Вершинный Детектор для с-т Фабрики

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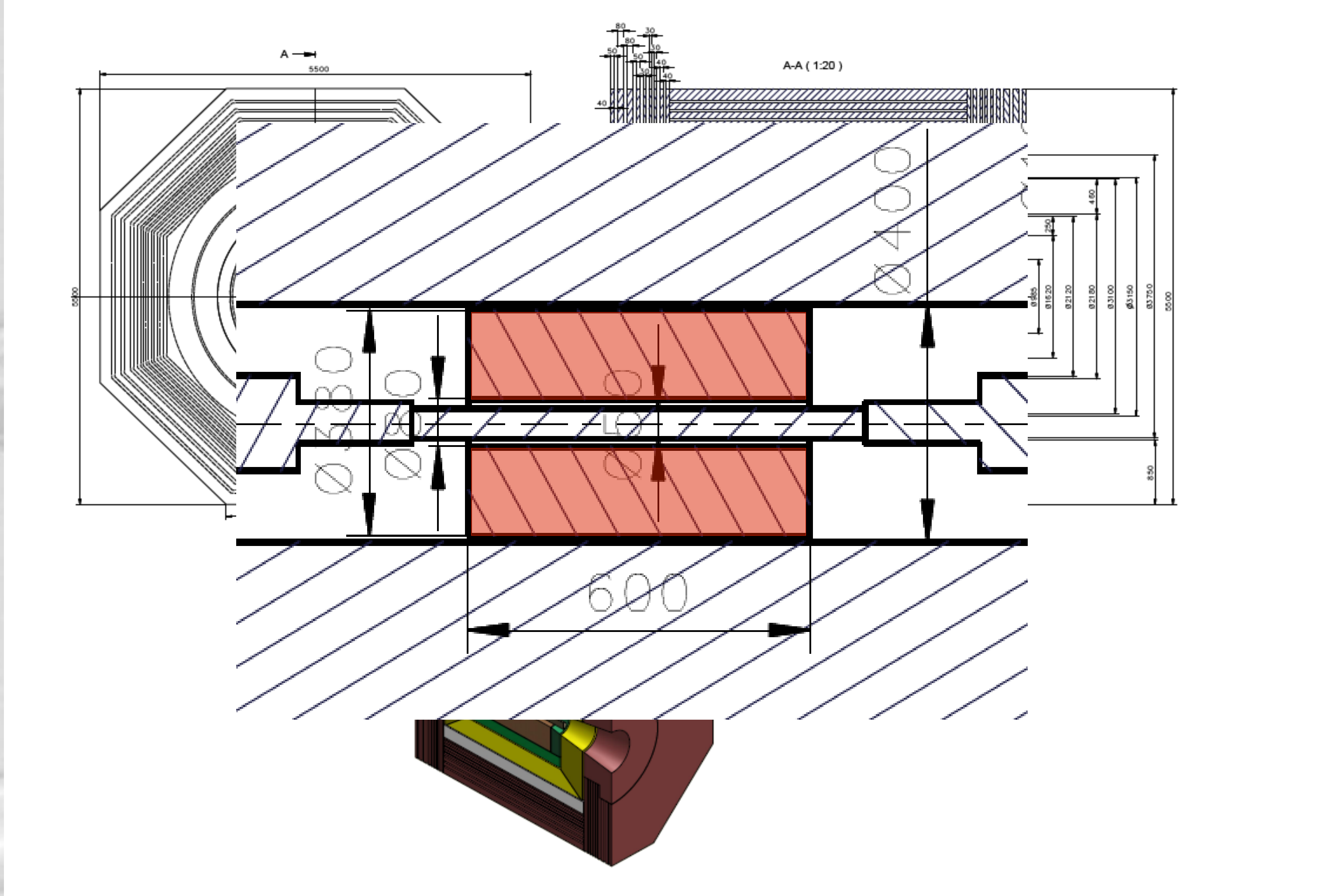
18 октября 2010 года

Схема Детектора



Требования к Детектору

- Хорошее пространственное разрешение (~ 100 μ);
- Хорошее угловое покрытие (> 96% 4π);
- Работа с высокой загрузкой (1.6 млн. треков/сек)
- Измерение продольной координаты;
- Хорошее двухтрековое разрешение;
- Возможность измерения dE/dX;
- Радиационная стойкость;
- Малая толщина (~1% X_0);
- Работа в непрерывном режиме.

Time Projection Chamber

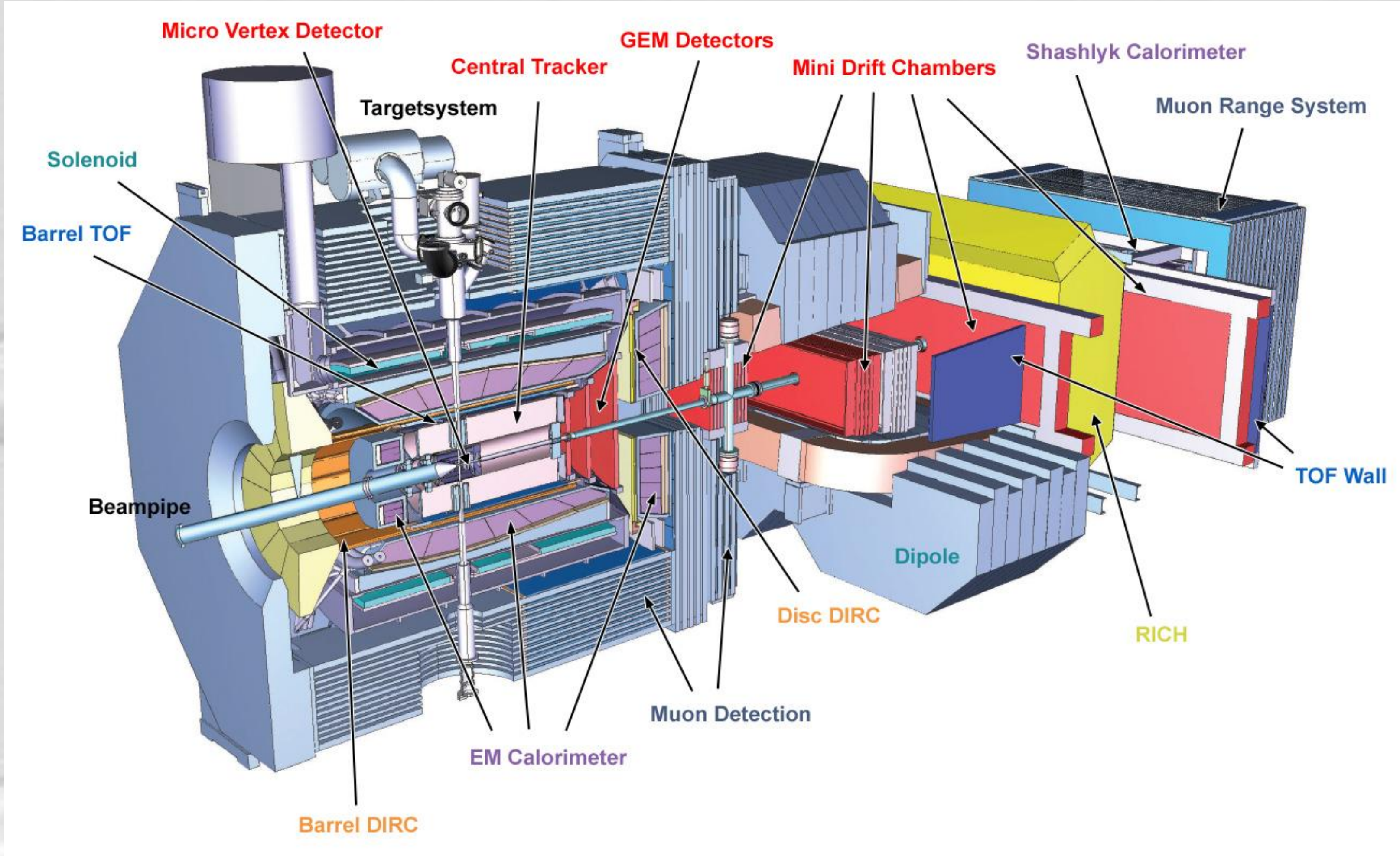
Одним из возможных кандидатов на роль вершинной камеры является Время-Проекционная Камера (TPC).

В настоящее время в мире разрабатывается несколько проектов TPC с непрерывным считыванием, использующих технологии MPGD (Micro-Pattern Gas Detector).

Time Projection Chamber

- PANDA TPC
  - 4π TPC;
  - CB-ELSA TPC;
- Linear Collider TPC.

PANDA Detector



PANDA Central Tracker Requirements & Layout

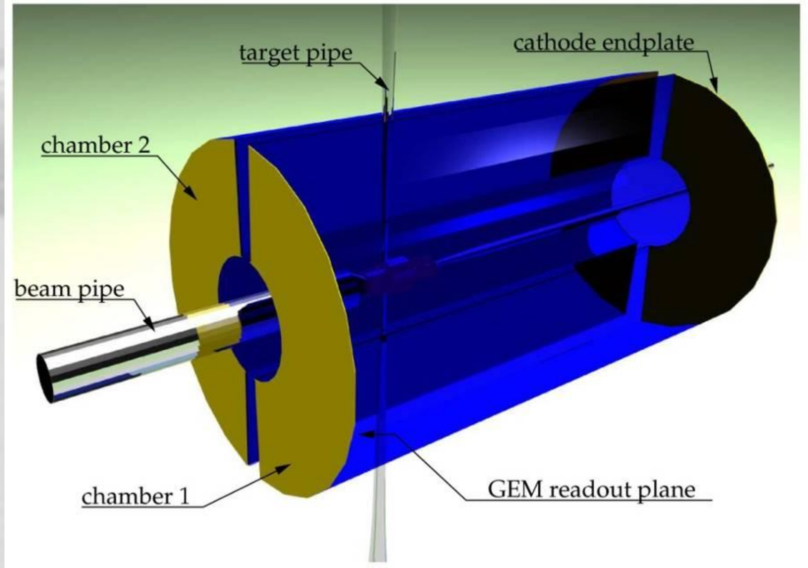
- Full solid angle coverage
- Secondary vertex resolution *$\sigma_{r\varphi}$~150µm, σ_z~1mm*
- Momentum resolution *δp/p~(2)%*
- Minimal material budget *X/X_0~(2)%*
- Particle Identification *δE/E~(7)%*
- Operation in 2T magnetic field

⇨ Time Projection Chamber (TPC*)
MPGD: high granularity, fast signal, good multi-track resolution

- Continuous operation at high rate (space charge, event mixing)

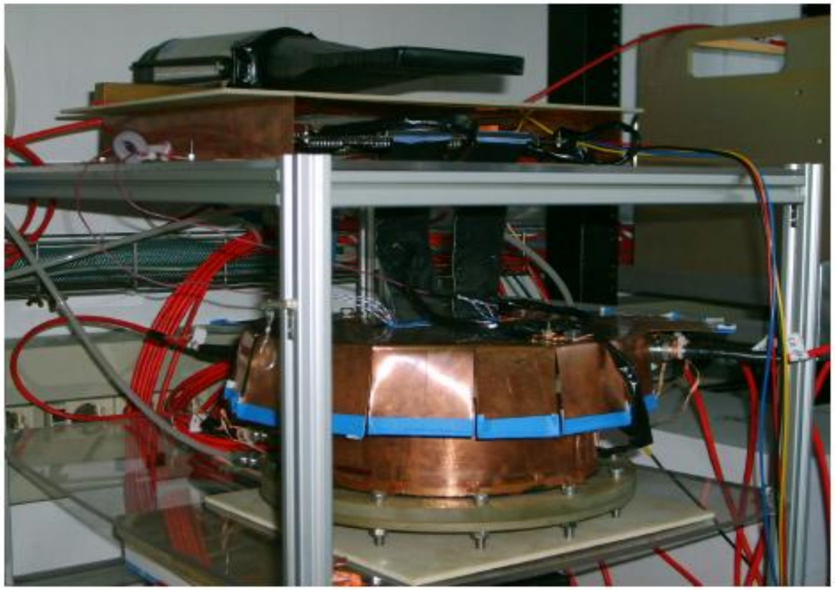
⇨ …with GEM amplification
reduced *ExB* effect,
suppressed ion feedback

*D.R. Nygren et al., Phys. Today 31, 46 (1978)



- 2 half cylinders L=150cm R=15/42cm
- Drift field 400 V/cm
- Ne/CO_2 (90/10), max. drift time 55µs
- Multi-GEM stack
- Pad Size ~2x2mm², 100.000 ch

Detector Setup and Readout Electronics

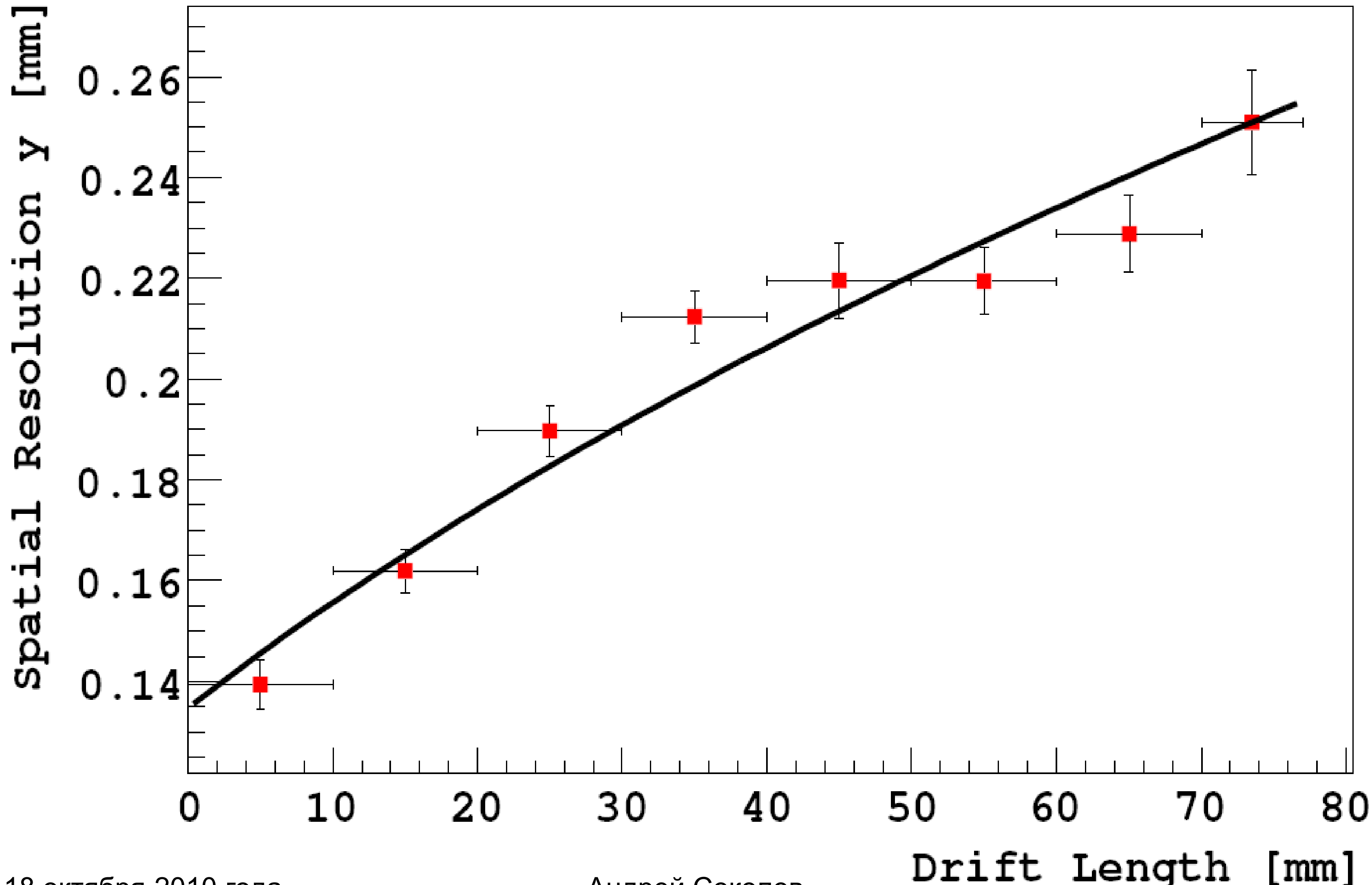


- Gas: Ar/CO_2 (70/30)
- Triple-GEM configuration
  $\Rightarrow$ amplification: $\sim 5\,000$
- Drift field: 250 V/cm
- 10×10 cm^2 active area,
  ~ 8 cm drift length
- Pad size: 1.0×6.2 mm^2
- Coincidence-trigger for muons

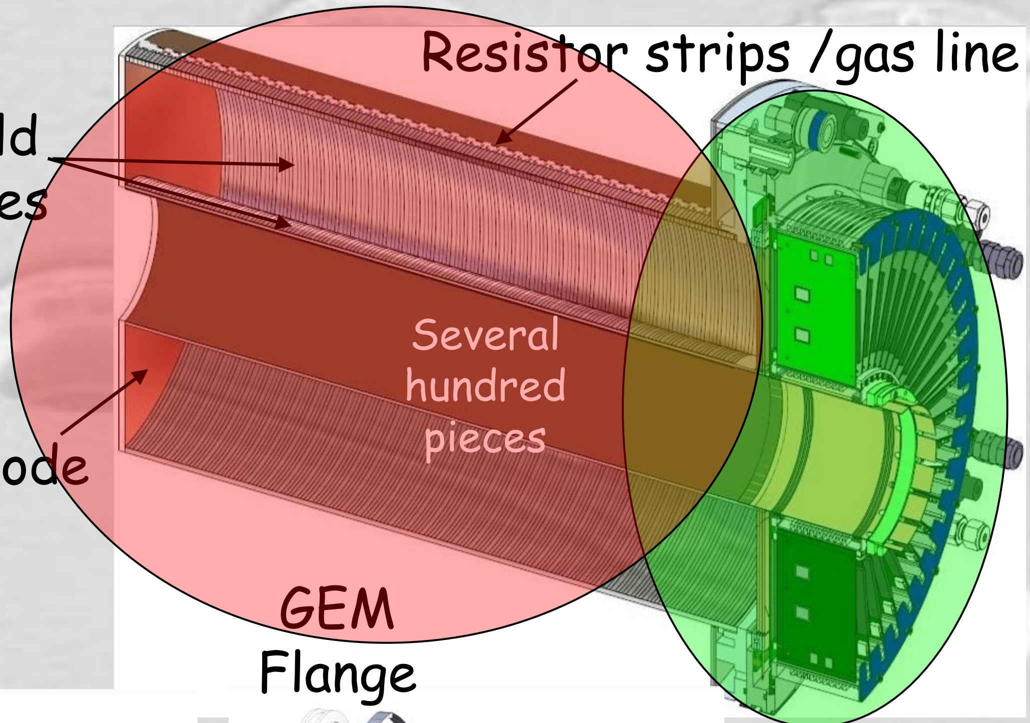
ALICE electronics (128 chan.):

- Inverter card
- PASA (preamplifier):
  12 mV/fC, 190 ns
- ALTRO (ADC, zero-suppr.):
  10 MHz, 6 ADC cts./fC
- Noise: 1.88 ADC cts.
  "comm. mode" corr. (5%)

Dependence of Spatial Resolution on Cluster *z*-Positions



Detector Assembly 'large' TPC Prototype

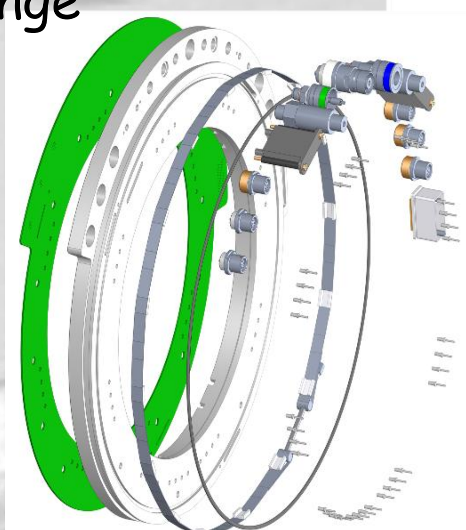


Assembly done

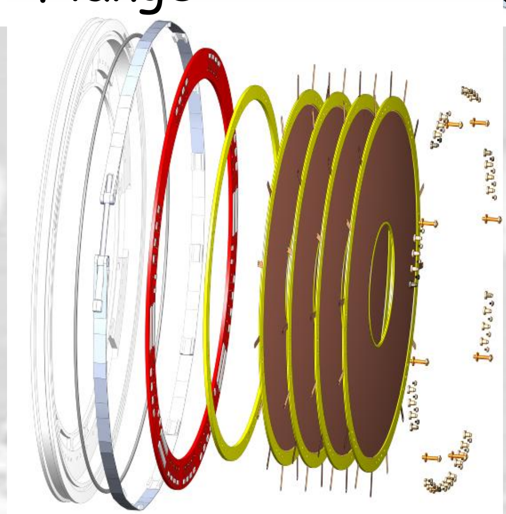
In preparation

Ready by the end 2010

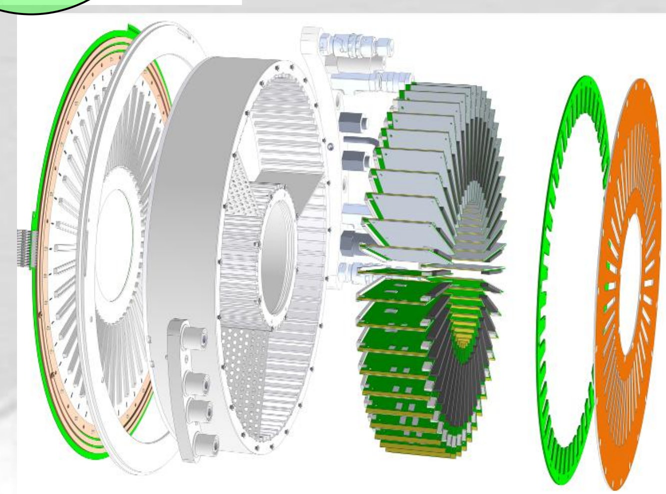
Media Flange



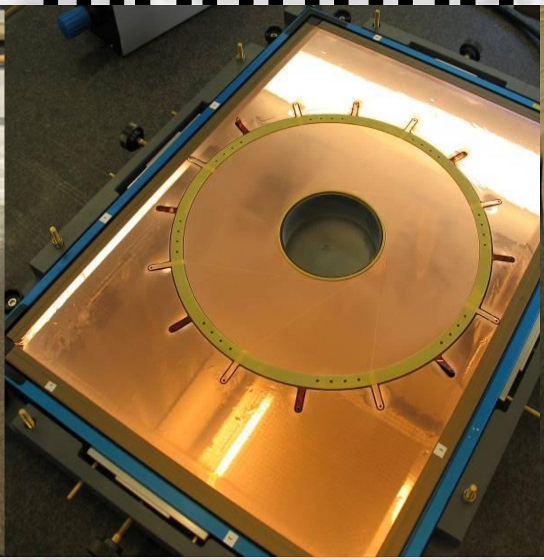
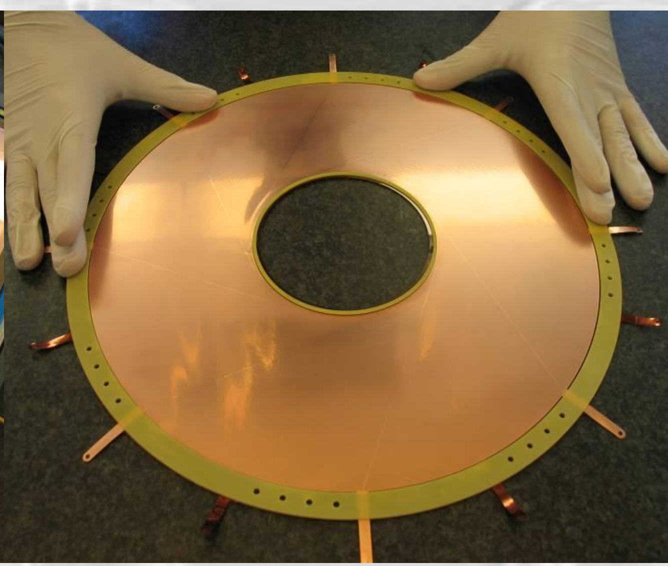
GEM Flange

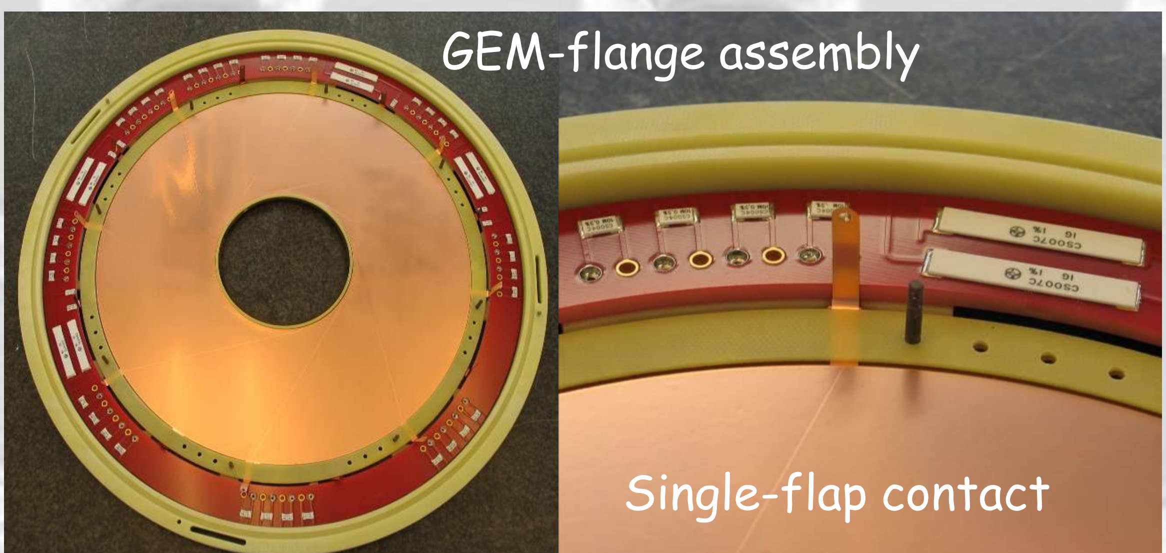


Electronic Flange



GEM-Assembly Foil mounting

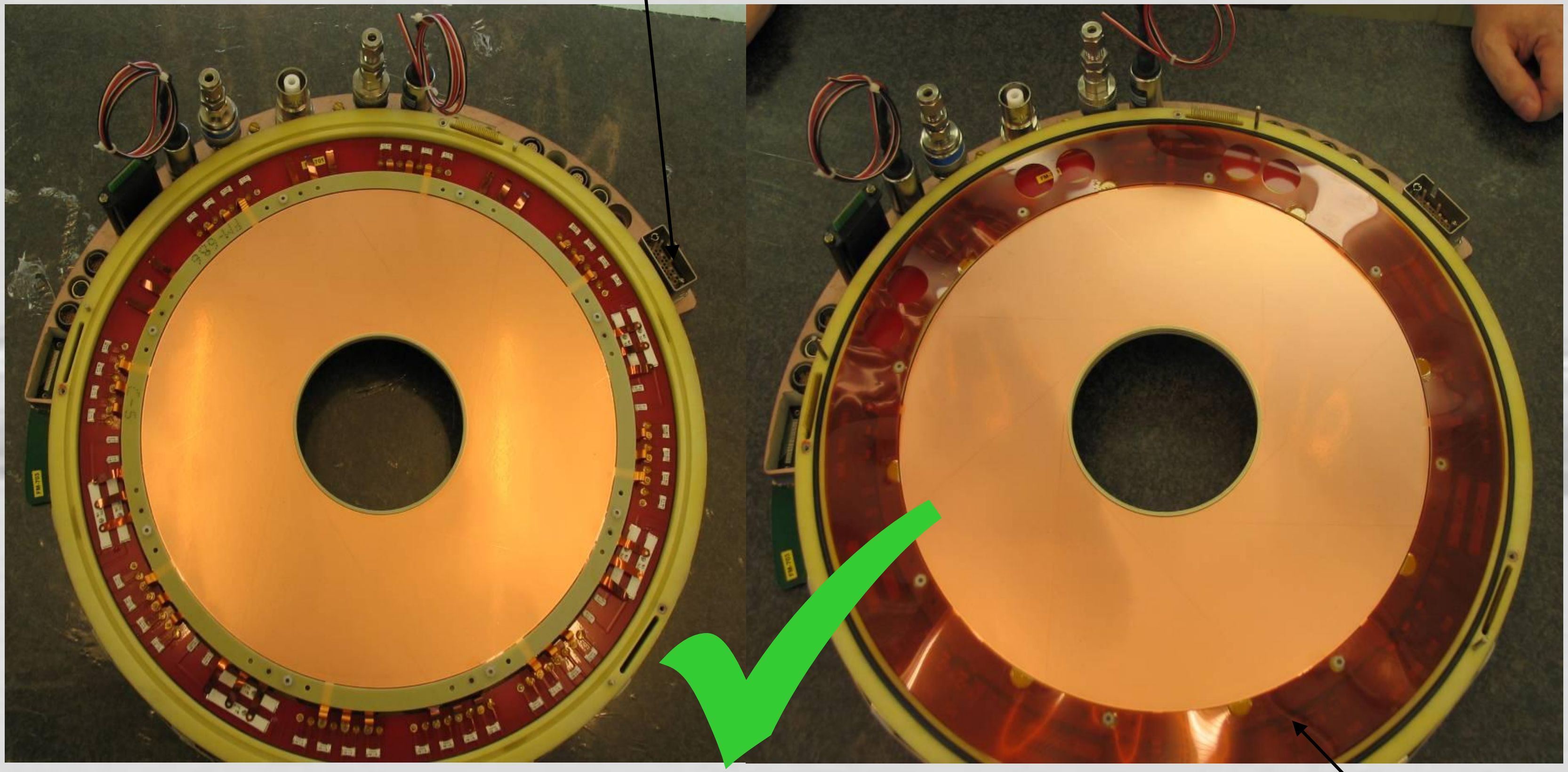






5 / 50 μm Cu on Kapton
105 / 300 mm 'active' diameters
8 sectors iris like pattern
70 /140 μm double conical CERN 'standard' arrangement
18 Mio holes in total
Inner & outer GFK support rings
leakage current < 10 nA/sector@650V
Hole geometry checked at 5 points
Optical transmission (36 ± 3)%
@2x3mm check once per sector

GEM assembly '…stacked on the flange'

Central GEM-HV supply



→ HV-stability tested, Design goals accomplished

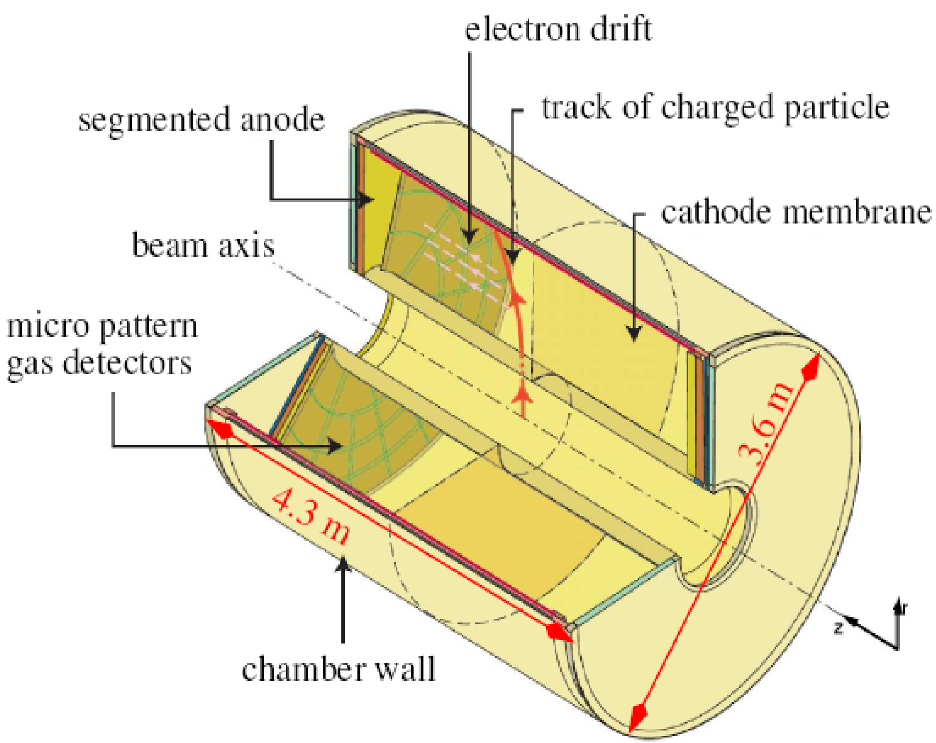
HV-protection cover

Requirements for a TPC at a Linear Collider

- ILD concept defines stringent requirements to all subdetectors

Requirements for TPC (ILD)

- $\sigma_{\perp}^{\text{point}} \leq 100\,\mu\text{m}$
- material budget
  $\rightarrow 1\,\%\,X_0$ inner wall
  $\rightarrow 4\,\%\,X_0$ to outer wall
  $\rightarrow 15\,\%\,X_0$ endcap
- $\sigma(1/p_{\perp}) \approx 9 \cdot 10^{-5}\,\text{GeV}^{-1}$
  (total: $2 \cdot 10^{-5}\,\text{GeV}^{-1}$)

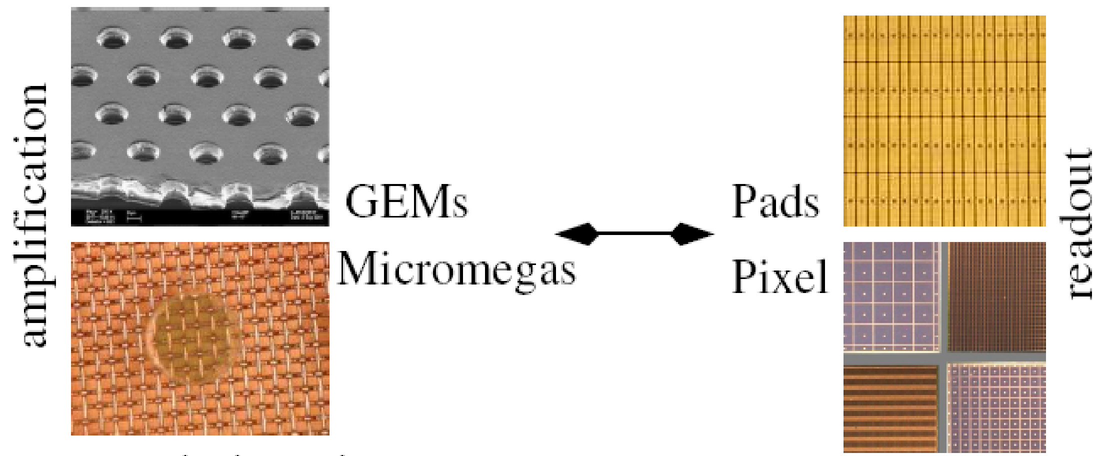


- point resolution closely related to momentum resolution
  $\rightarrow$ requirements driven by physics (Higgs recoil analysis)

$\Rightarrow$ performance about ten times better compared to previous TPCs

Technology for a TPC at a Linear Collider

- performance goals require substantial improvements of traditional readout techniques
  → LCTPC studies TPC readout with micro pattern gas detectors (MPGD)



www.mpgd.web.cern.ch

Goal: Optimal Readout Technology for a LC TPC

- fulfill performance goals in resolution
- lightweight electronics → end plate with small material budget
- reliable operation in a LC detector

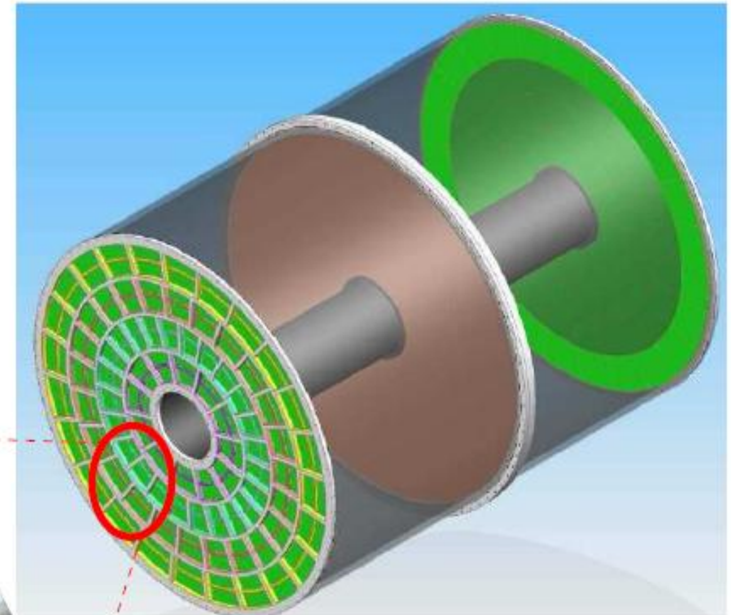
Large TPC Prototype - Anode End Plate

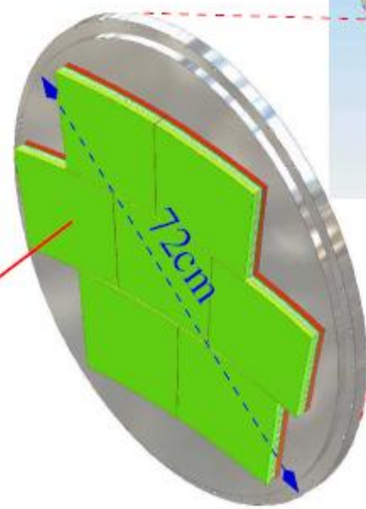
Modular End Plate

- first end plate for the LP made from Al
- 7 module windows $\rightarrow$ size $22 \times 17\,\mathrm{cm}^2$

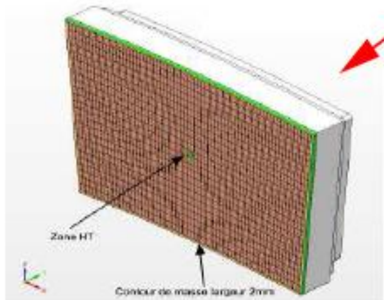
$\rightarrow$ D. Peterson, U. Cornell

TPC @ Linear Collider Detector

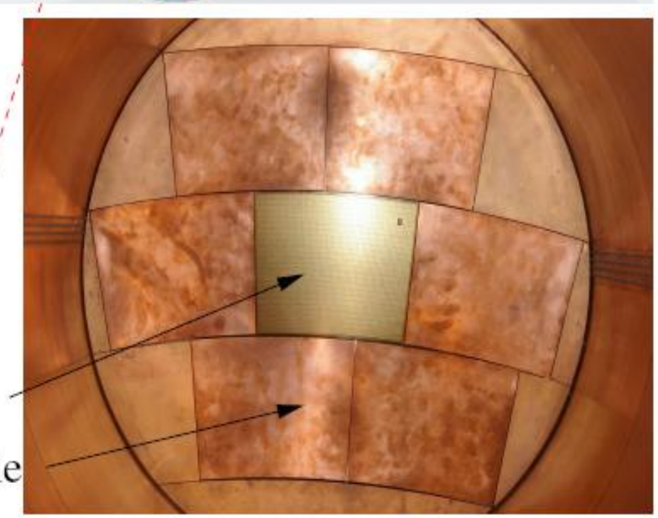




Prototype module



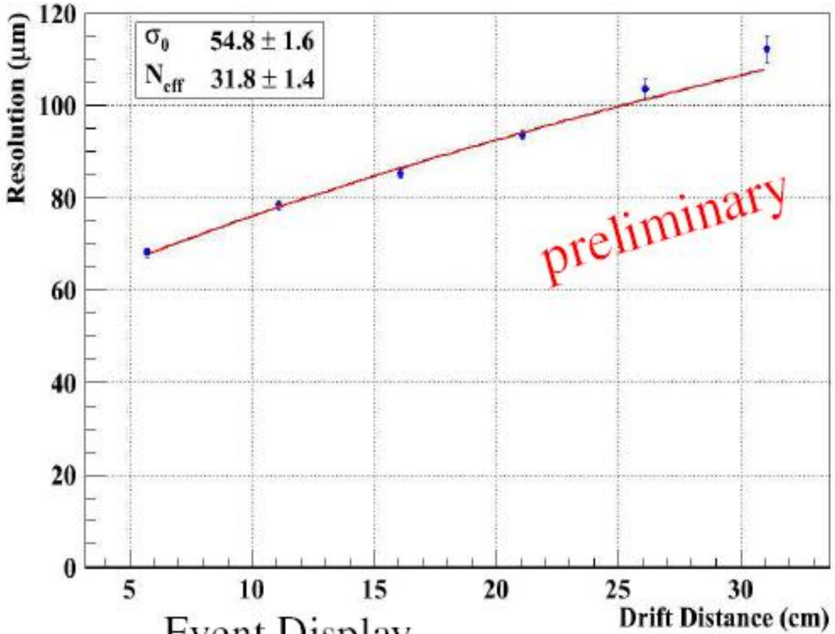
Detector side

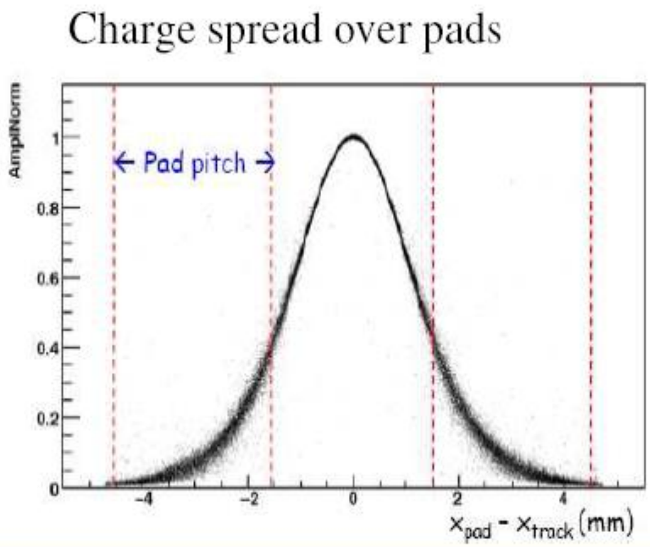


micromegas

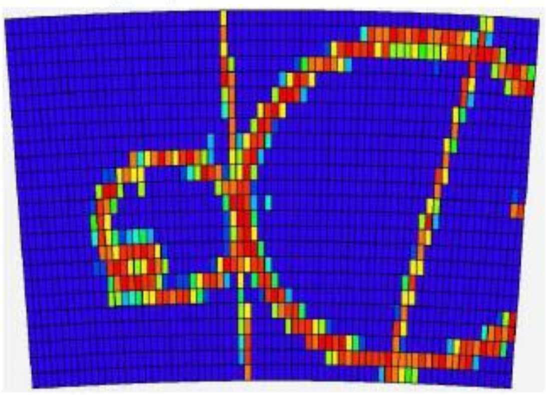
blind module

Test Beam with Micromegas Module





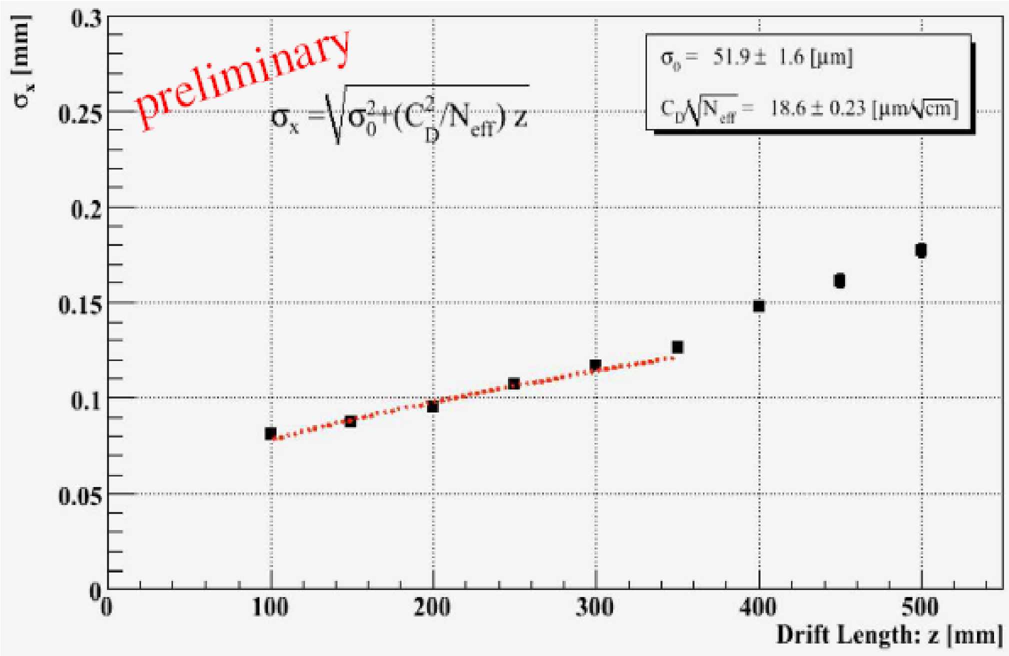
Event Display



First Results (Micromegas)

- setup: $5\,\mathrm{GeV}\,e^-$ - $B = 1\,\mathrm{T}$
- res. parametrized as
  $\sigma_\perp = \sqrt{\sigma_0^2 + D^2/N_{\text{eff}} \cdot z}$
  $\rightarrow \sigma_0 = 54.8 \pm 1.6\,\mu\mathrm{m}$
  $\rightarrow N_{\text{eff}} = 31.8 \pm 1.4$ per pad height $(4.5\,\mathrm{mm}^{-1})$

Test Beam with GEM Modules

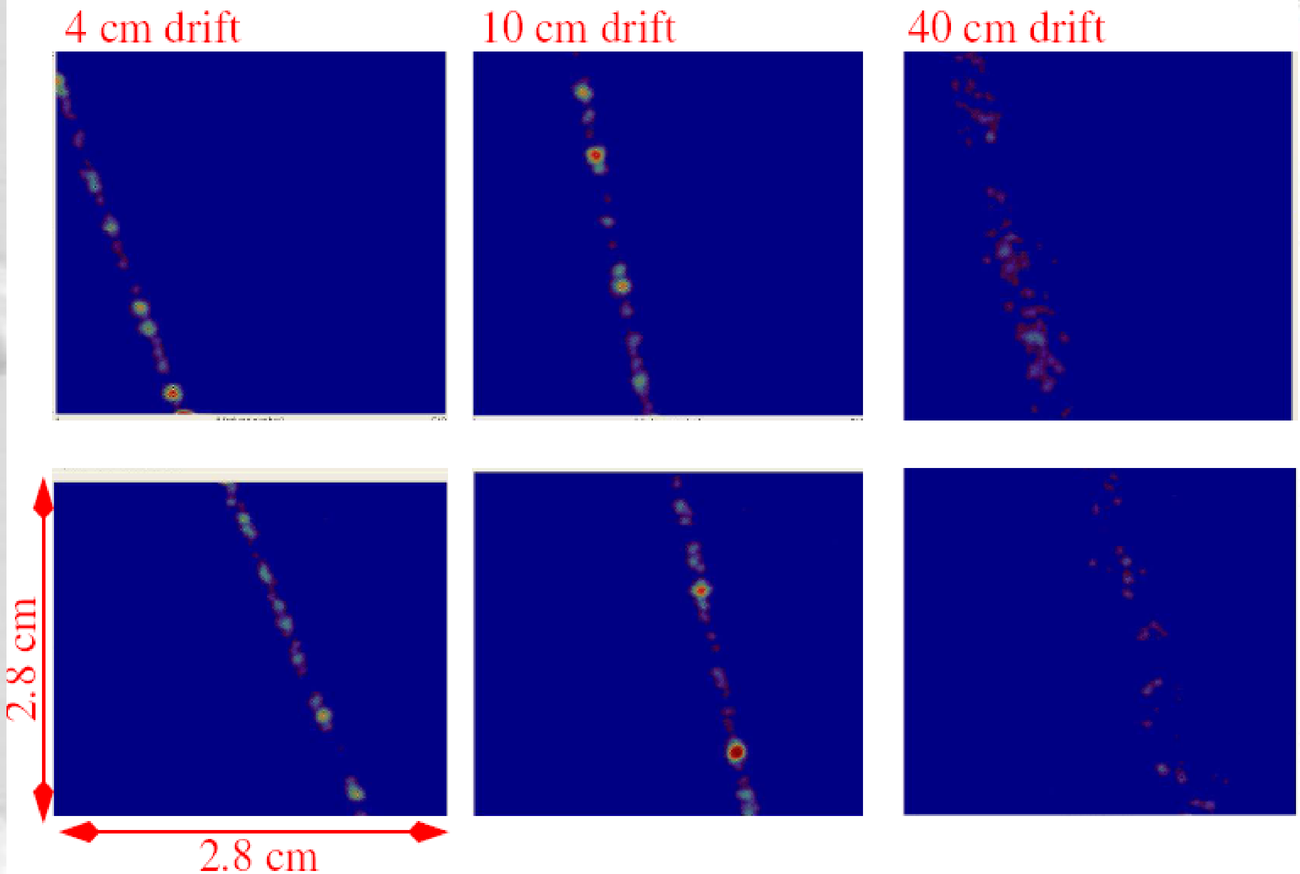


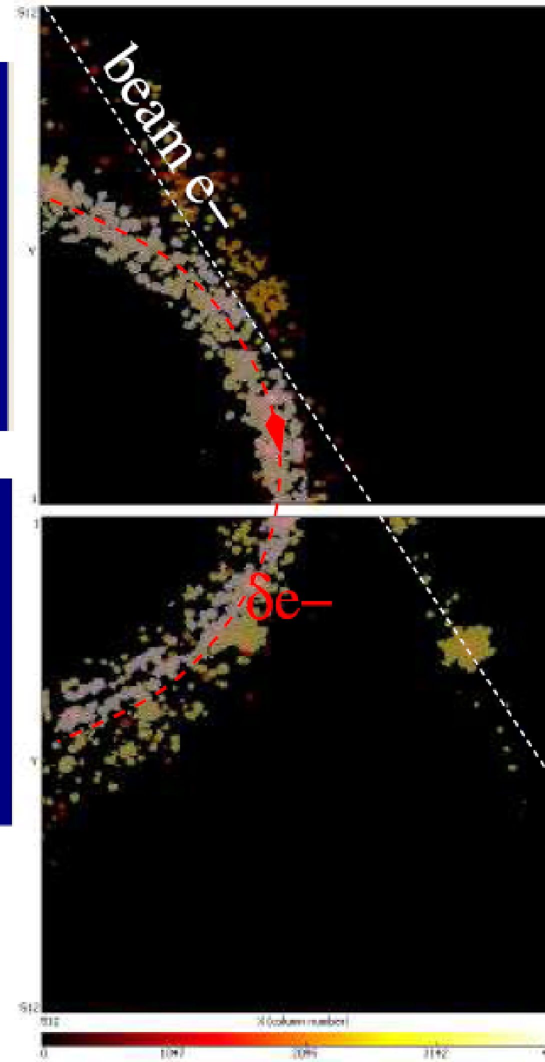
First Results (GEM Modules)

- setup: $5\,\mathrm{GeV}\, e^-$ - $B = 1\,\mathrm{T}$
- resolution parametrized as $\sigma_\perp = \sqrt{\sigma_0^2 + D^2/N_{\text{eff}} \cdot z}$
  $\rightarrow \sigma_0 = 51.9 \pm 1.6\,\mu\mathrm{m}$
  $\rightarrow N_{\text{eff}} = 21 \pm 2$ per pad height $(4.1\,\mathrm{mm}^{-1})$

$\Rightarrow$ GEM and Micromegas module show similar performance

GEM Structure & Timepix

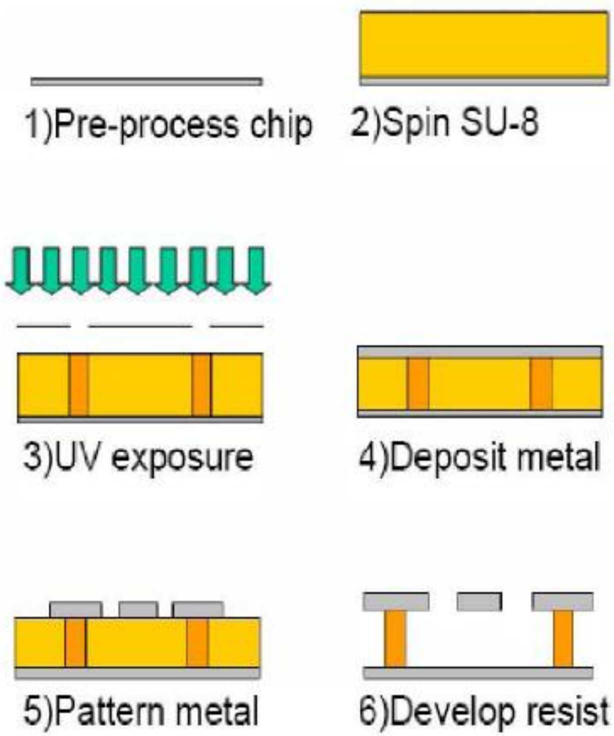


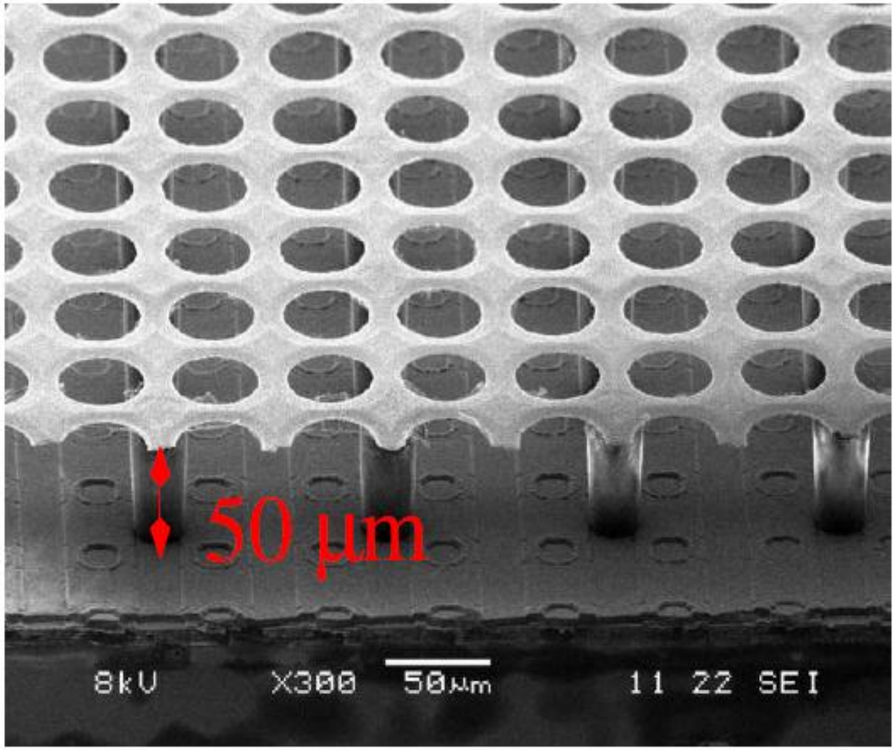


- integrated electronics → low X_0 end plate
- finest granularity for a TPC readout
  - → allows for highest resolution
  - → clear identification of clusters & δ-e^- possible

→ analysis of test beam data ongoing

InGrid Technology





InGrid Chip

- fabrication in a waver post processing technology
  → silicon pixel chip : 1 μm thick AL grid on 50 μm pillars
- one hole per pixel and very flat surface

→ J. Timmermans, NIKHEF

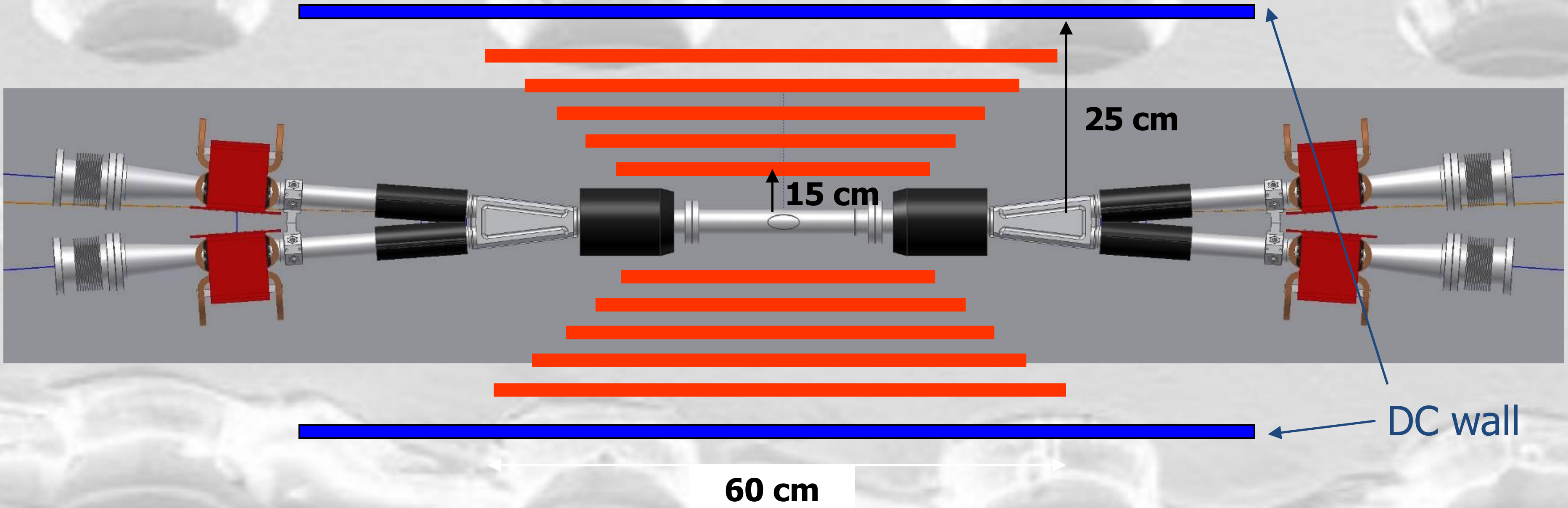
Трекер на основе цилиндрических GEMов

Ещё одним кандидатом на роль вершинного детектора для c-т фабрики является трекер на основе цилиндрических GEMов. В настоящее время такой детектор создаётся коллаборацией KLOE-2.

KLOE-2 Inner Tracker

Detector Requirements:

- $\sigma_{r\phi} \times \sigma_z \approx$ 200x500μm single layer spatial resolution for fine vertex reconstruction of **K_s** and **η rare decays** and **interferometry** measurements
- 5 tracking layers with low material budget (< 1.5% X_0): each is a triple-GEM detector
- $R \geq 20\tau_s$ to preserve $K_L K_s$ interference
- Rate capability 30 ÷ 40 hits/plane/μs (< 50 kHz/cm^2)



Cylindrical GEM for KLOE-2 Inner Tracker

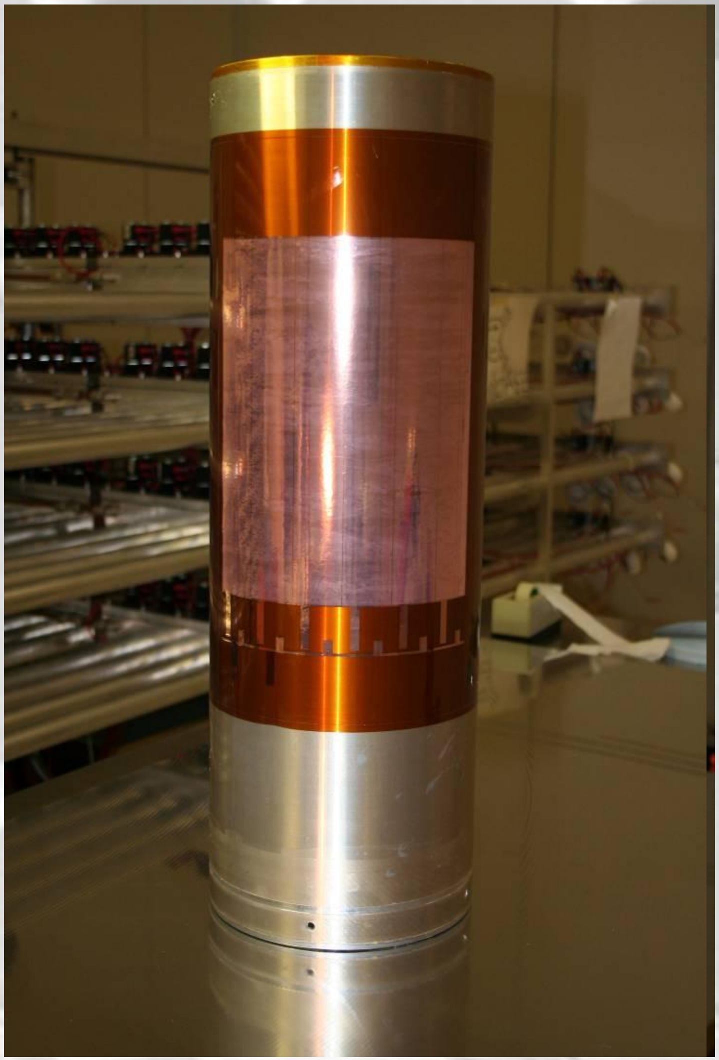
THE IDEA:

- We propose a **low-mass**, **fully cylindrical** and **dead-zone-free** GEM detector as Inner Tracker for the KLOE-2 experiment.
- The IT is composed by five concentric layers of cylindrical triple-GEM detectors (**C-GEM**).
- Each **C-GEM** is realized inserting one into the other the required five cylindrical structures made of very thin polyimide foils: the cathode, the three GEMs and the readout anode.
- Very light detector: only **0.3% of X_0 per layer** inside the active area.

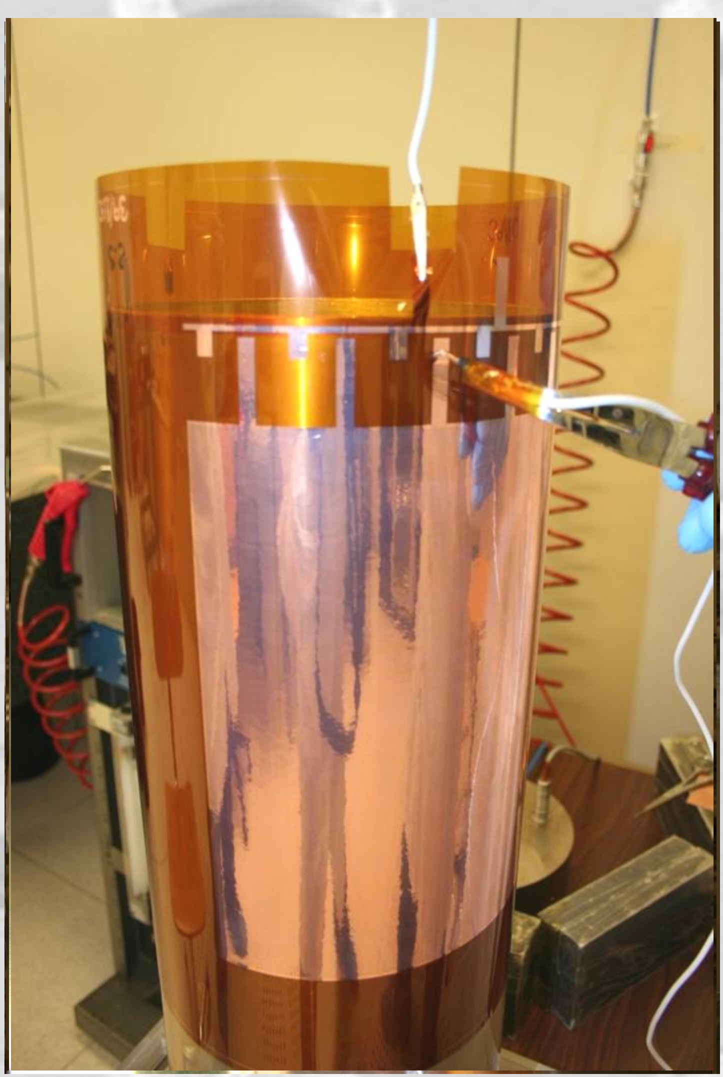
HOW to do that?

A cylindrical GEM electrode is obtained exploiting the **vacuum bag technique, rolling the polyimide foil up on machined PTFE** cylindrical mould.

Preliminary tests of large foils extraction



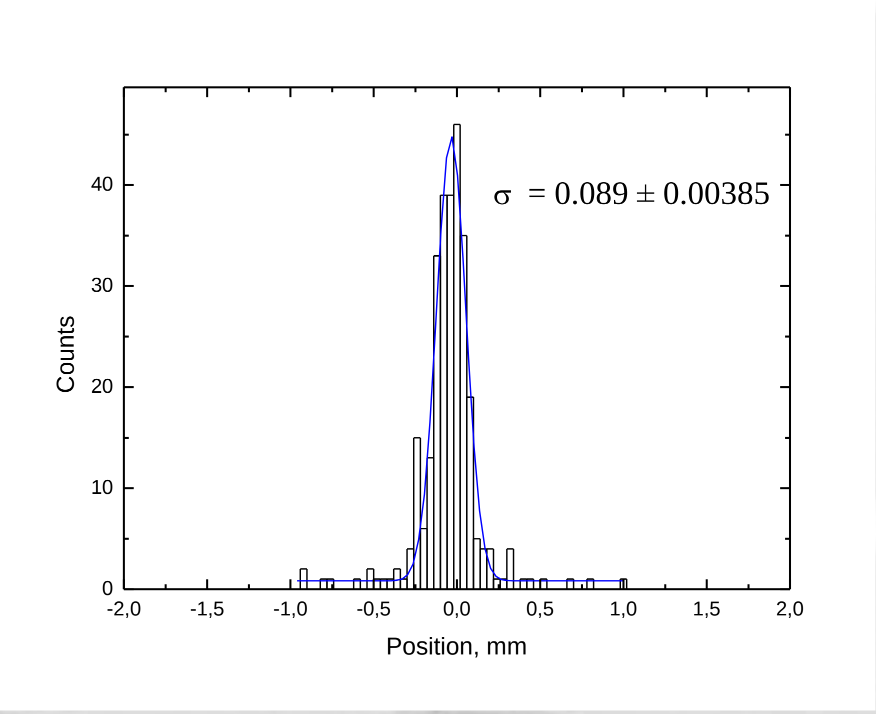
200 mm diameter C-GEM



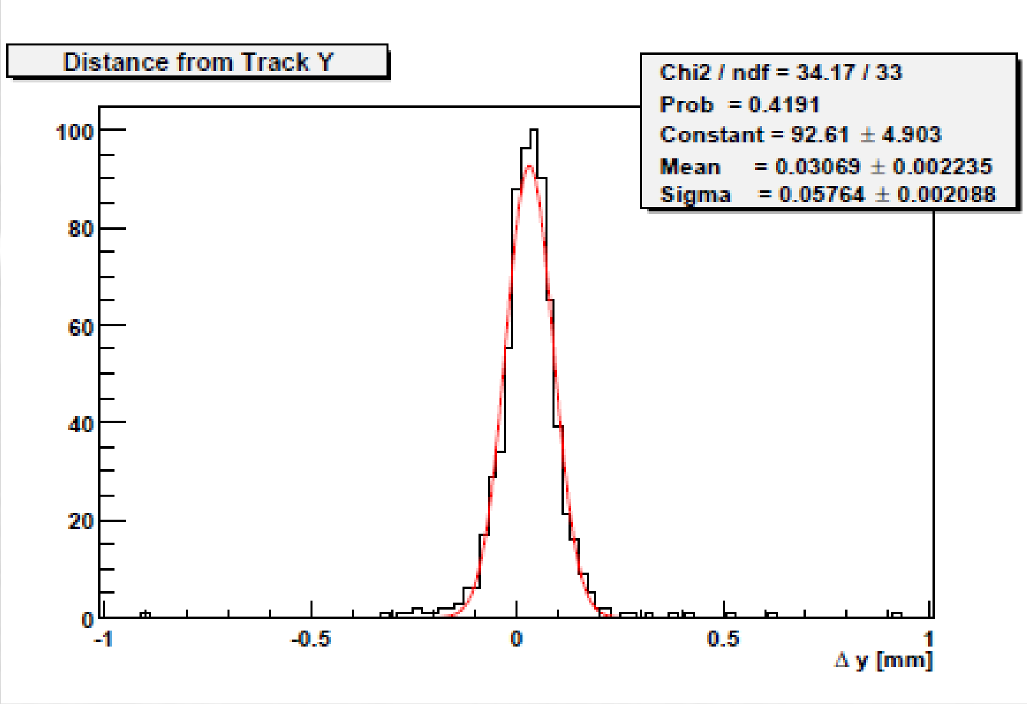
Successfully tested at 500 V

SPATIAL RESOLUTION

GEM-TS, KEDR



GEM, COMPASS



pitch=0.5mm, σ_{det} = 0.073 mm

pitch=0.4mm, σ_{det} = 0.046 mm

Сравнение двух подходов

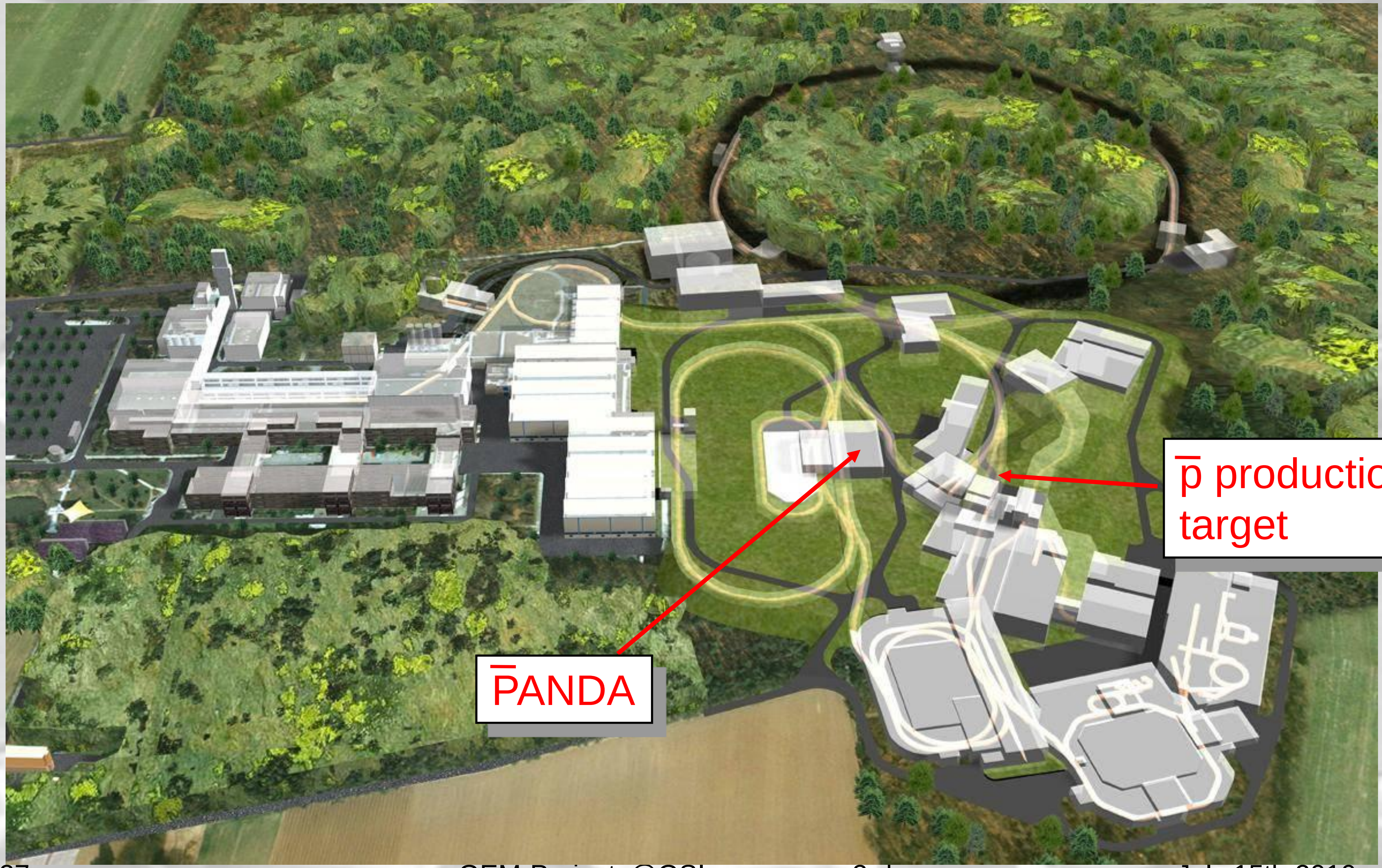
Параметр	TPC	Cylinder GEMs
Простота изготовления	✔	✖
Измерение dE/dX	✔	✖
Быстродействие	✔	✔
Число каналов электроники	> 50 000	~ 8000
Временное разрешение	~ 20 нс	~ 2 нс
Радстойкость	✔	✔
Доступность технологии	2010	2011
?		

Заключение

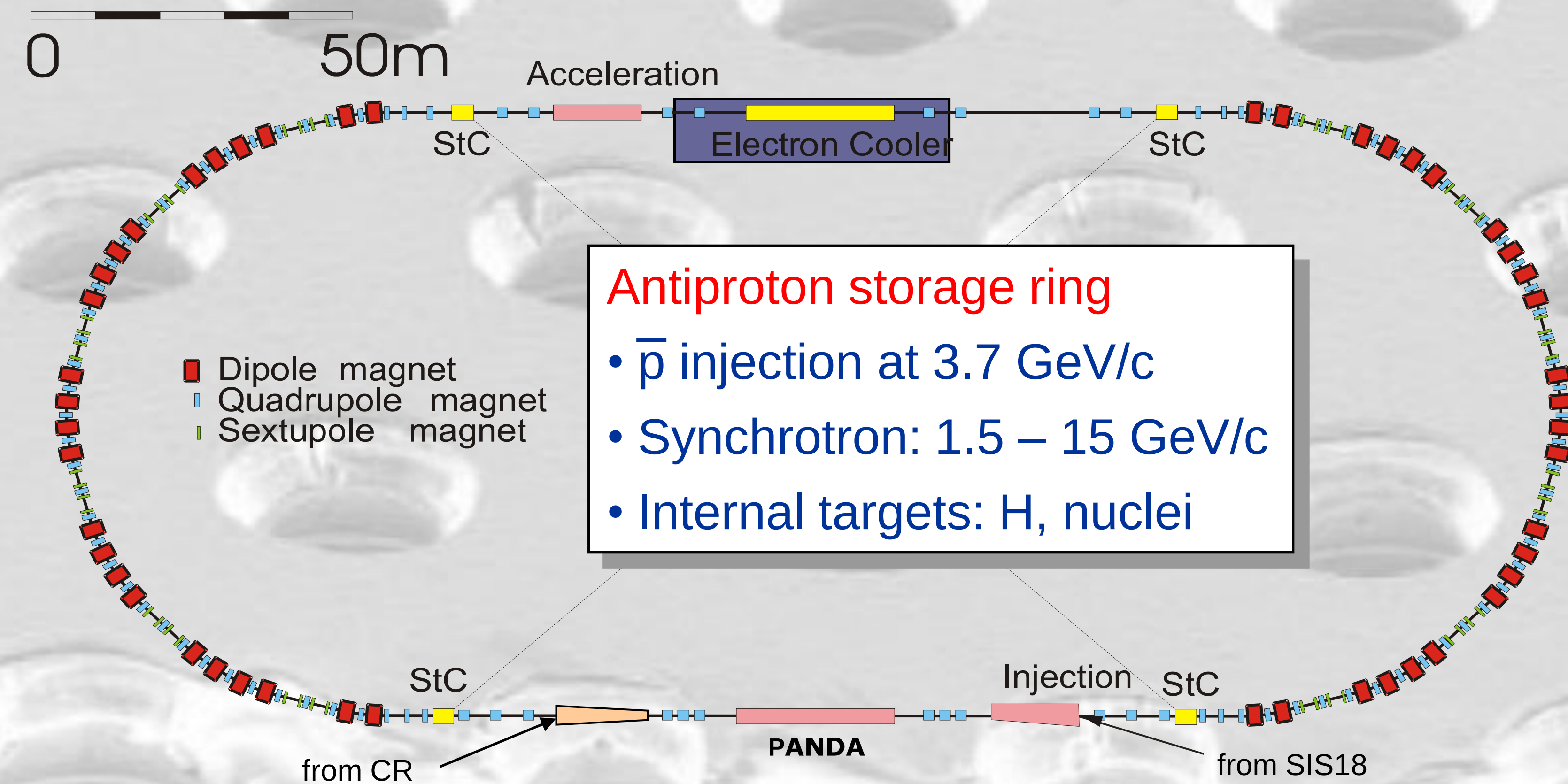
- Технологии MPGD-TPC и цилиндрических GEMов подходят для создания вершинного детектора для c-т фабрики
- Обе технологии активно развиваются и к концу 2011 года следует ожидать запуска детекторов созданных на их основе;
- Окончательный выбор должен быть сделан на основе моделирования детектора.

PANDA at FAIR

Facility for Antiproton and Ion Research, Darmstadt, Germany



High Energy Storage Ring (HESR)



Antiproton storage ring

- $\bar{p}$ injection at 3.7 GeV/c
- Synchrotron: 1.5 – 15 GeV/c
- Internal targets: H, nuclei

ELectron Stretcher Accelerator (ELSA)