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The CLAS12 Barrel Micromegas Tracker: *Five years and counting of data taking*

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MPGD CONFERENCE 2022 WEIZMANN INSTITUTE OF SCIENCE, REHOVOT, ISRAEL







- The Micromegas Vertex Tracker
- The barrel cylindrical detectors
- Performance and status in data taking





cea Outline

Cea The CLAS12 Experiment



- Upgrade of the CLAS Experiment at Jefferson lab
- Study of the nucleon structure with 11 GeV electron beam at high luminosity (up to 10³⁵ cm⁻²s⁻¹)



Micromegas Vertex Tracker :

- Improve the track reconstruction in the vicinity of the target
- Reduced volume between the magnet and the Silicon Vertex Tracker (SVT)
- Large curved Micromegas
- 5T field
- Remote off-detector frontend electronics
- Small dead space
- High particle rate (30 MHz)



cea The Micromegas Vertex Tracker



- 4 m² of Micromegas detectors to be installed in 2017
- **DREAM** based Front-End Electronics
- Remote off-detector frontend electronics connected with 2m microcoaxial cables

Forward Detectors

- High particle rate (30MHz) => Fast detectors
- Resistive strips divided in 2 zones inner/outer
- Dimensions: 6x 430 mm diameter disk with a 50 mm diameter hole at the center

Cylindrical Barrel

- Low momentum particles => Light Detectors
- Limited space of ~10 cm for 6 layers
- High magnetic field (5T)
- 6 Layers (18 Det.)

Cea The Micromegas Vertex Tracker



- Total of 6 layers segmented in phi (3 x 120° sectors)
- 6 Different detector's radii
- 2 different types (C and Z types)
- Drift gap: 3mm; Amplification gap: 128um
- Mesh: 70/30
- Material (PCB/Bulk + Drift) from the CERN Workshop
- Assembly to cylindrical shape at Saclay
- Test and Characterization at Saclay before shipping to JLab



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Layer	Detector	Radius (mm)	Length (mm)	Width (mm)	Channels	Active area Length (mm) x width (mm)	
6	CR6C	222.53	712	459	1152	445	438
5	CR6Z	207.54	712	427	768	445	407
4	CR5C	192.65	712	396	1024	420	376
3	CR5Z	177.57	712	364	640	421	344
2	CR4Z	162.56	712	333	640	373	313
1	CR4C	147.57	712	302	896	372	281

cea The DREAM FRONT-END electronics

- Signals are continuously pre-amplified, shaped, sampled at 20-30 MHz and kept in the circular analog memory
 - Deep enough to sustain 16 µs trigger latency
- At each trigger the 4 to 10 corresponding samples are readout and digitized
- Readout does not disturb sampling
- Retained samples are digitally processed
 - Pedestal equalization online
 - Common noise subtraction online
 - Zero suppression online
 - Measure charge and time off-line
- Micro-coax cables 64 channels low capacitance 43 pF/m





Parameter	Value
Polarity of detector signal	Negative or Positive
Number of channels	64
External Preamplifier option	Yes; access to the filter or SCA inputs
Charge measurement	
Input dynamic range/gain	50 fC; 100 fC; 200 fC; 600 fC, selectable per channel
Output dynamic range	2V p-p
I.N.L	< 2%
Charge Resolution	> 8 bits
Sampling	
Peaking time value	50 ns to 900 ns (16 values)
Number of SCA Time bins	512
Sampling Frequency (WCk)	1 MHz to 50 MHz
Triggering	
Discriminator solution	Leading edge
HIT signal	OR of the 64 discriminator outputs in LVDS level
Threshold Range	5% or 17.5% of the input dynamic range
I.N.L	< 5%
Threshold value	(7-bit + polarity bit) DAC common to all channels
Minimum threshold value	≥ noise
Readout	
Readout frequency	Up to 20 MHz
Channel Readout mode	all channels excepted those disabled (statically)
SCA cell Readout mode	Triggered columns only
Test	
Calibration (current input mode)	1 channel among 64; external test capacitor
Test (voltage input mode)	1 channel among 64; internal test capacitor (1/charge range)
Functional (voltage input mode)	1, few or 64 channels; internal test capacitor/channel
Trigger rate	Up to 20kHz (4 samples read/trigger).
Counting rate	< 50 kHz / channel
Power consumption	< 10 mW / channel





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Latest snapshot of running parameters

	Sulp	(' *)	
L\S	1	2	3
1	500	500	500
2	500	500	500
3	500	500	500
4	490	480	500
5	480	150	500
6	510	520	510

Ctrin (1)

	Drift (-V)	
L\S	1	2	3
1	1400	1400	1400
2	1600	1600	1600
3	1400	1600	1600
4	1400	1400	1400
5	1130	1550	1400
6	1400	1400	1400

BMT HV HV Safe Status Not Safe 'Not Safe" means voltages are above 300 V e.g. not safe for beam

🚟 MVT Overview 🛙

Gas:

- Argon 95% Isobutane 5%
- Total system flux: 8.8 l/h
- Each three tiles in series
 - Up to 2020, series per layer across sectors
 - From 2020, series per sector (1,2,3)(4,5,6)

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MPGD 2022 - 12/12/2022



						BMT FMT	ias Flows 8.8 0.1	0 5 . L/h . L/h
						BMT FMT	Wa	arn Fault
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Crate	2	ON			-			
Crate	: 3	ON			Bypas	sed: 0		
Crate	: 4	ON			,	Neathe	r	
Crate	: 5	ON		Hu	mid Av	g <u>Te</u>	mp Avc	
Crate	: 6	ON		8.5	56 %	6.	50 C	
	-							
Crate	1	Crate	urrent	Crate	3 (de	eg) Crate		
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No Central Tracker

LD28LH2 targets

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LH2 target

Commissioning



NH3 ND3 targets

Nuclear targets

Cea Maintenance

- The Silicon Vertex Tracker (SVT) was designed to operate at room temperature
- During commissioning (early 2018), the higher than expected dose, forced to cool the SVT at -20C
- No thermal insulation was inserted between the SVT and the BMT
- Temperatures dropped well below the dew point in the Micromegas envelope
- Condensation in HV boxes caused corrosion and shorts of few tiles
- Few tiles shown sign of mechanical deformation of the PCBs



Condensation on barrel detectors





cea Maintenance

- Intervention in Summer 2018 to install
 - Dry air pipes to flush the BMT volume
 - Humidity and temperature sensors
- Currently, the Micromegas are working a very dry environment (less than 10% relative humidity) with temperatures between 1C and 15C
- Protocols to prevent water condensation during maintenance and installations have been put in place
- No issues with humidity after Summer 2018



Condensation on barrel detectors





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cea Maintenance

- Spring 2020 and Winter 2020: complete disassembly and re-assembly of the system to unplug the signal cables for the Bonus experiment
- Winter intervention done by Jlab staff remotely guided by Saclay's expert









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- Clear correlation between the instantaneous luminosity (beam current) and the strip currents
- In data taking, currents between 0.5 and 1.5µA

2022 – Carbon target Strip HV ~500V



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cea Integrated currents





- Strip currents integrated over the whole data taking activity
- Between 10 and 20 C
- Depending on the tile gain and surface

Column B • Surface: 0.1m² (L1) – 0.2m² (L6)

Cea Occupancy

- Data taking with polarized NH3 target showed the largest occupancy
- At 8nA with the NH3 target
- 1.2% occupancy in random events
- 1.8% occupancy with physics trigger

Sector 1

L1 100 L2 L3 Random L4 L5 L6 10^{-1} 10-2 10^{-3} 20 40 60 80 0 100 number of strips



Sector 1





Player

• Linear dependence of the occupancy with the beam current, i.e. the luminosity



Sector 1 -- occupancy

Cea Hit distributions



- The hit distribution for C detectors tight to the fixed target event topology: more particle downstream the target
- Z detectors hit distribution is expected to be uniform
- · Structures related to detector effects, not fully understood





Hit distribution in Z detectors still under investigation

Change position with B orientation



B field = -5T

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Average cluster size: ~4

- Centroid residuals after alignment:
 - Z detectors: 432µm

cea Clusters

C detectors: 258µm







-L1

18/24

Clusters – Time distributions

- Time of a hit: time of the signal peak with respect to the trigger
- Tmin of the cluster: the smallest hit time
- Clear correlation of the Tmin for clusters attached to a track

LH2 target, 50nA

 Background hits are not correlated with the trigger



On track

Not on track



cea Efficiency



Efficiencies above 90%

- Lower efficiencies in 2022 due to:
 - Different gas distribution (under investigation)
 - Adjusted HV strip settings to cope with higher rates



2019, LH2, 50nA



2022, NH3, 8nA

cea Efficiency

- Efficiency scan in August 2022
- Most of the tiles reach the plateau around 500V on the strip
- Layer 3 and Layer 6 at 500V still rising
- They are the last in the gas distribution series
- Modifications to the gas distribution under discussion





cea Outlook: EIC

Motivation

A full (no acceptance gaps) light-weight modular Micromegas barrel tracker to complement the silicon vertex detector

Needs

- Light cylindrical tiles (~0.5% X0 per layer)
- 2D readout: ~150µm resolution

Less challenging environment

- B field up to 2T
- Particle rate at least 1000x less than CLAS12

Upgrades CLAS12 MM to fit the EIC needs:

- Simpler construction: •
 - about one module size bent at different radii ٠
 - overlap tiles for no acceptance gaps ٠
- 2D readout: keeping the channel count as low as possible

Objectives

- 2022-2023:
 - Optimization of the 2D readout for low number of channels on small ٠ prototypes
- 2023-2024:
 - Build a full scale prototype of a Micromegas tile (50x70cm²) with the chosen ٠ 2D readout



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- The low-mass CLAS12 cylindrical **Micromegas Vertex Tracker is taking data** since 2017
- Challenging environment:
 - 5 T field
 - High flux of charged particles, resulting in integrated currents of several Coulombs
 - Temperatures as low as 1C due to the unforeseen silicon cooling
- Overall performance are good:
 - Efficiencies above 90%
 - Cluster sizes around 4
- Some "features" still under study
- Perspective:
 - This technology is well suited for the EIC





cea Summary



Thanks for the attention!

Further reading:

- The CLAS12 Micromegas Vertex Tracker, Nucl.Instrum.Meth.A 957 (2020) 163423
- Alignment of the CLAS12 central hybrid tracker with a Kalman Filter, e-Print: 2208.05054

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The Saclay CLAS12 team