Triggerless Micro Vertex Detector with low material budget in the PANDA experiment

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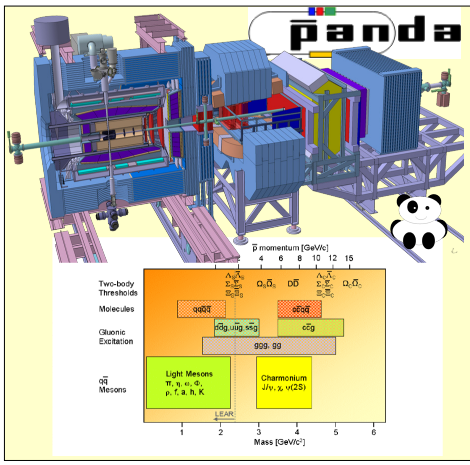
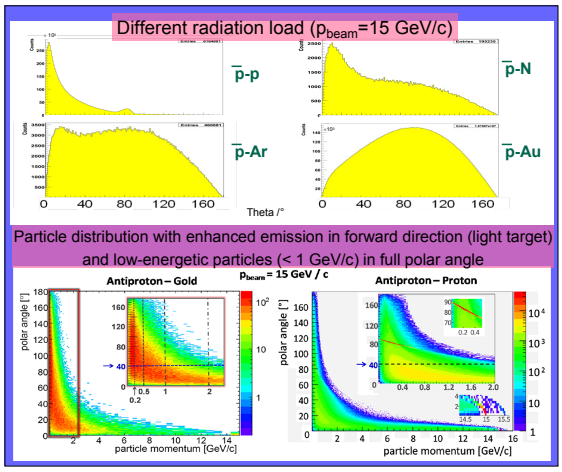
On behalf of the PANDA MVD group



MVD requirements

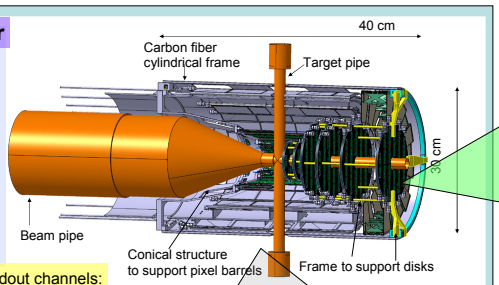
- Good spatial resolution in r - ϕ
  Momentum measurement of pions from D* decays
- Good spatial resolution especially in z
  Vertexing, D-tagging
- Good time resolution
  better than 50 ns with $2 \cdot 10^7$ pbar-p annihilations/s
- Triggerless readout
- dE/dx measurement to improve particle ID
- Low material budget
  low momentum particles (starting from some hundreds of MeV/c) (<1% X_0 for each layer)
- Radiation hardness: ~$4 \cdot 10^{14}$ $n_{1MeV\ eq}$ /cm² (10 years (50%) of pbar-p, 15 GeV/c pbar momentum)
  Depends on target material
  Different radiation load



Micro Vertex Detector

4 barrels
Two inner layers:
hybrid pixel detectors
Two outer layers:
double sided silicon strip detectors

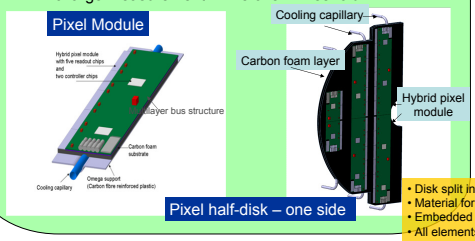
and **6 forward disks**
Four disks:
hybrid pixel detectors
Then two disks:
Mixed pixel and strips



Readout channels:
~ 11 million (pixel)
~ 200.000 (strip)

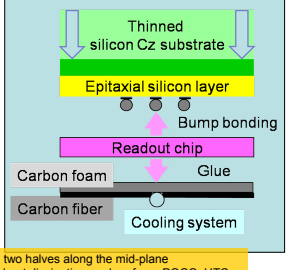
Custom hybrid pixel detector

- **Thin epitaxial silicon sensors**
  - pixel size: 100μm x 100μm
- **Readout developed in 130nm CMOS technology**
  - dynamic range: 12 bits
  - charge measurement: Time over Threshold



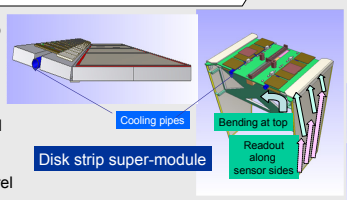
- Disk split in two halves along the mid-plane
- Material for heat dissipation: carbon foam POCO, HTC
- Embedded cooling capillary between the two halves
- All elements glued with thermal glue

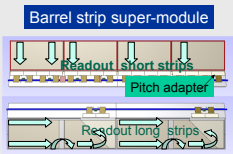
Standard hybrid technology



Double sided silicon strip detectors

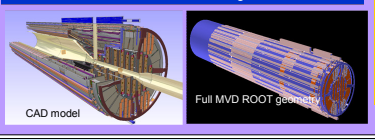
- **Thickness**
  - 300 μm
- **Strip sensor shape**
  - rectangular for the barrel
  - trapezoidal for the disk
- **Readout: pitch/ stereo angle**
  - 130 μm / 90° for the barrel
  - 70 μm / 15 ° for the disk



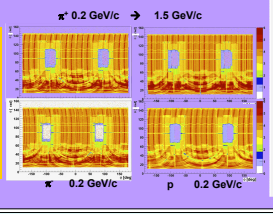


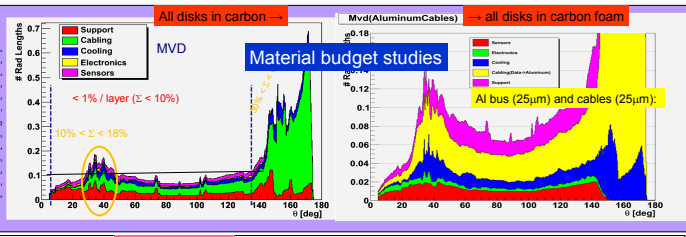
CAD Converter

translates CAD drawings (STEP-files) into ROOT geometries → access to full pandaROOT simulation with realistic detector design



Spatial coverage
2D mapping: Number of MVD points / track
Design optimization for a minimum of 4 track points
No significant effect for particle-antiparticle
No significant energy dependence
No significant effect for different particle species

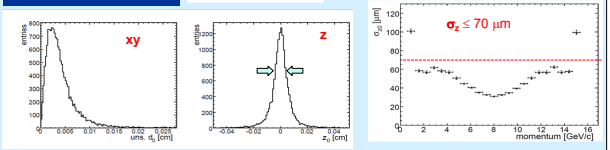




MVD Performance

Primary vertex resolution

$\bar{p}p \rightarrow \pi^+\pi^-$ 15 GeV/c



Vertex resolution

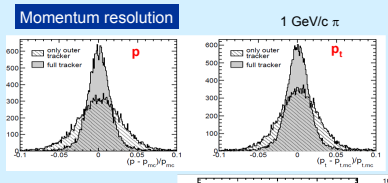
$\bar{p}p \rightarrow D^+D^-$ (6.57 / 7.50 / 8.50) GeV/c

momentum GeV/c	vertex resolution [μm] primary $\sigma_{prim,x}$	$\sigma_{prim,y}$	$\sigma_{prim,z}$	secondary $\sigma_{sec,x}$	$\sigma_{sec,y}$	$\sigma_{sec,z}$
6.57	30.7	30.7	493.6	35.4	35.2	77.1
7.50	30.4	30.3	208.5	37.1	36.4	84.0
8.50	30.0	29.0	157.4	36.7	36.2	92.4

→ Secondary vertex resolution:
$\sigma_{x,y} \leq 35$ μm
$\sigma_z \leq 100$ μm

Momentum resolution

1 GeV/c π



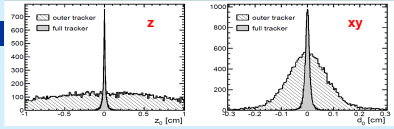
σ(p) without MVD = 2.6 %
σ(p) with MVD = 1.4 %

$\sigma(p_t)$ without MVD = 2.9 %
$\sigma(p_t)$ with MVD = 1.4 %

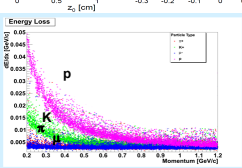
→ Improvement by 50%

Single track resolution

→ No resolution along z without MVD

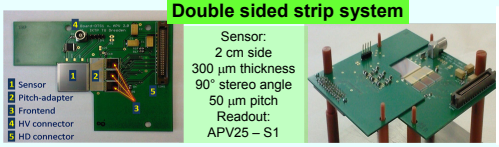


Energy loss information (in progress)



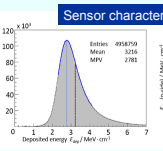
Prototypes

Double sided strip system

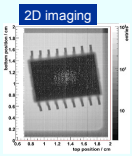


Sensor:
2 cm side
300 μm thickness
90° stereo angle
50 μm pitch
Readout:
APV25 – S1

Sensor characterization



2D imaging

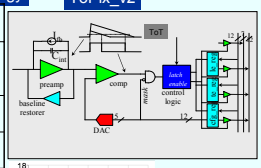


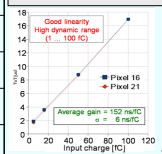
Pixel detector

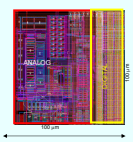
ToPix specifications
130 nm CMOS technology

Pixel radout size:	100 x 100 μm²
Chip active area:	11.4 x 11.6 mm² (116 rows, 110 columns)
dE/dx measurement:	ToT, 12 bits dynamic range
Noise:	< 0.032 fC (200 e⁻)
Clock frequency:	155 MHz
Time resolution:	6.4 ns (1.85 ns rms)
Power consumption:	<< 500 mW/cm²
Max. event rate:	(@ 2 10⁷ pbar-p ann/s): ~ 12·10⁶ hits/ (cm² s)

ToPix_v2





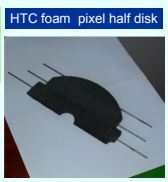


Two halves and three pipes embedded (MPN35N Ni-Co alloy; 2 mm external diameter, 1.84 internal diameter).
The surfaces are milling machined to final thickness (4 mm).
Planarity reached < 20 μm/m
Cooling system based on water, input temperature: 18°C

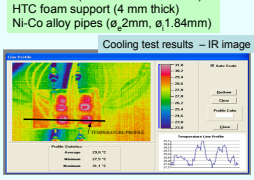
HTC Foam
Density: 0.9 g/cm³
Thermal conductivity: 245/70/70 W/ m·K

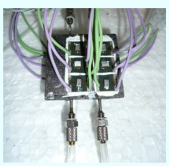
Small and partial prototype of a disk
12 resistors (1 W/cm² each resistor)
HTC foam support (4 mm thick)
Ni-Co alloy pipes (ø$_e$2mm, ø$_i$1.84mm)

HTC foam pixel half disk



Cooling test results – IR image

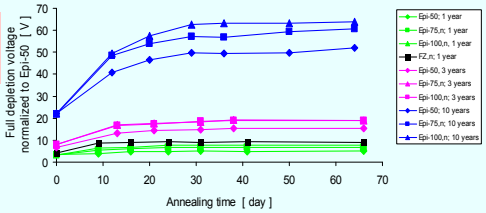




Epitaxial material for sensor already studied:
49 μm (4060 Ω·cm, n/P) + 50 μm Cz substrate (0.01-0.02 Ω·cm, n⁺/Sb)
74 μm (4570 Ω·cm, n/P) + 50 μm Cz substrate (0.01-0.02 Ω·cm, n⁺/Sb)
98 μm (4900 Ω·cm, n/P) + 50 μm Cz substrate (0.01-0.02 Ω·cm, n⁺/Sb)

Test of radiation damage with neutrons
Equivalent fluences corresponding to
~ 1, 3 and 10 years of PANDA lifetime

Epitaxial material with lower resistivity study is in progress



Conclusion

MVD design is in progress with parallel software development to check physics performance
Prototyping phase is started…but still some challenging tasks have to be studied and optimized…

INPC10 – International Nuclear Physics Conference, July 4-9, 2010, Vancouver