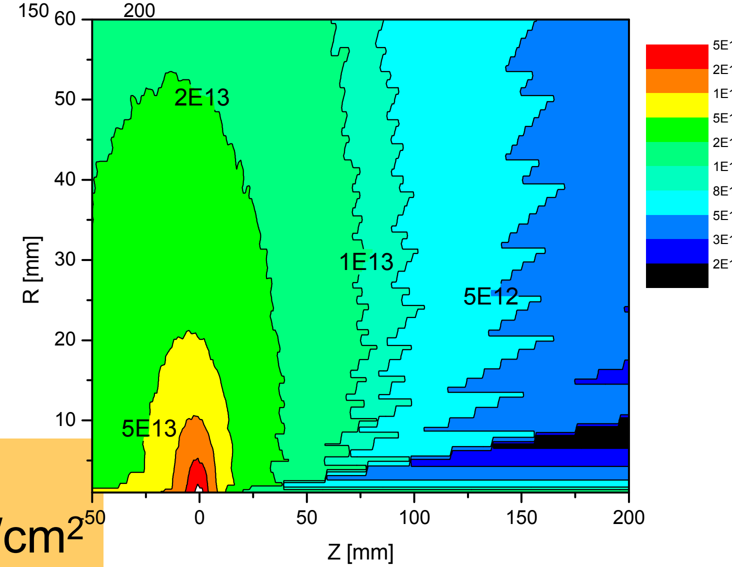
antipCu @ 4.05 GeV/c
fluence below $2.5 \times 10^{13} n/cm^2$



antipAu @ 4.05 GeV/c
fluence below $6 \times 10^{13} n/cm^2$

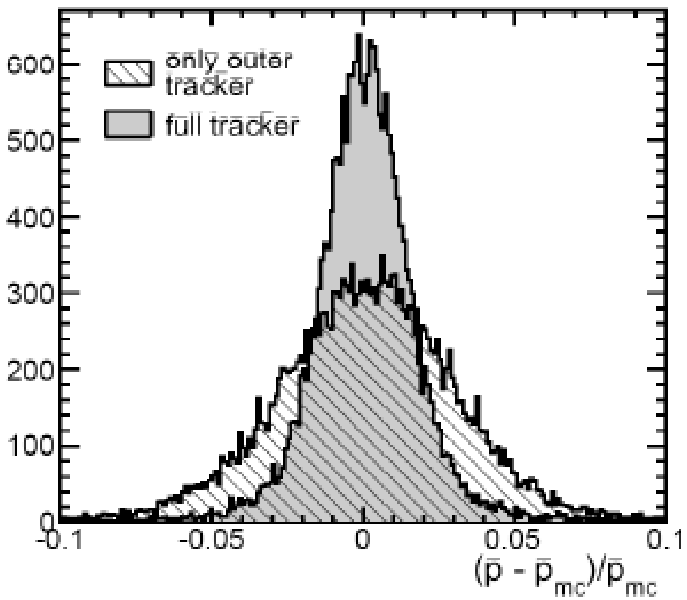


antipPb @ 4.05 GeV/c
fluence below $6 \times 10^{13} n/cm^2$

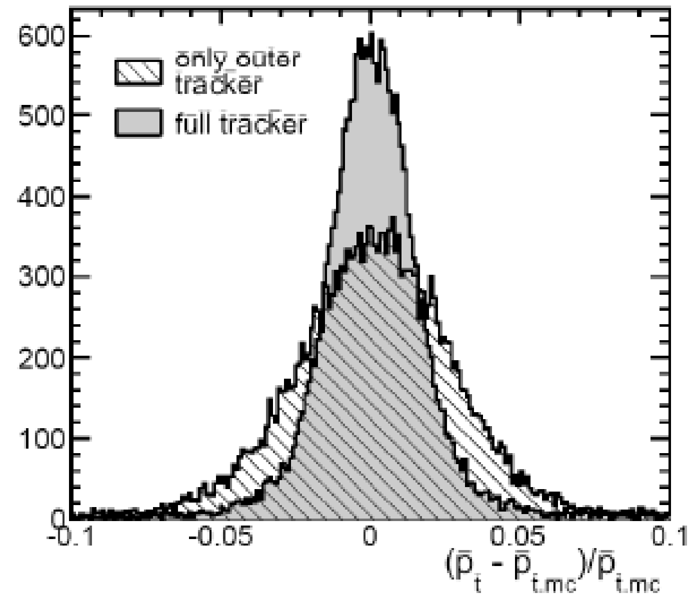


Momentum resolution of PANDA detector

p



p_t



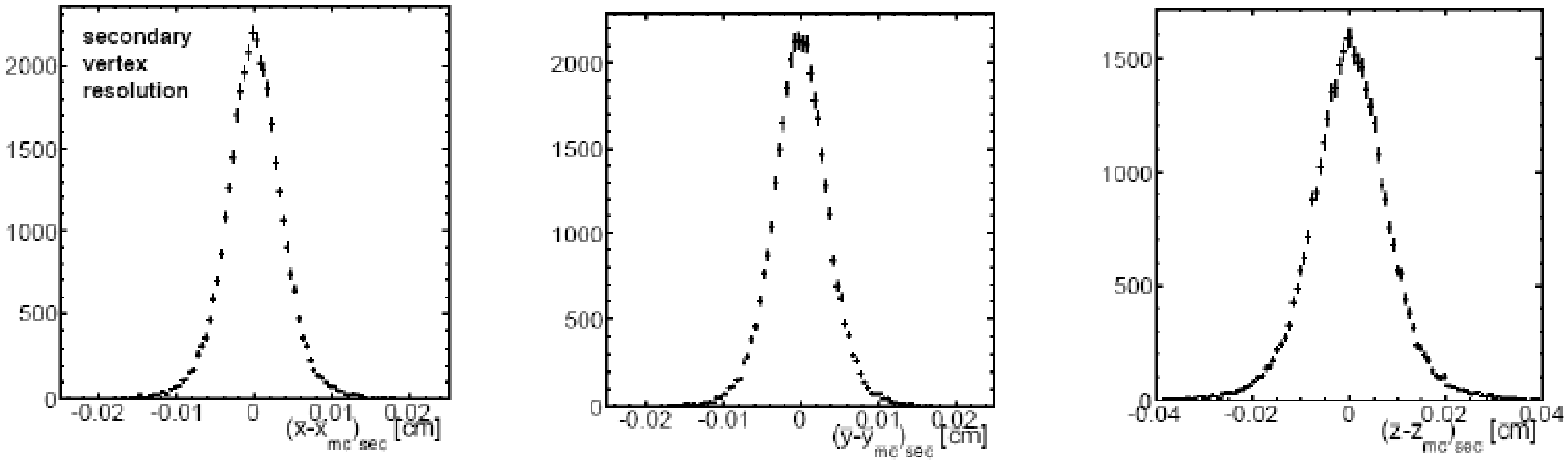
R. Jäkel PhD thesis in preparation

$\sigma(p)$ [1GeV/c pions] without MVD = 2.6%

$\sigma(p)$ [1GeV/c pions] with MVD = 1.4%

Secondary vertex resolution

antip p -> D^+D^-



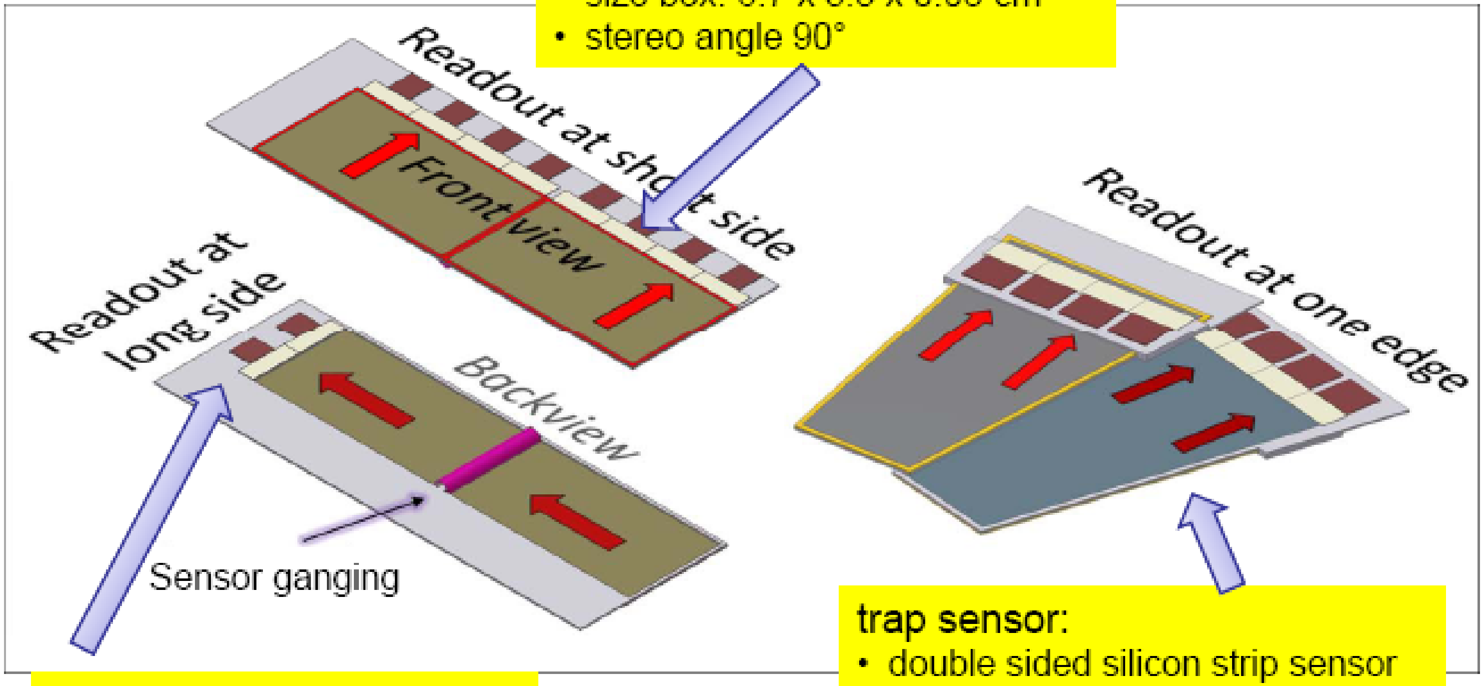
R. Jäkel PhD thesis in preparation

- Fully reconstructed D+D- pairs
- Vertex resolution:
  35 μm in x and y
  77 μm in z (at 6.57 GeV/c beam momentum)

R. Jäkel PhD thesis in preparation

Strips detector

rectangular sensor:
- double sided silicon strip sensor
- pitch: 130 µm (0.65 µm)
- size box: 6.7 x 3.3 x 0.03 cm^3
- stereo angle 90°



front-end electronic:
- custom development together with GSI
- untriggered readout

trap sensor:
- double sided silicon strip sensor
- pitch: 70 µm
- size box: 6.1 x 3.5 x 0.03 cm^3 15°
- stereo angle 15°

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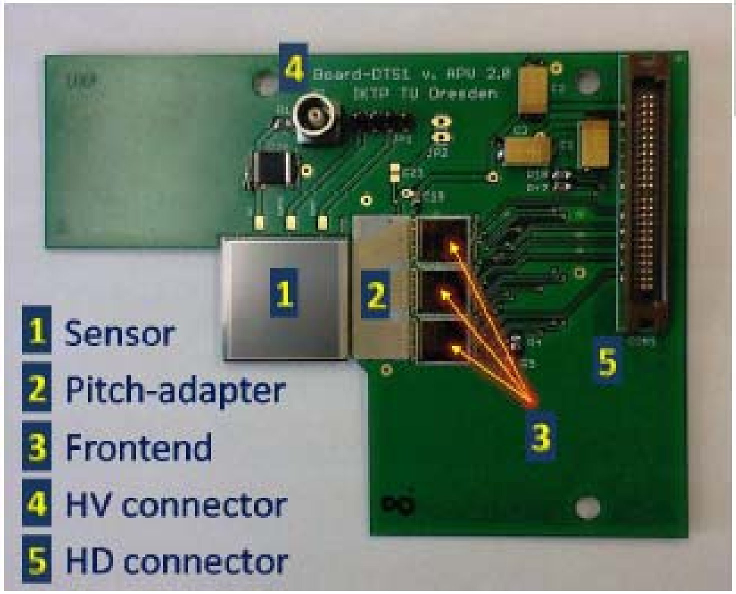
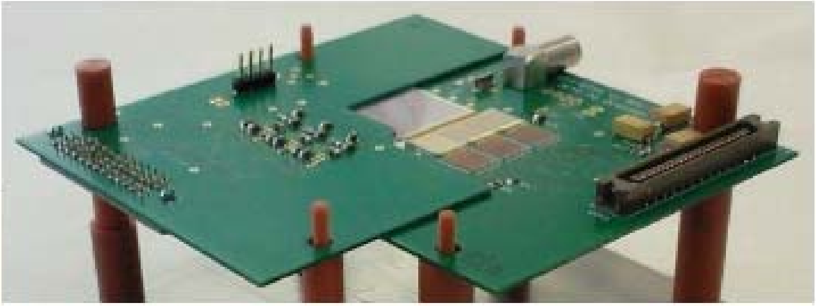
Strip prototype

First small sensor prototype with APV readout





Pixel Detector

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Pixel Detector

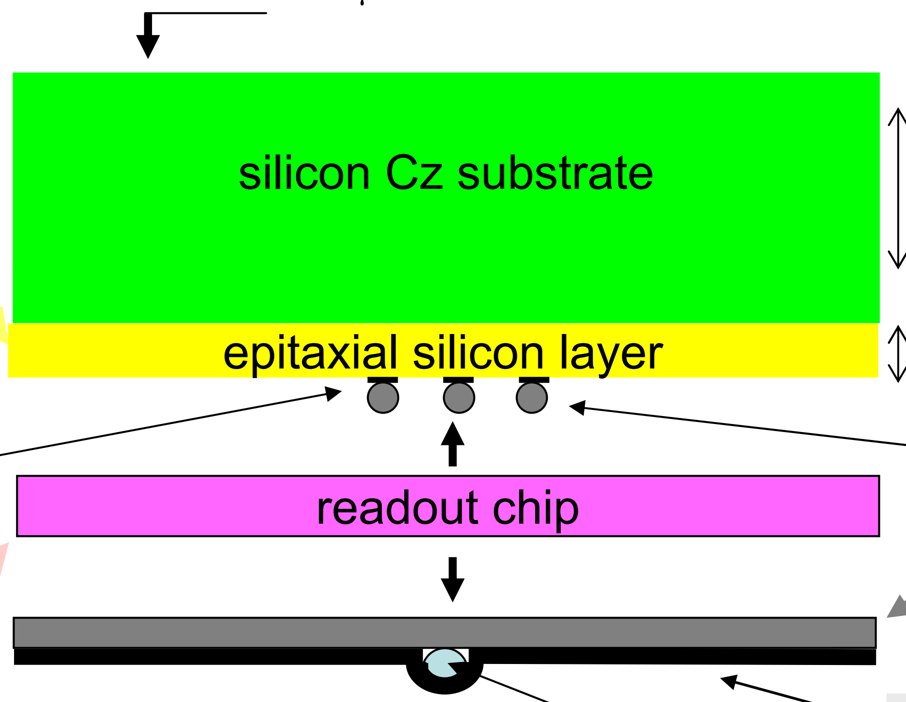
Pixel Detector (~ 0.12 m^2):

- ~ 11 Mpixel with 100 μm x 100 μm size
- ~ 1100 FE readout chip (~ 100x100 pixel)
- continuous data transmission without trigger
- maximum chip rate: ~ 12.3 MHz for pbar-Au at 15 GeV/c
- maximum chip data rate: ~ 0.6 Gb/s (~ 50 bit/pixel)
- energy loss measurement: Time over Threshold; dynamic range: → 100 fC

Standard hybrid technology

THIN PIXEL SENSORS (< 150 μm) realized with EPITAXIAL SILICON material (FBK)
(At LHC experiment Si sensors 200 μm thick. At RD50 epitaxial silicon material only for diodes)

The thinning starts from this side, reducing the substrate to tens of μm.



ρ = 0.01÷ 0.02 Ω·cm
d = some hundreds of μm

ρ = 3 ÷ 4 KΩ·cm
d = 25 ÷150 μm

Several processes for defining geometry and for obtaining pixel sensors are made on this side

Bump bonding

Carbon foam support to improve power dissipation

Carbon fiber mechanical support

Cooling system

ASIC developed by the 130 nm CMOS technology with triggerless readout.
Up to now only in 250 nm CMOS technology (see LHC experiment with trigger)

Epitaxial silicon devices

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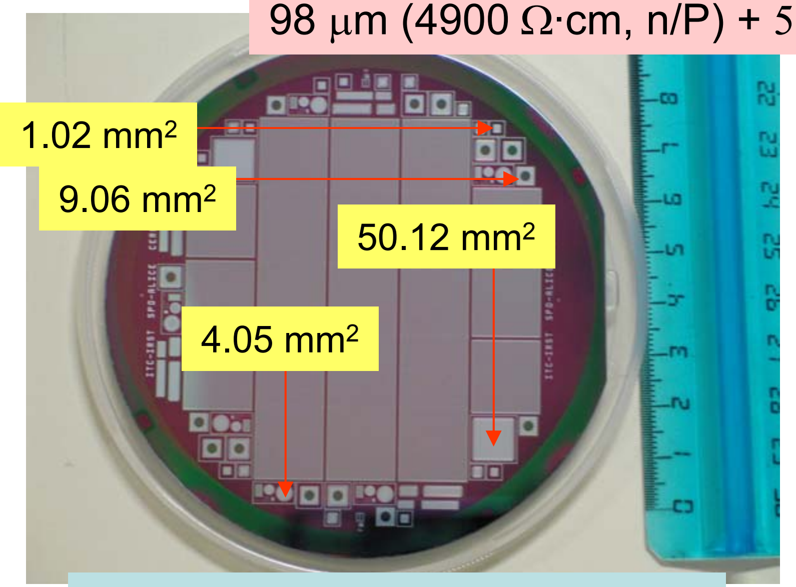
Diodes and single chip sensor from epi-wafers

49 μm (4060 Ω·cm, n/P) + 500 μm Cz substrate (0.01-0.02 Ω·cm, n^+/Sb) → 100 μm
74 μm (4570 Ω·cm, n/P) + 500 μm Cz substrate (0.01-0.02 Ω·cm, n^+/Sb) → 120 μm
98 μm (4900 Ω·cm, n/P) + 500 μm Cz substrate (0.01-0.02 Ω·cm, n^+/Sb) → 150 μm

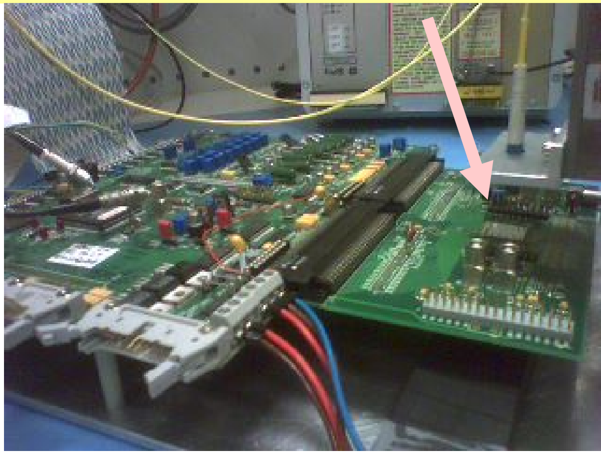


with the ALICE layout at FBK

300 μm FZ wafer have been used as reference

Single chip assembly

- ✓ pixel obtained with the ALICE masks (50 μm x 425 μm)
- ✓ test performed using ALICE pixel readout chip and test system in collaboration with P. Riedler

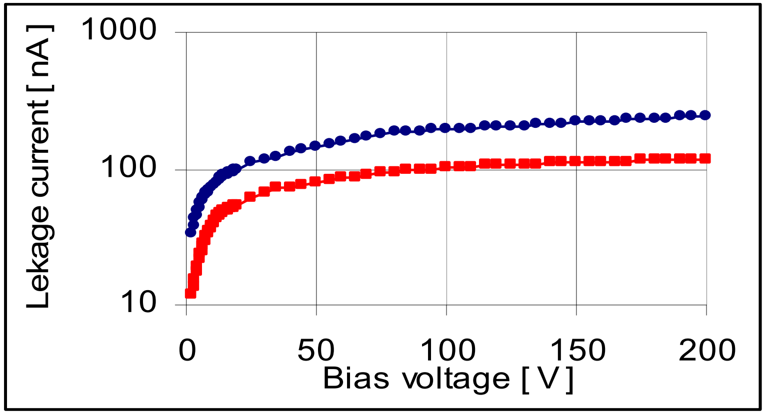


Diodes

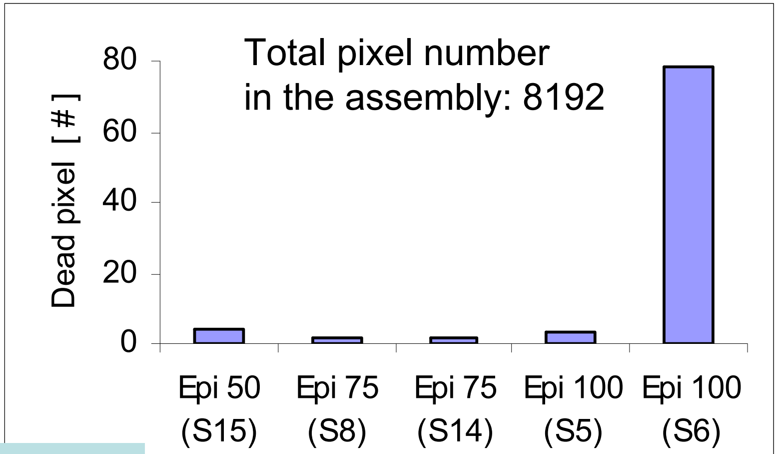
Test of radiation damage with neutrons from Pavia nuclear reactor. Equivalent fluence values on the diodes : 5.13×10^{13}, 1.54×10^{14}, 5.13×10^{14} $n(1MeV_{eq})/cm^2$ corresponding to 1, 3 and 10 years of PANDA lifetime

Results from thin Si-epitaxial pixel assemblies

Epi 75 and Epi 50

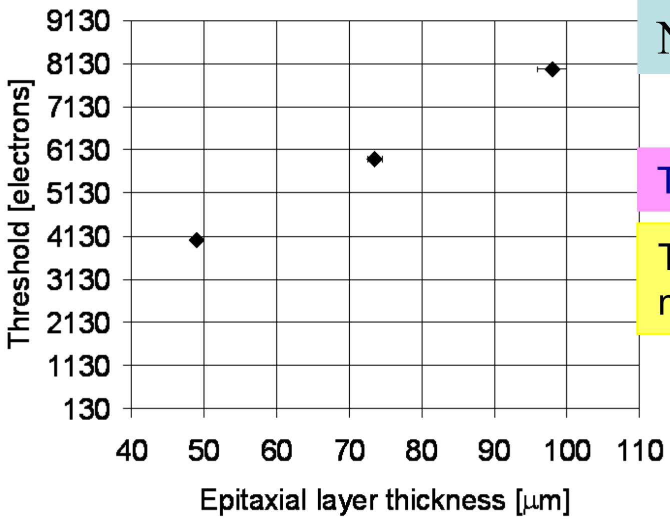


Test performed with a ^{90}Sr source to verify the bump bonding process



Dead pixel % ≤ 0.05 %; ≤ 1% (worst case)

NIM A594 (2008) 29–32



Test performed with a ^{90}Sr source

Threshold values in electrons corresponding to the Landau most probable value for the different epitaxial layer thicknesses

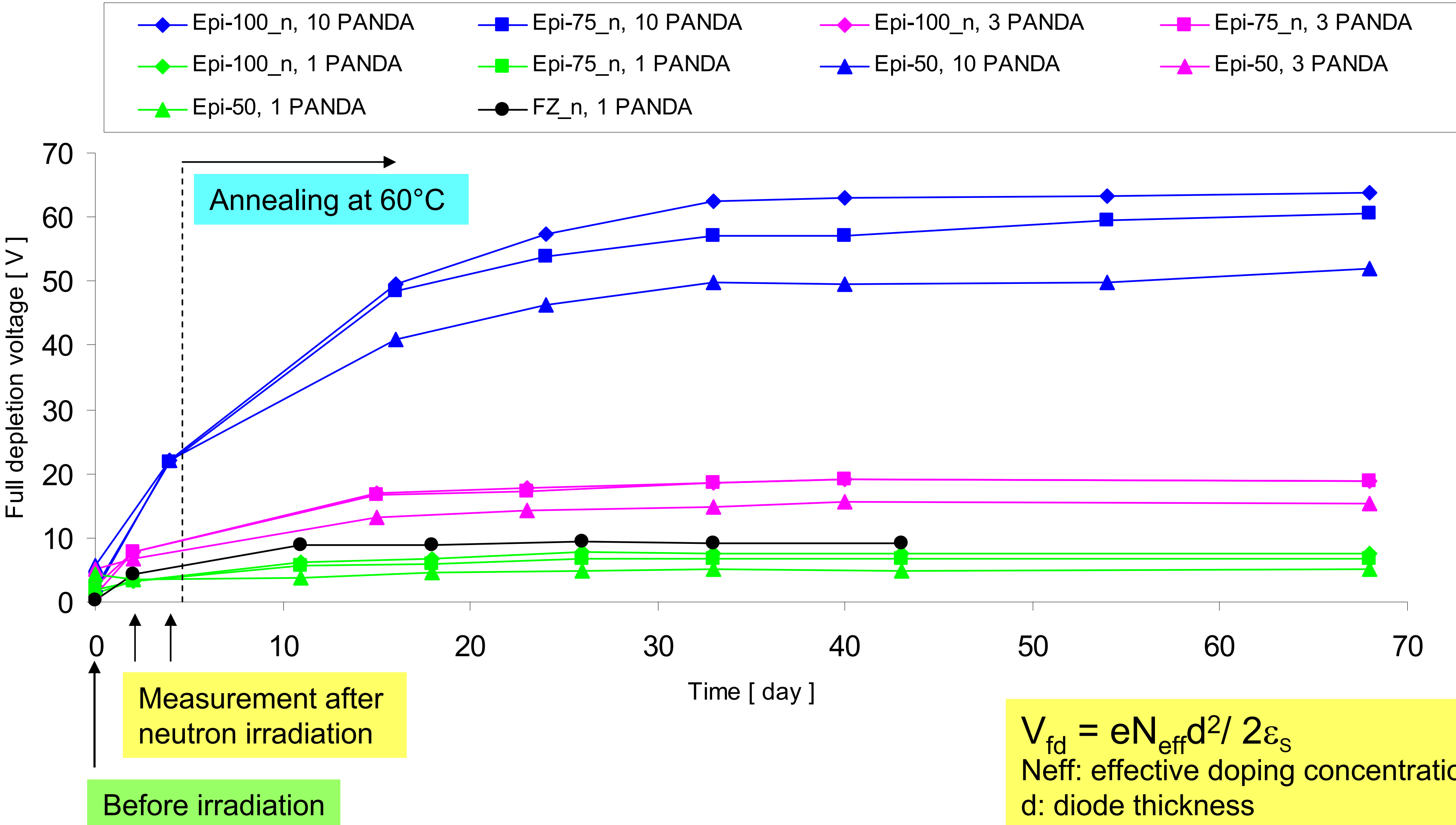
Confirmed by the linearity of the result, charge sharing is not a major issue – despite the 50μm pixel width – due to the fact that the active thickness is equally limited

Taking 22.500 electrons for a true MIP in 300μm of silicon -> 7500 electrons from 100μm of silicon,
the beta source should raise that value somewhat (about 8000 electrons in 100μm)
the agreement seems more than satisfactory.

Results from radiation damage test:

full depletion voltage normalized to epi50

Equivalent fluence values on the diodes : 5.13×10^{13} 1.54×10^{14} 5.13×10^{14} $n(1MeV_{eq})/cm^2$
corresponding to 1 3 and 10 years of PANDA lifetime



$V_{fd} = eN_{eff}d^2/ 2\varepsilon_S$

Neff: effective doping concentration

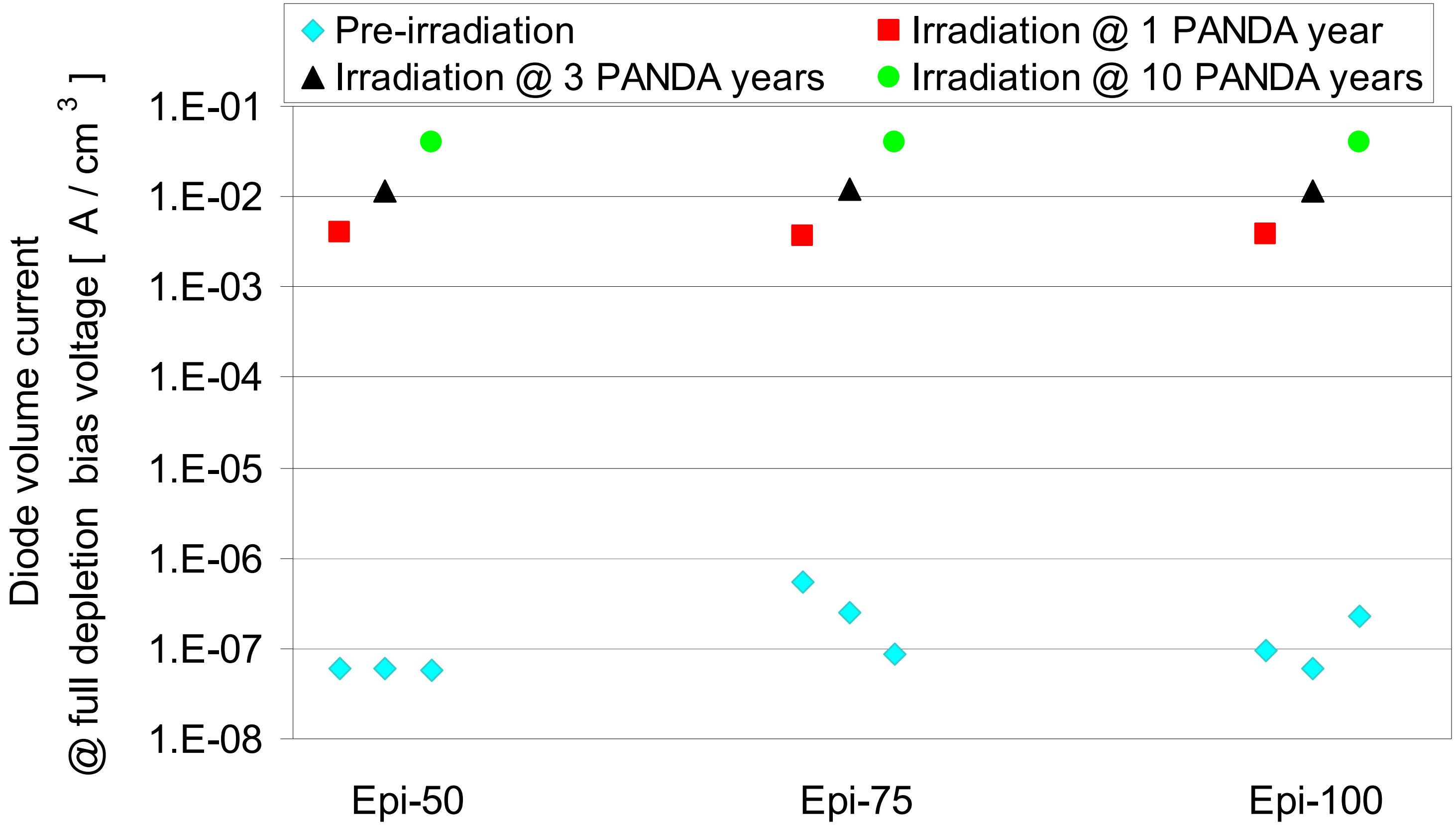
d: diode thickness

ε_S : silicon dielectric constant

Results from radiation damage test:

the radiation damage constant

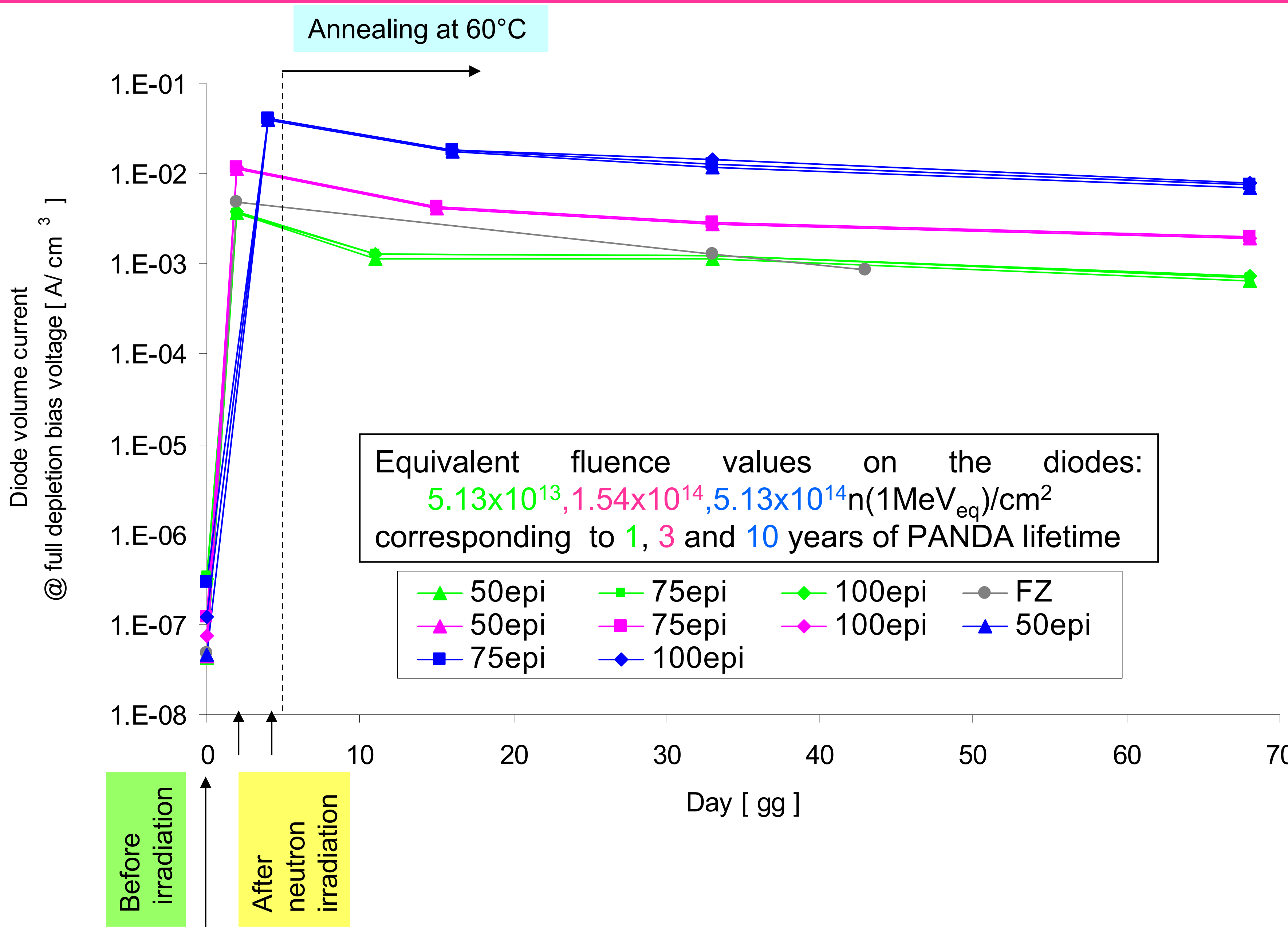
Equivalent fluence values on the diodes : 5.13×10^{13}, 1.54×10^{14}, 5.13×10^{14} $n(1MeV_{eq})/cm^2$ corresponding to 1, 3 and 10 years of PANDA lifetime



The radiation damage constant is
$\alpha = \Delta J/\Phi = 7.6(\pm 0.3) \times 10^{-17}$ A/cm for all diodes.

Lekage current < 50 nA/pixel (100 μmx100μm size, 100 μm thick)

Results from radiation damage test:
diode volume current @ full depletion voltage

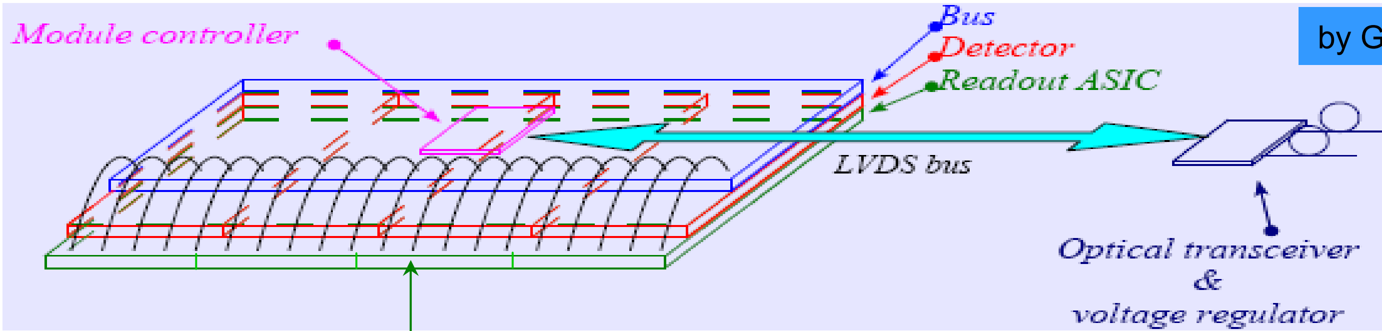


ASIC prototype

D. Calvo

First pixel readout prototype

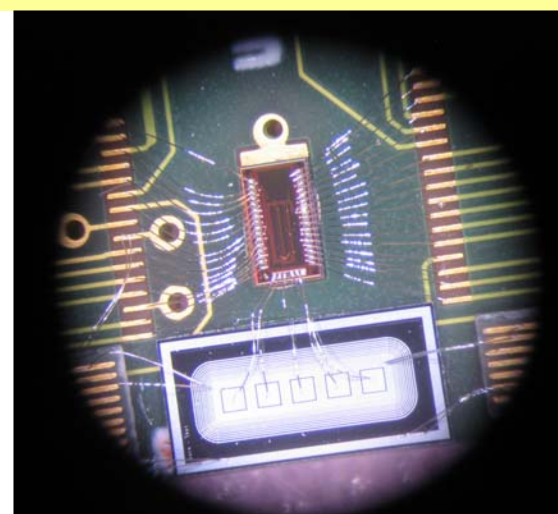
by Gianni Mazza



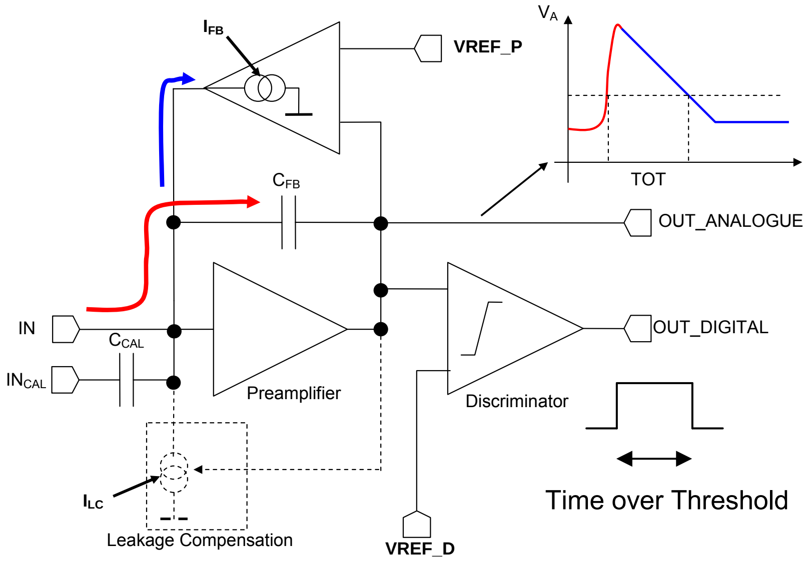
Readout chip

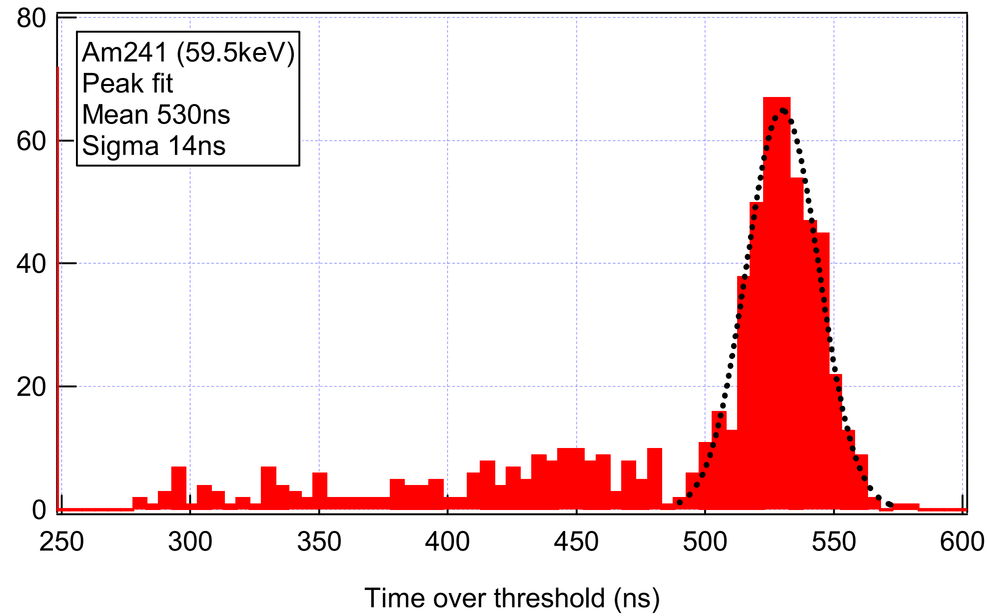
ToPix_1, CMOS 130 nm technology

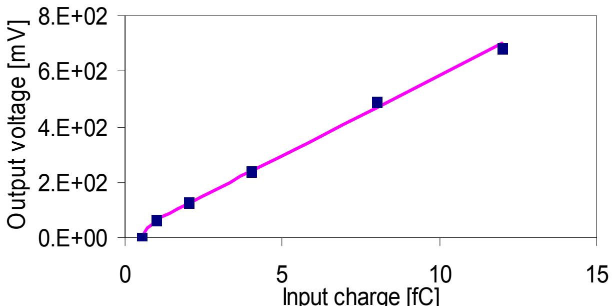
- ✓ 3x2 mm² area, 32 cells (8 selectable groups) with pre-amplifier and discriminator
- ✓ no bump bonding pads, but 6 input lines for connecting external sensors
- ✓ analog power consumption below 12µW @1.2V
- ✓ absence of enclosed structures to study the radiation tolerance of the 130nm CMOS technology



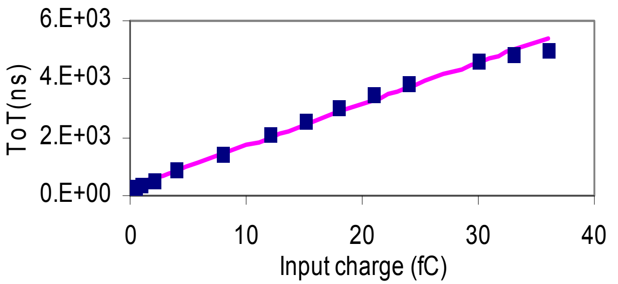
Results from ToPix_1







The preamplier saturates at 12 fC, but….



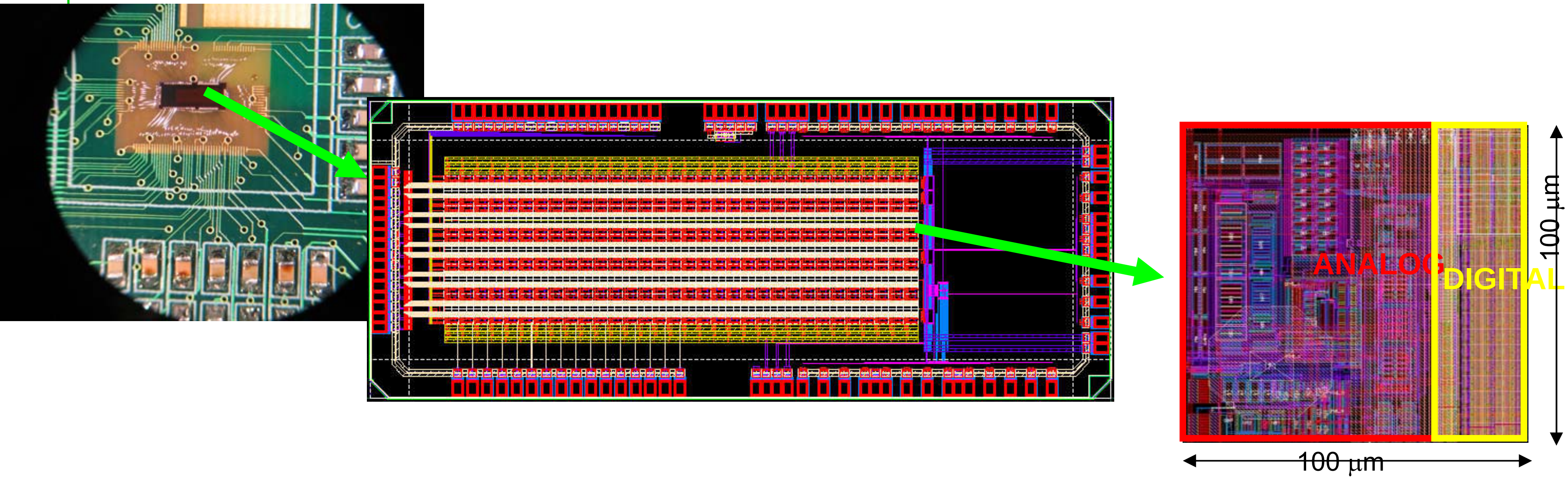
….the ToT preserves good linearity at least up to 40 fC

TID test with X ray sources at CERN and Alessandria University	High dose rate 400 rad/s (20 Mrad)	Low dose rate 1.1 rad/s (3Mrad)
Leakage current max. variation (mean value 3mA)	11 %	8 %
Threshold and baseline max. variation (mean value:300 mV)	11 %	5.5 %
Preamplifier gain relative variation	3 %	1.5 %
ToT gain relative variation	18 %	9 %

Second pixel readout prototype

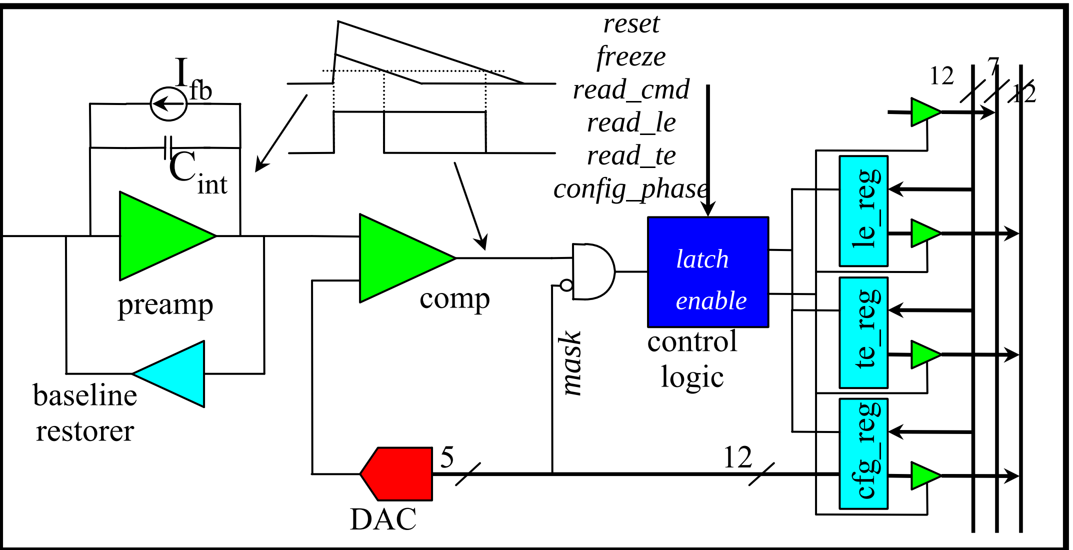
ToPix_2, CMOS 130 nm technology

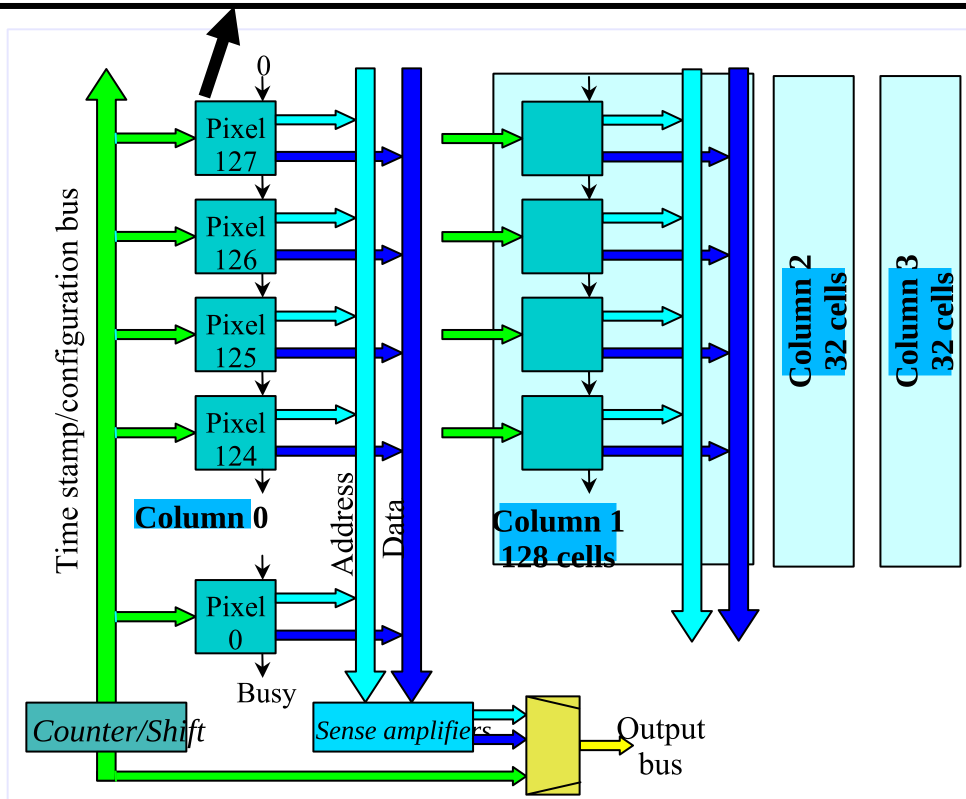
- 5x2 mm^2 area with 4 folded columns with a total of 320 readout cells of 100x100μm^2 size
- analogue + digital circuits (analog power consumption below 12μW @1.2V)
- Time over Threshold technique implemented to obtain a energy loss measurement
- SEU-hardened memory cells (Dice layout)
- absence of enclosed structures to study the radiation tolerance of the 130nm CMOS technology
- inputs for connecting external sensors
- selectable input polarity
- comparator threshold controlled by DAC (5 bits)
- 12 + 12 bits leading and trailing edge, 12 bits configuration registers
- 12 bits bus for time stamp and 12+7 bits output bus for data + address

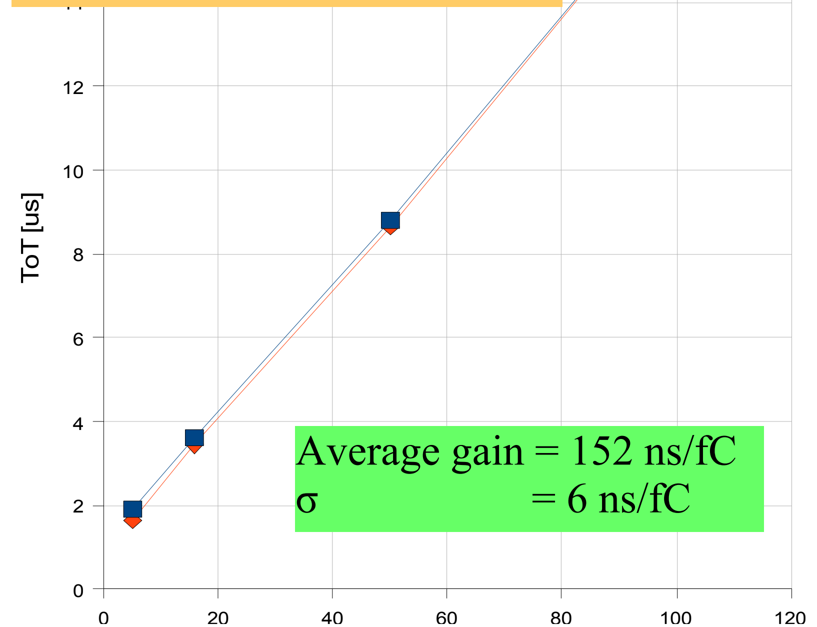


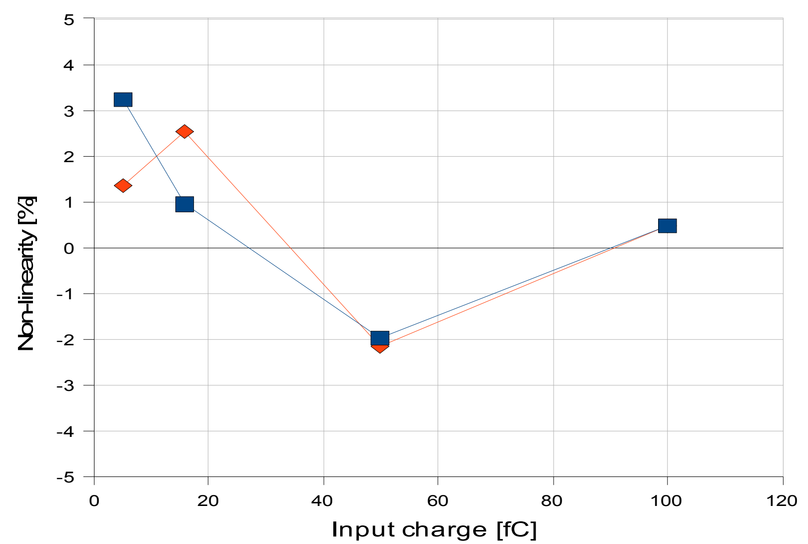
The architecture of ToPix_2

ToT technique allows to achieve good linearity and resolution, even when the premplifier is satured (high dynamic range->1÷100fC)

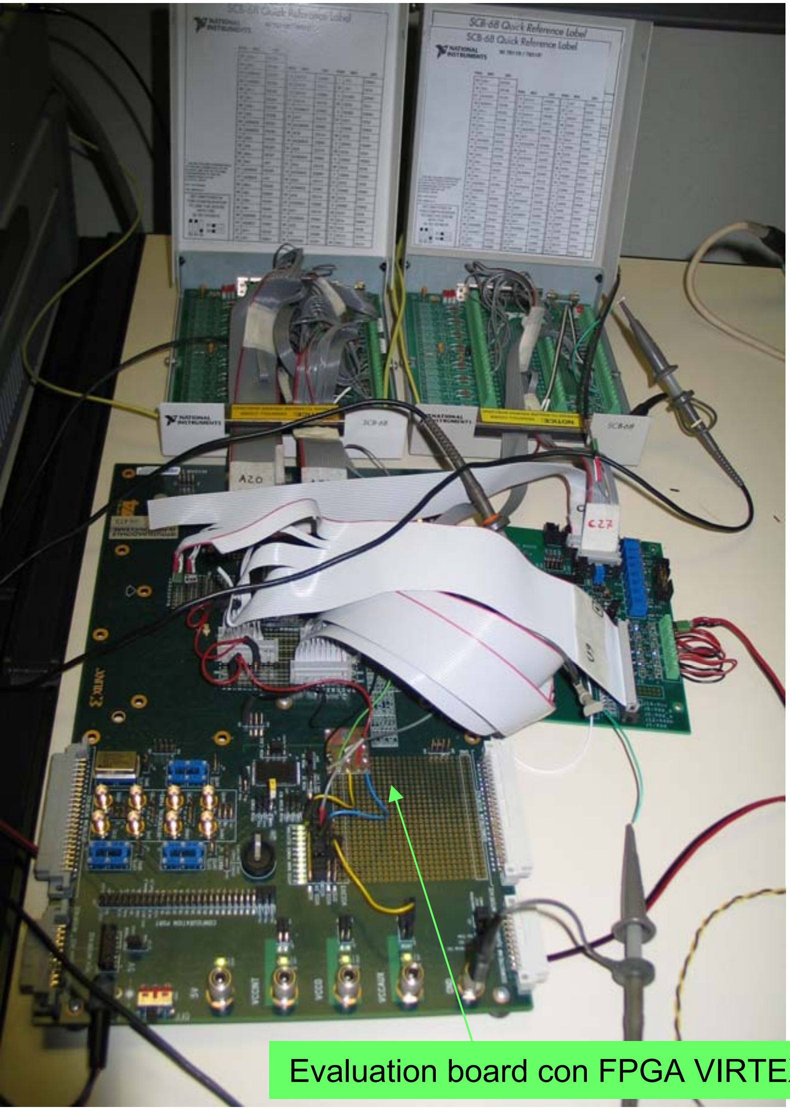






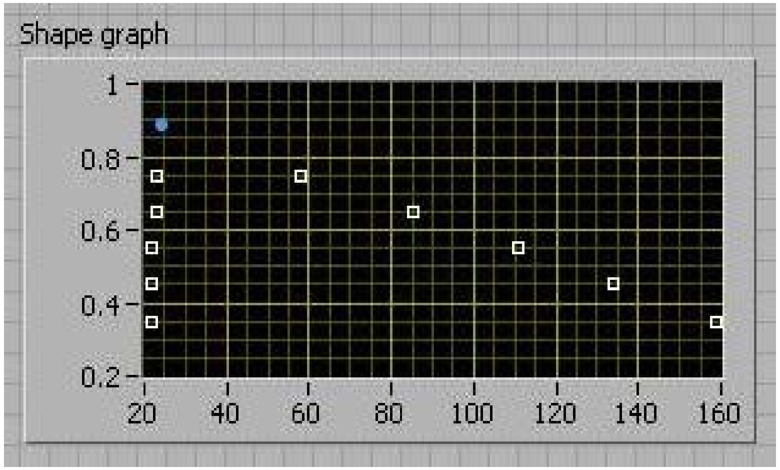


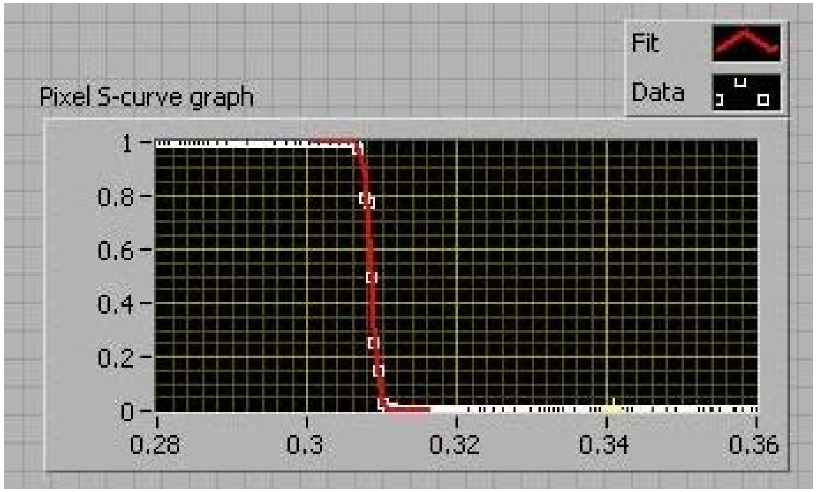
Test station of ToPix_2



Evaluation board con FPGA VIRTEX4

Communication protocol has been verified at 50MHz



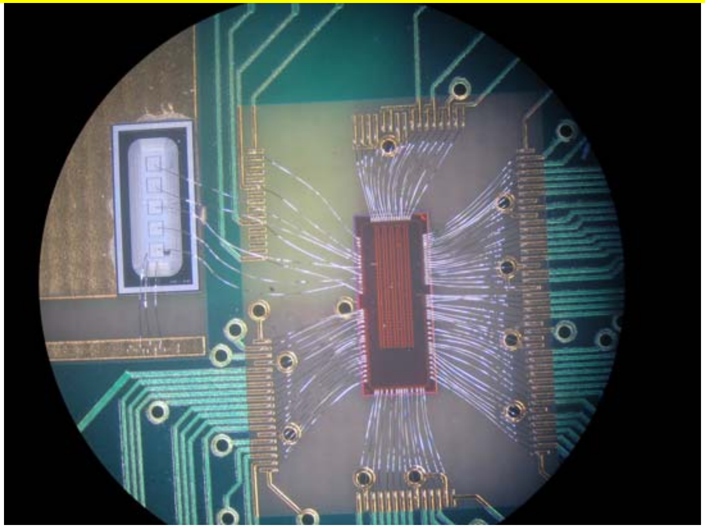


Parameter under test:

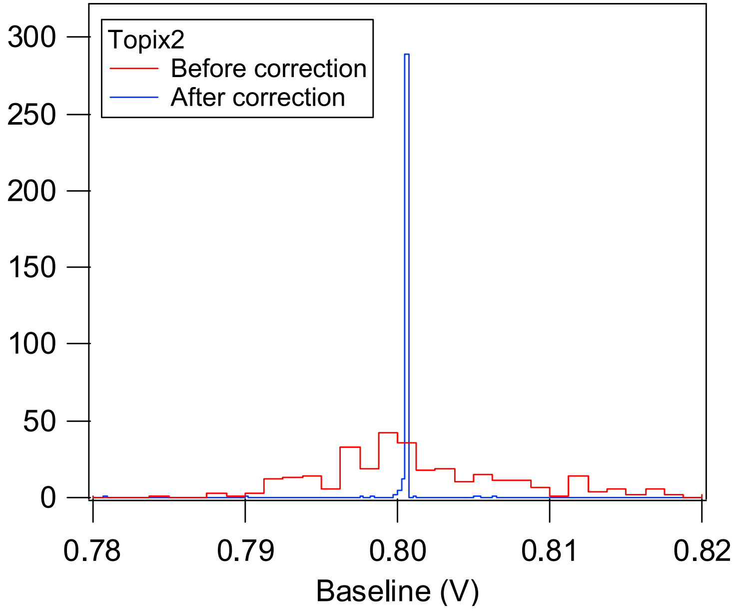
The tail slope of the amplifier, which provides the informations on the current generator.

The S curve of the discriminator, which gives the value of the amplifier baseline.

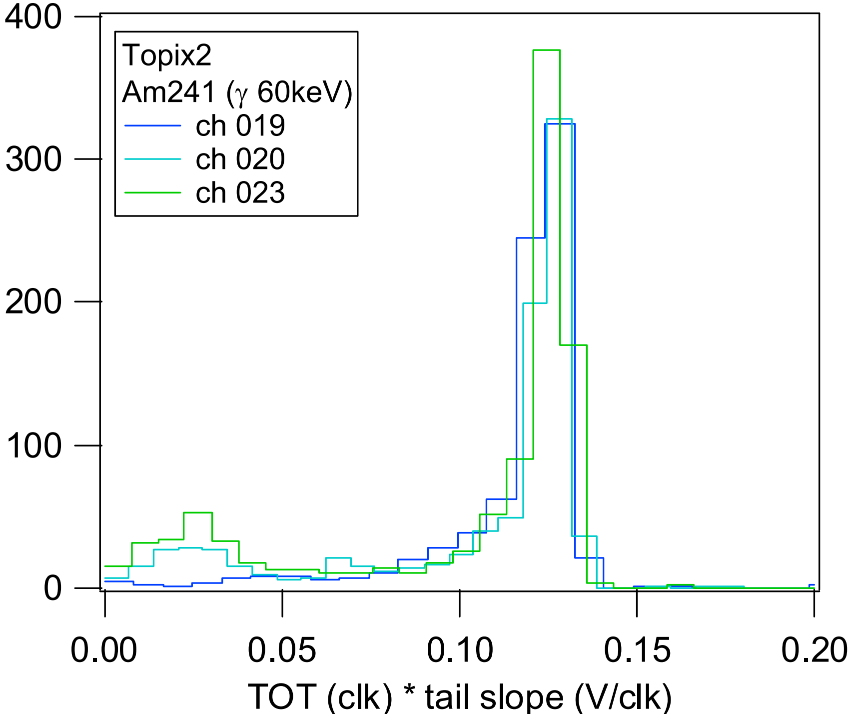
ToPix_2 and sensor



- ToPix_2 - FZ pixel (400μm x 400μm, 200 μm thick) connection using wire bonding
- test with gamma rays (60 KeV) from ^{241}Am radioactive source



Individual pixel DAC baseline correction

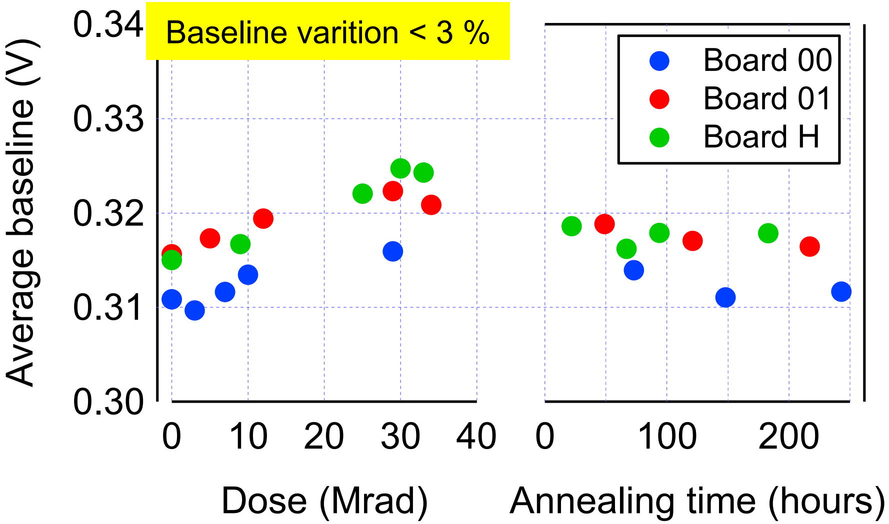


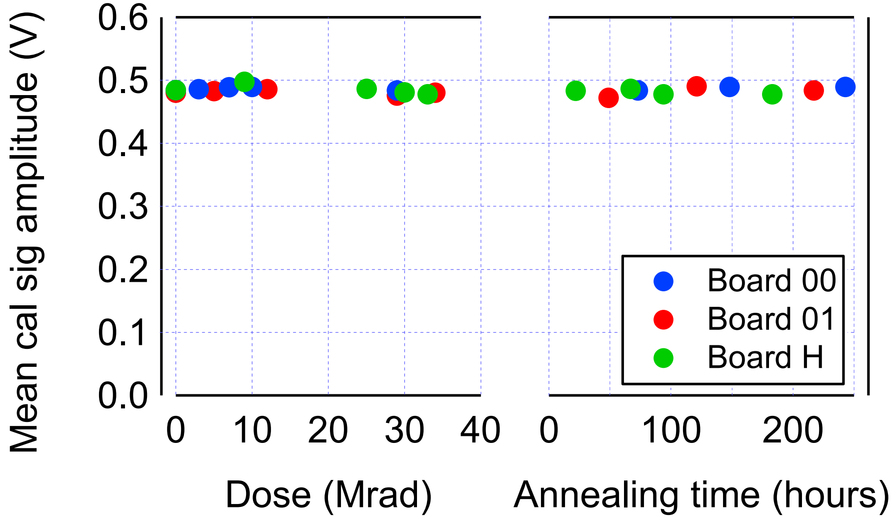
TOT calibration

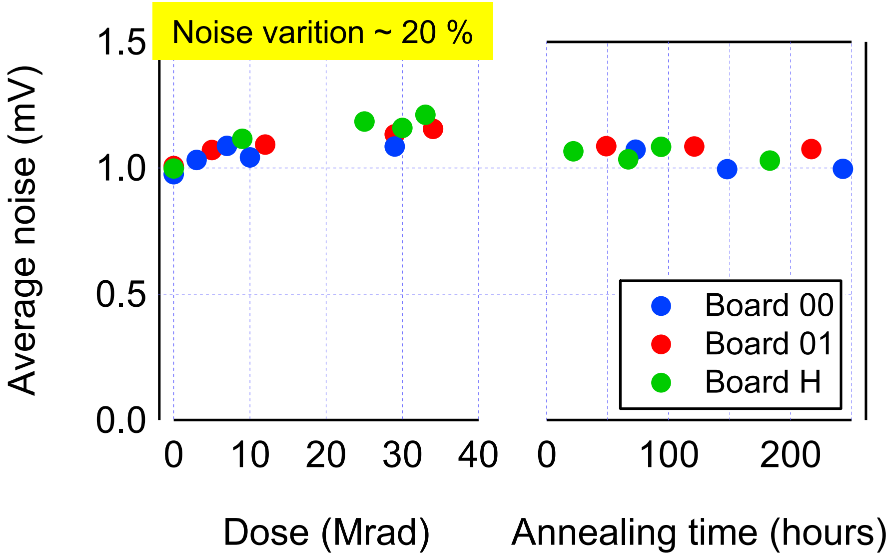
TID test on ToPix_2

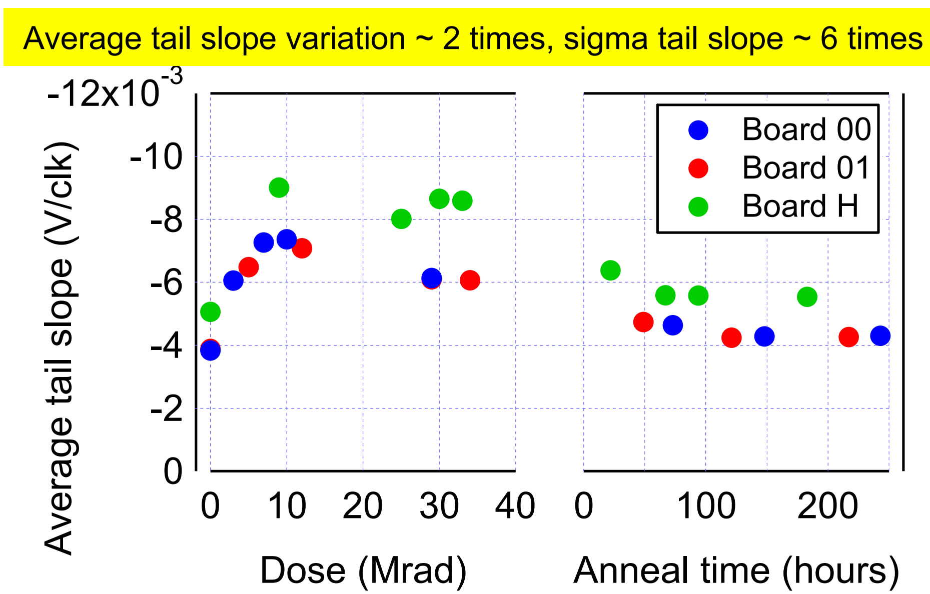
Total Ionizing Dose (TID) with X rays for 6 chips:

• 600 rad/s (> 30 MRad final dose) + annealing phase at 25/100 °C (X ray source provided at CERN by Federico Faccio)





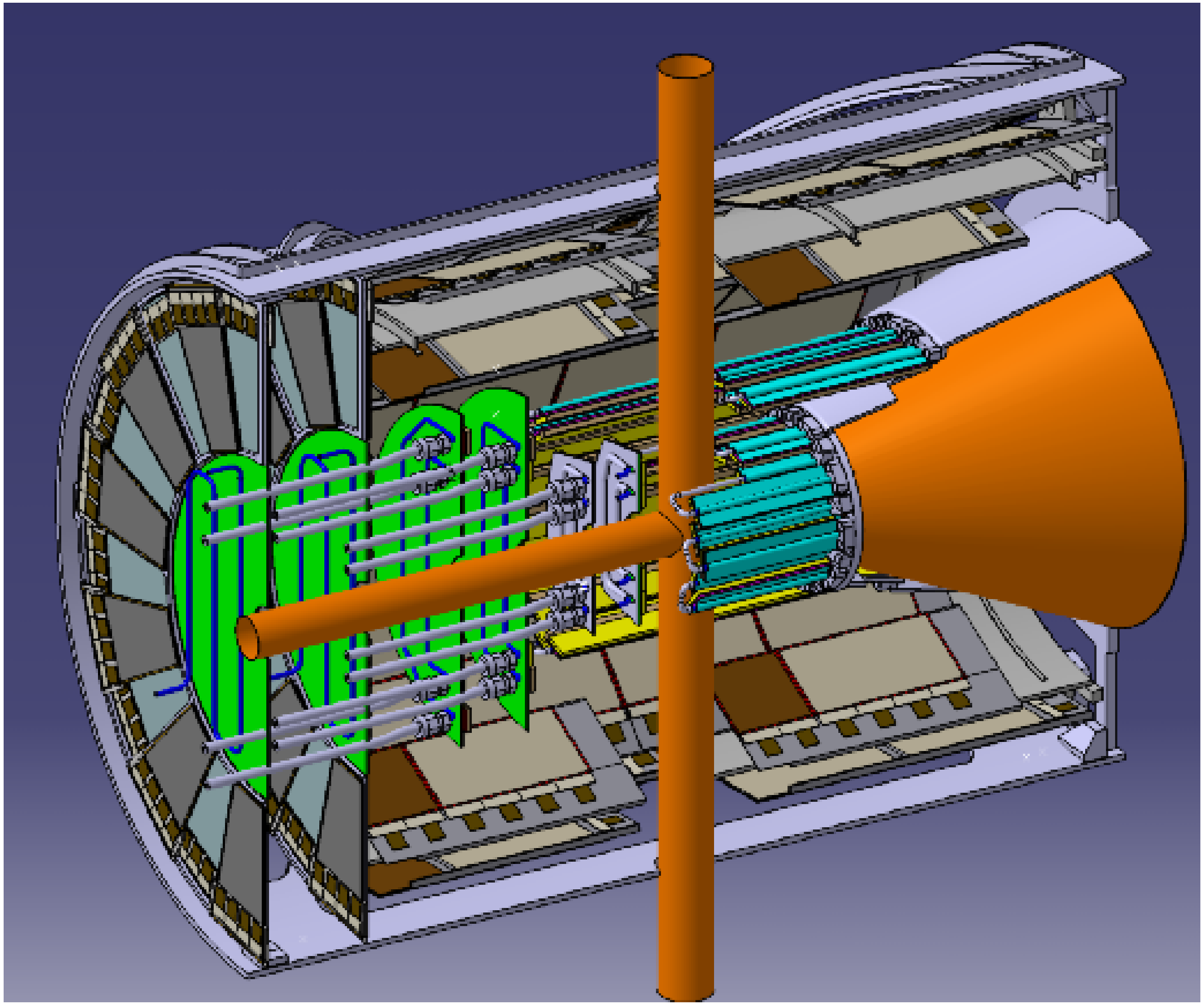




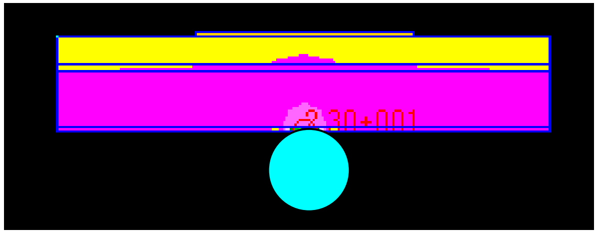
Mechanics and cooling

D. Calvo

Preliminary MVD mechanics and cooling design

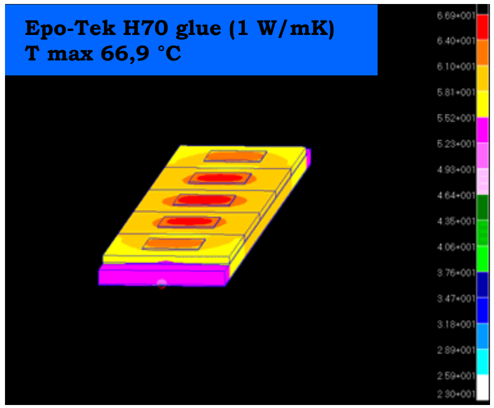


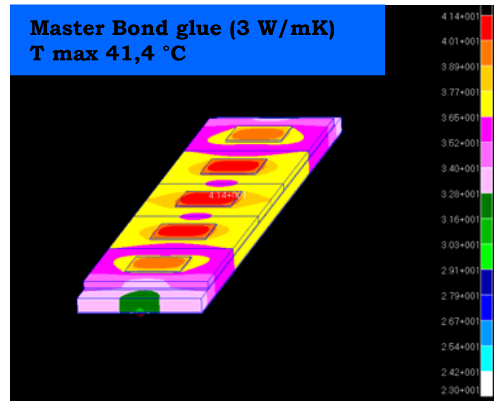
Thermal Slimulations of the Test Model

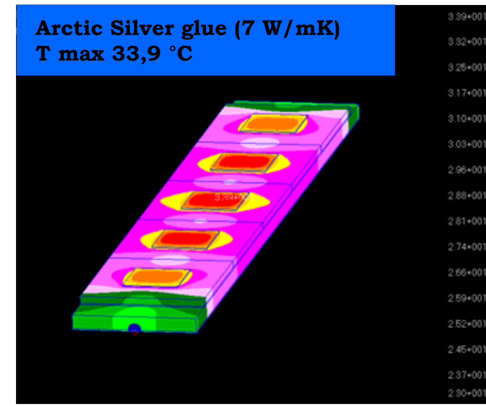


FIRST TEST MODEL:
Dummy FEE: 0,5 mm Alumina (20 W/mK) + 0,1 mm with Power: 5W
Glue layer: 0,1 mm (Epo-Tek H70, Master Bond EP30AN, Arctic Silver)
Carbon foam: 1 mm (40 W/mK)
Glue layer: 0,1 mm (Epo-Tek H70, Master Bond EP30AN, Arctic Silver)
Cooling water 18°C (about 23°C on the wall). Flow rate : 0,3 lit/min
MODEL LENGHT: 50 mm

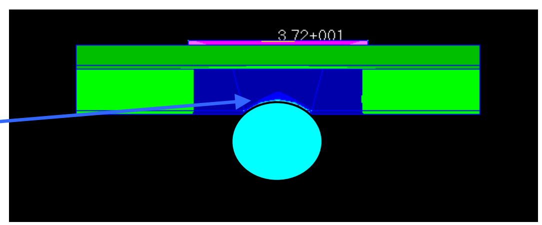
Different Thermal glues



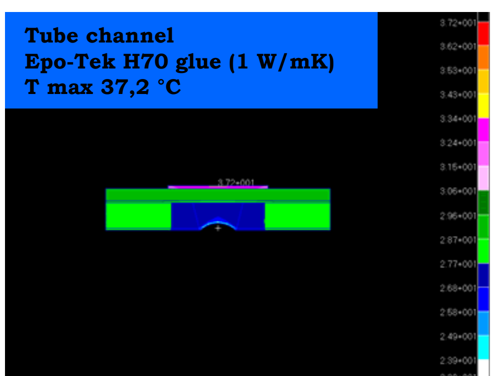


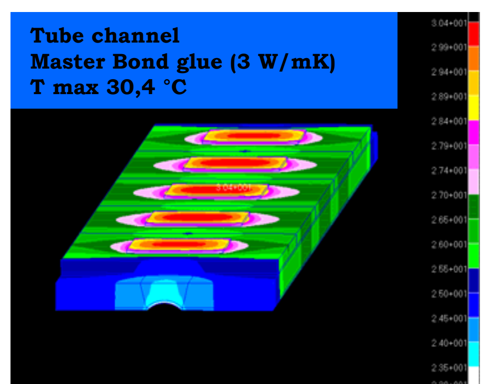


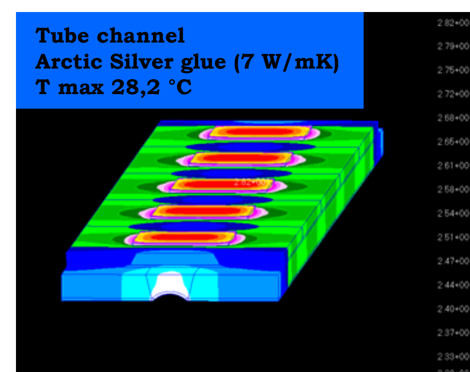
Improving contacts



Better contact and different glues

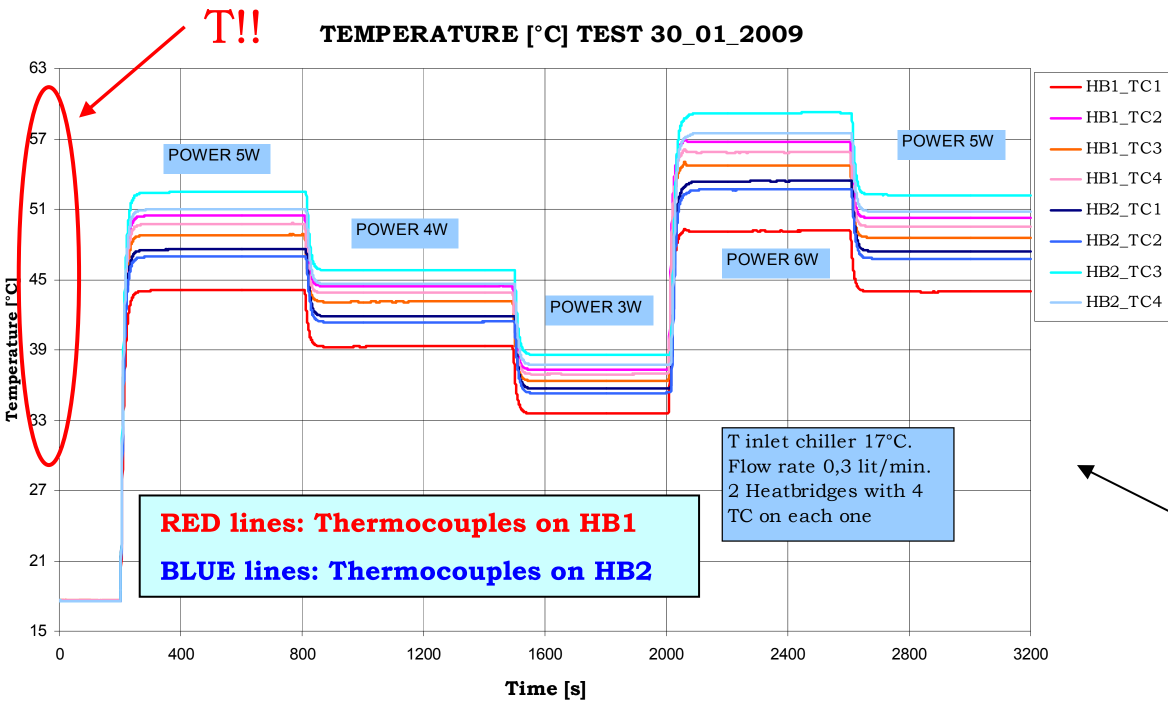


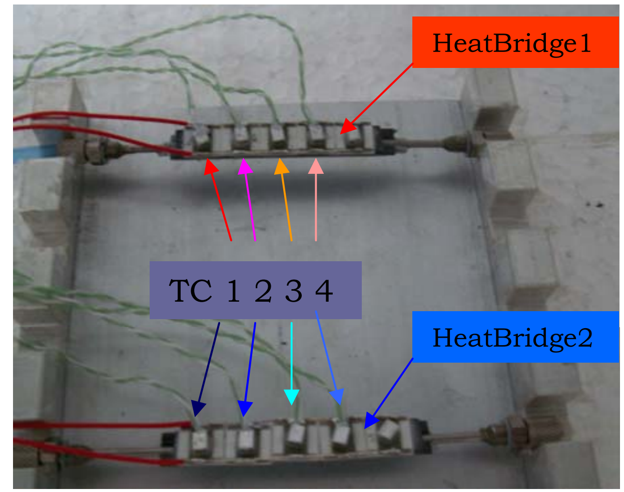


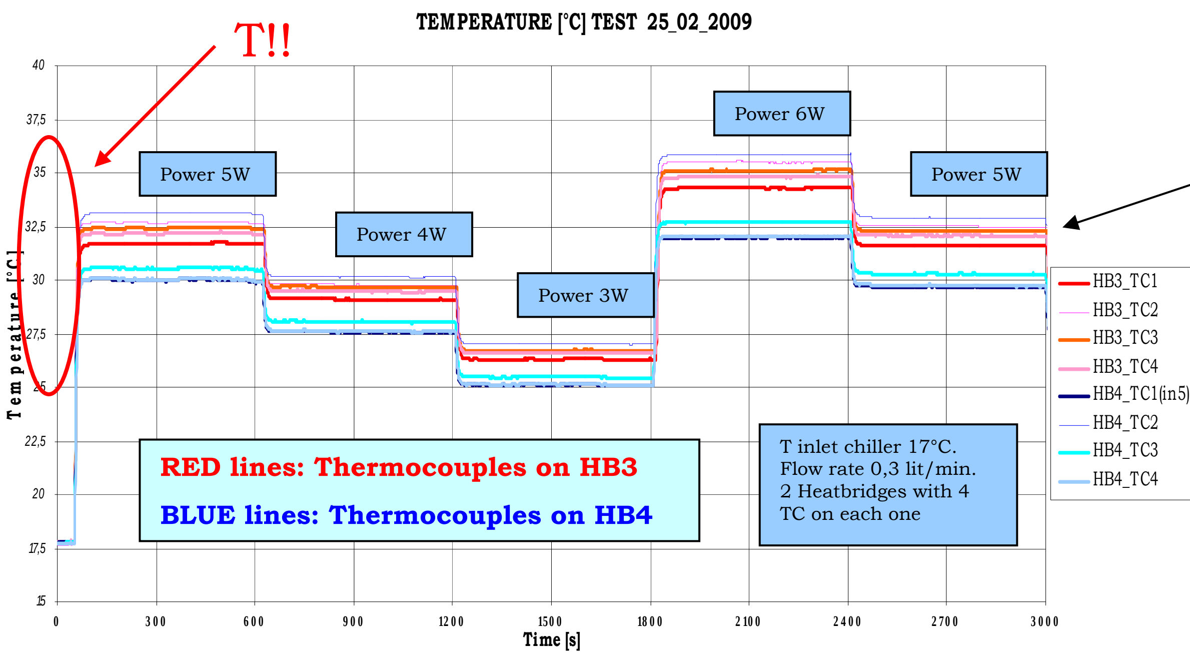


TEST RESULTS ON PROTOTYPES GLUED WITH MASTER BOND

HB1 and HB2: Omega in carbon fiber; tube in MP35N 2mm O.D. and 1,84 mm I.D; carbon foam 1 mm; dummy chip in alumina.





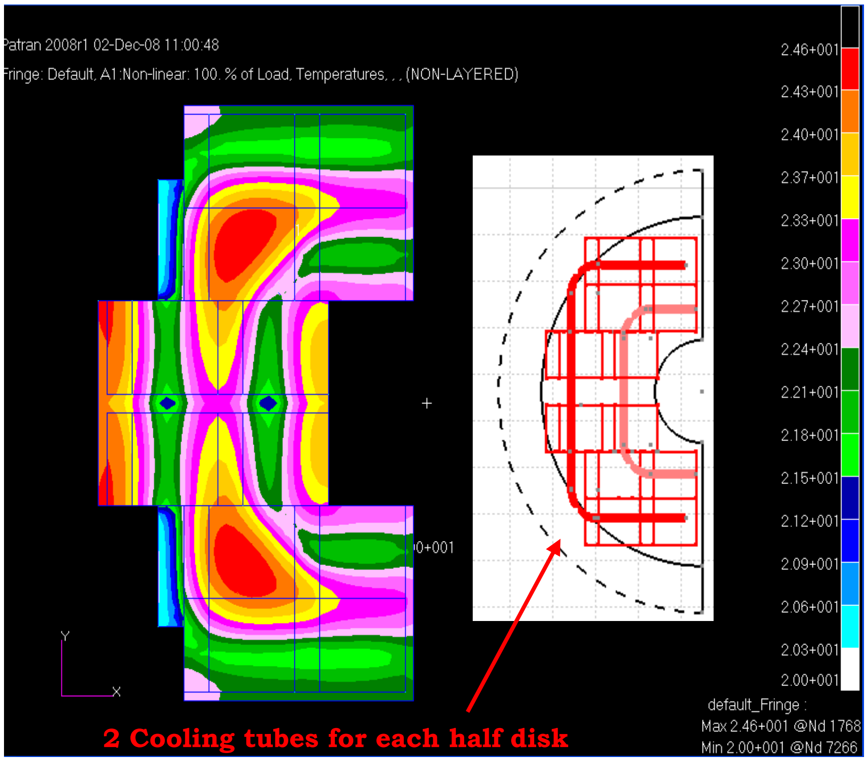


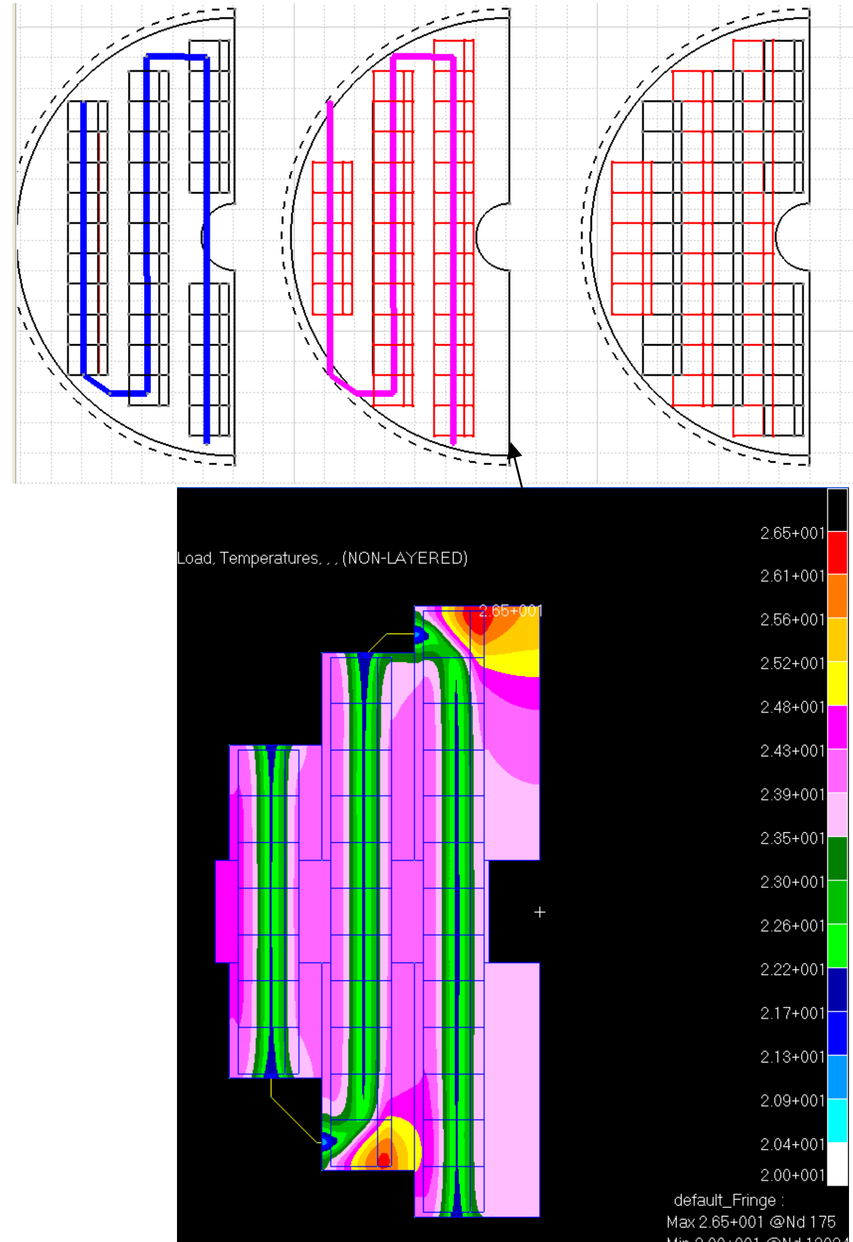
TEST RESULTS ON 2 PROTOTYPES GLUED WITH ARTIC SILVER

HB3: Omega in carbon fiber; tube in MP35N 2mm O.D. and 1,84 mm I.D.; carbon foam 1 mm; dummy chip in alumina. Problem with dummy chip2: probably damaged (HB3_TC2 instable).

HB4: Omega in carbon fiber; tube in MP35N 2mm O.D. and 1,84 mm I.D.; carbon foam 1 mm; tube contact improved; dummy chip in alumina. Problems with welds in dummy chip 1 and 2 (HB4_TC2 higher T respect blue TC1(in5), TC2, or TC3).

Disk cooling studies





D. Calvo

Conclusion

- FAIR is the future european facility for antiproton and ions research
- PANDA design is in progress and first detector prototypes have been made
- Simulation work in progress to optimize the MVD design
- New ASIC prototype under study for the pixel readout
- Further tests on sensors for the pixel detector

Thanks to MVD people !

MVD Group:

- HISKP, Universitat Bonn, Germany
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- IKP, Forschungszentrum Julich, Germany
- IKTP, TU Dresden, Germany
- Universita' di Torino – Fisica Sperimentale
- FBK di Trento

http://www.gsi.de/

http://www-panda.gsi.de/auto/_home.htm

http://panda-wiki.gsi.de/cgi-bin/view/Mvd/MvdPublic