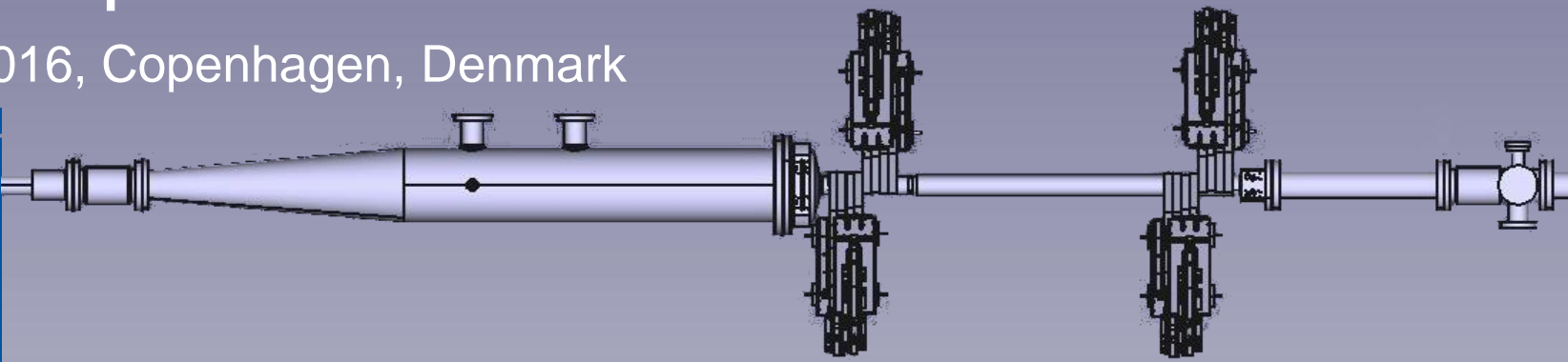


First LHC Transverse Beam Size Measurements with the Beam Gas Vertex Detector

A. Alexopoulos on behalf of the BGV team

May 16, 2016, Copenhagen, Denmark



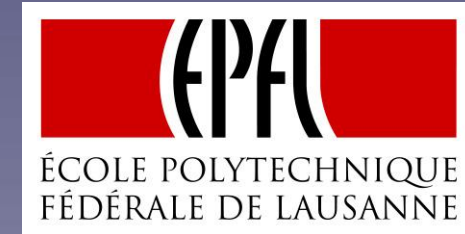
Research supported by the High Luminosity LHC project

The BGV team

A. Alexopoulos, C. Barschel, E. Bravin, G. Bregliozi, N. Chritin, B. Dehning, M. Ferro-Luzzi, M. Giovannozzi, R. Jacobsson, L. K. Jensen, O. Rhodri Jones, V. Kain, R. Matev, M. Rihl, V. Salustino Guimaraes, R. Veness, S. Vlachos, B. Würkner



A. Bay, F. Blanc, S. Giani, O. Girard, G. Haefeli, P. Hopchev, A. Kuonen, T. Nakada, O. Schneider, M. Tobin, Q. Veyrat, Z. Xu



R. Greim, W. Karpinski, T. Kirn, S. Schael, A. Schultz von Dratzig, G. Schwering, M. Wlochal



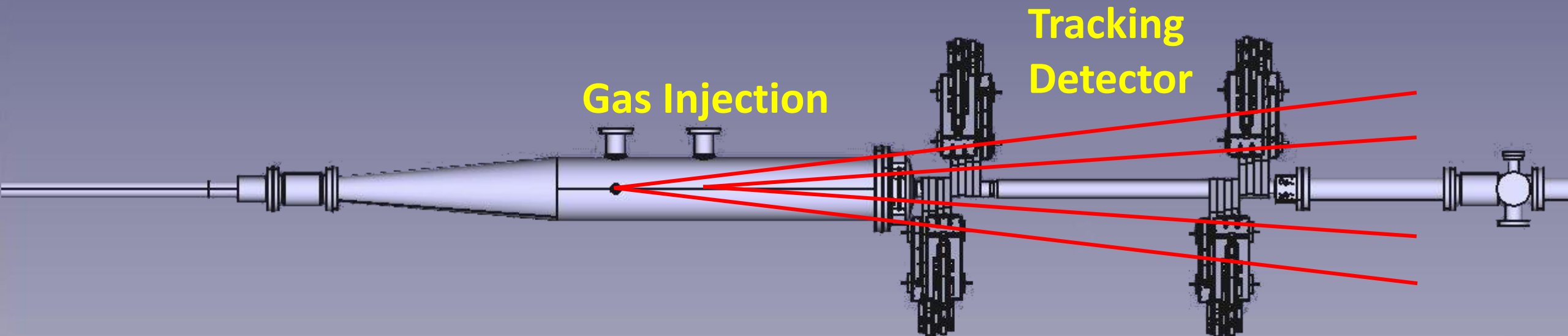
...and significant support by LHCb collaboration & BE-BI-BL section

Outline

- The BGV Demonstrator
 - Detector Design
 - Readout System
- BGV Data Analysis
 - Analysis Method
 - Results from 2016 LHC Run
- Summary

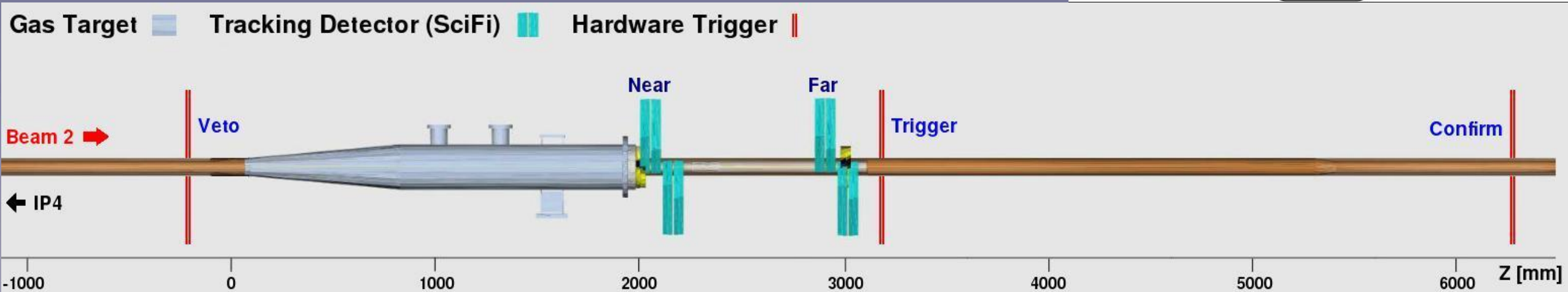
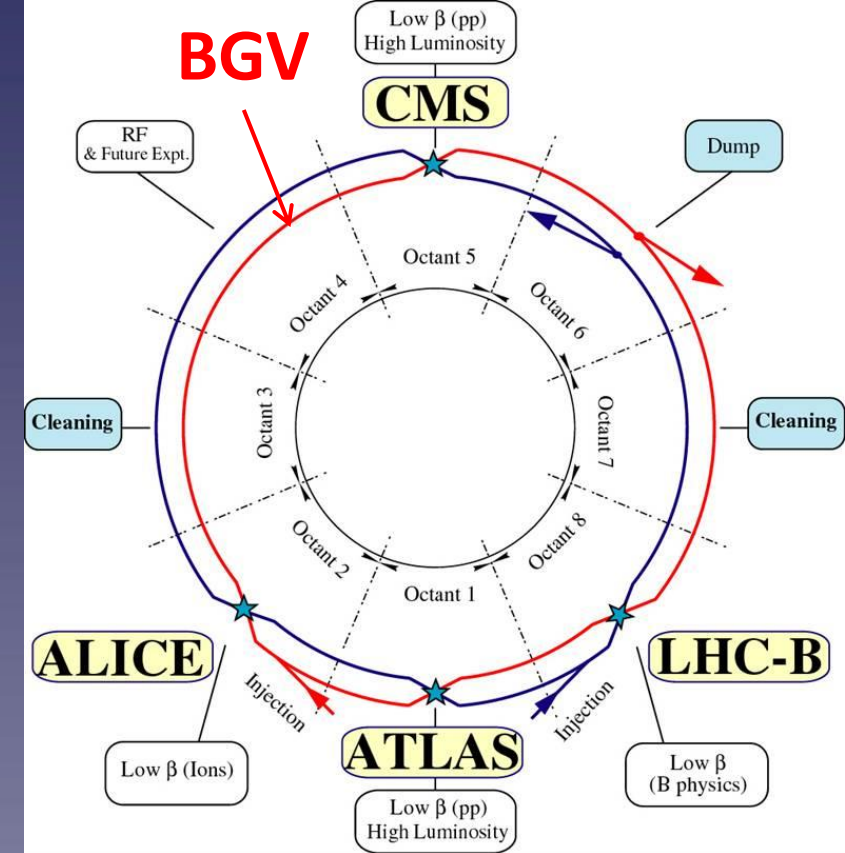
The BGV Demonstrator

- Non-destructive beam size measurement
 - Based on the reconstruction of beam-gas interaction vertices
 - Independent of accelerator luminosity or energy
 - Initial target to estimate bunch-by-bunch beam shape with a resolution of about 10% in 5 minutes

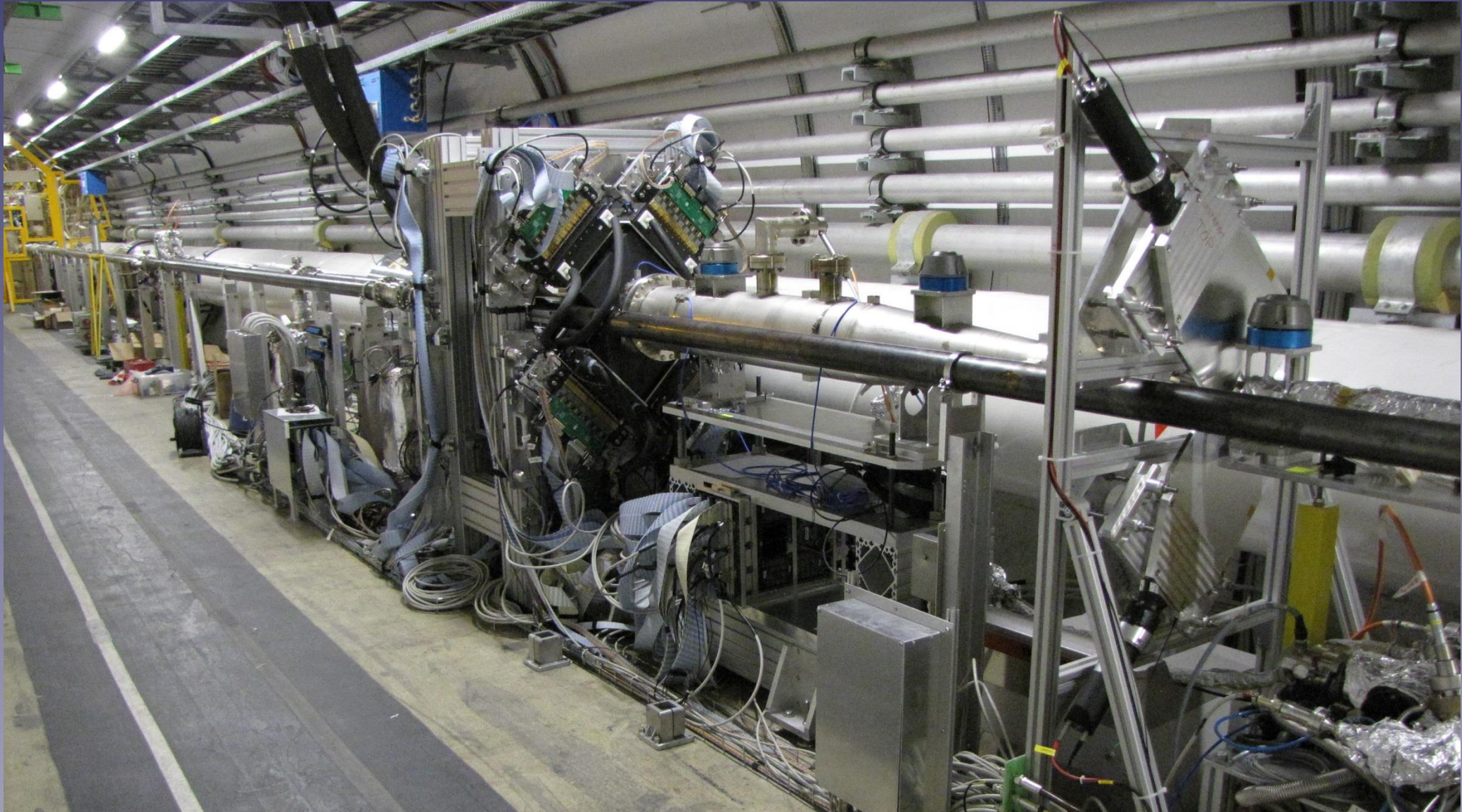


The BGV Demonstrator

- Detector fully installed in LHC Pnt.4 on the Beam 2 ring
- Main parts: Gas target volume, tracking detector & hardware trigger



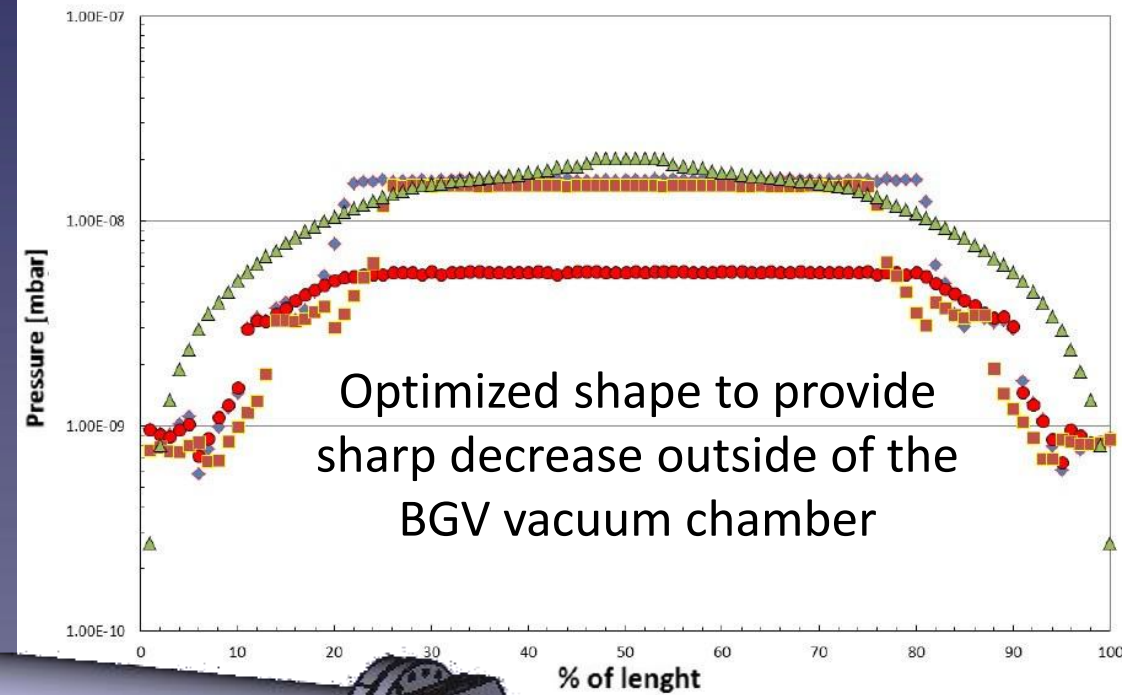
The BGV Demonstrator



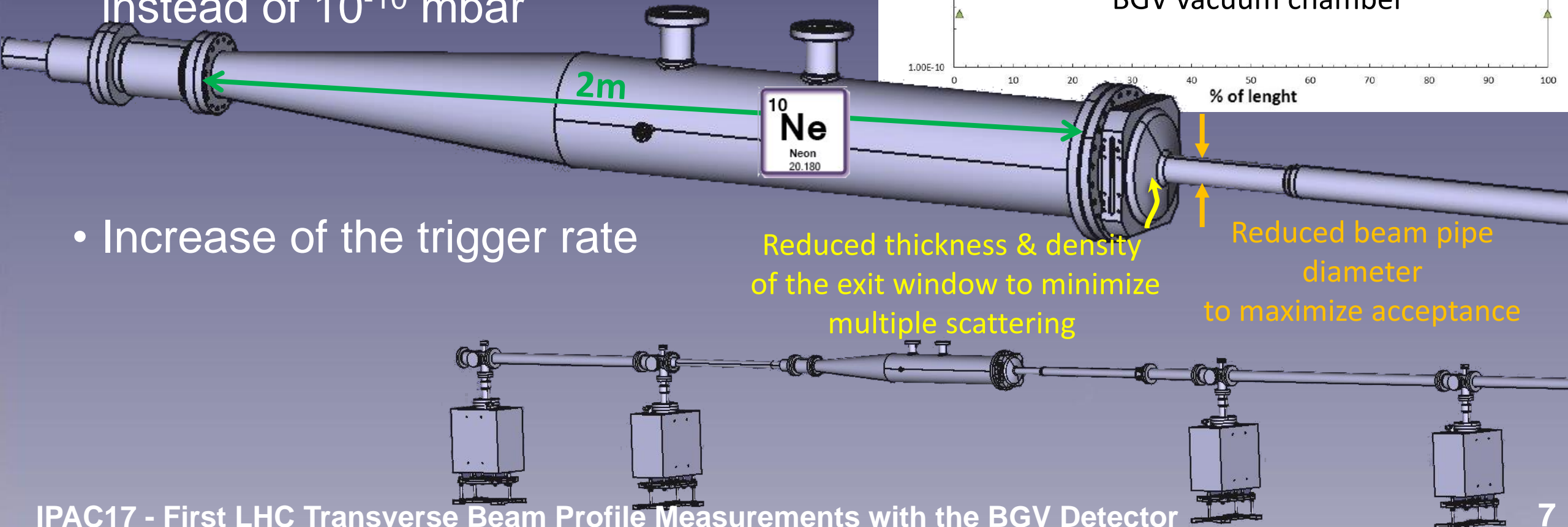
Detector Design

- Gas Target

- Pressure bump up to 10^{-7} mbar instead of 10^{-10} mbar



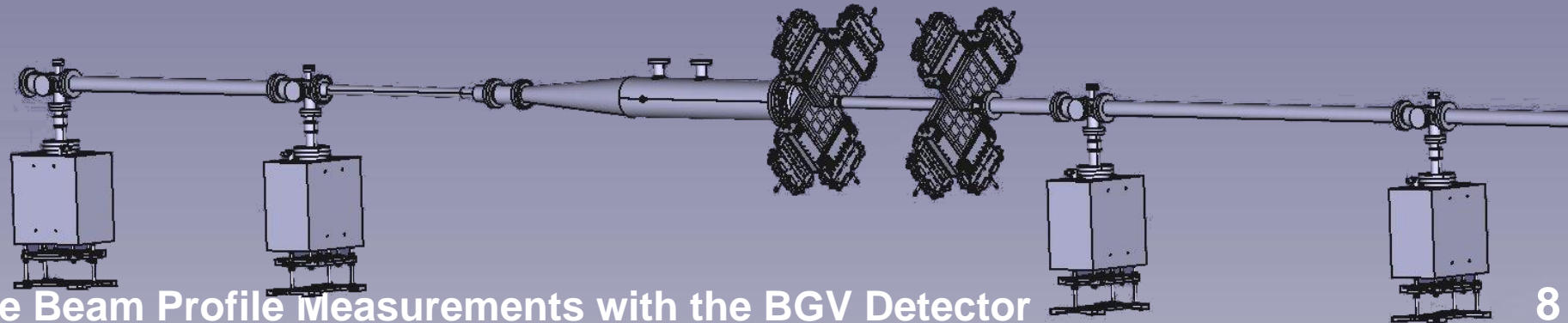
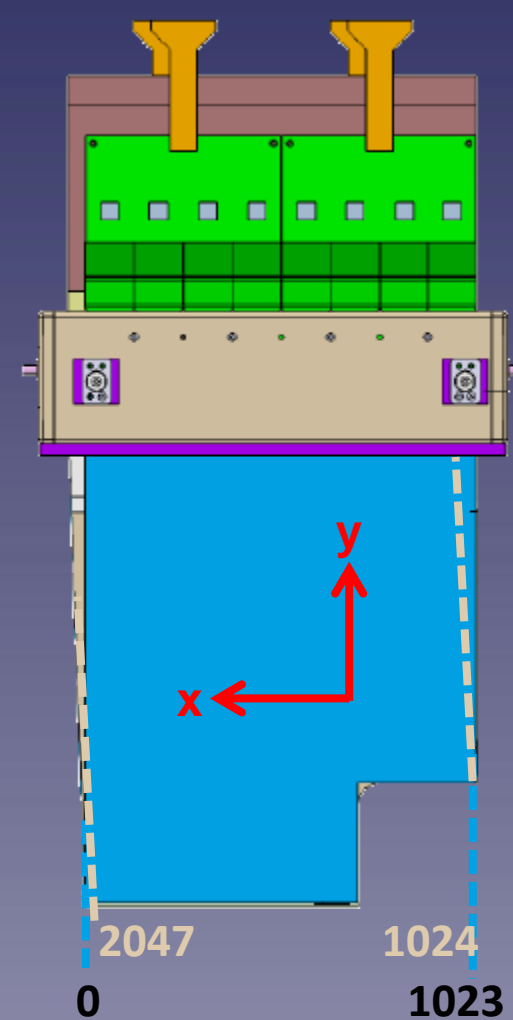
- Increase of the trigger rate



Detector Design

- Tracking Detector

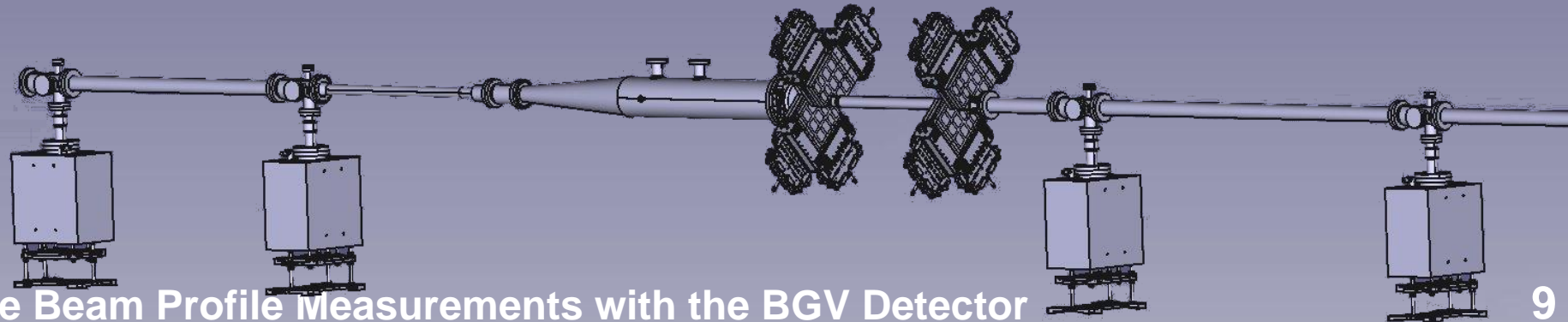
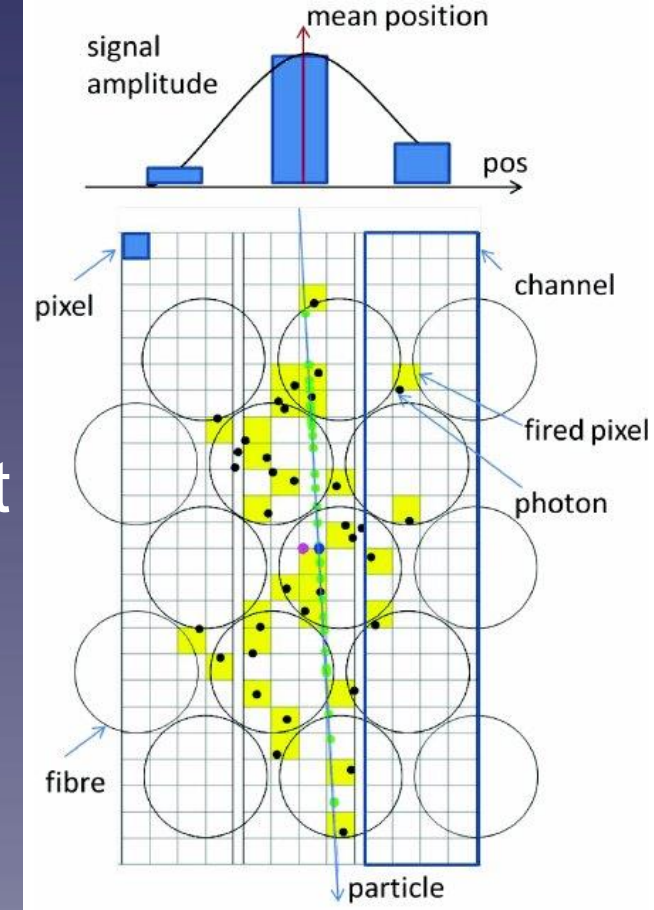
- Consists of 2 stations ('near' and 'far')
- Four scintillating fiber (SciFi) modules per station
 - Each pair of modules is perpendicularly placed
 - Each module has two mats, also rotated by 2° with respect to each other to facilitate pattern recognition
 - Module read out by 16 Silicon Photo Multipliers (SiPMs) of 128 channels each



Detector Design

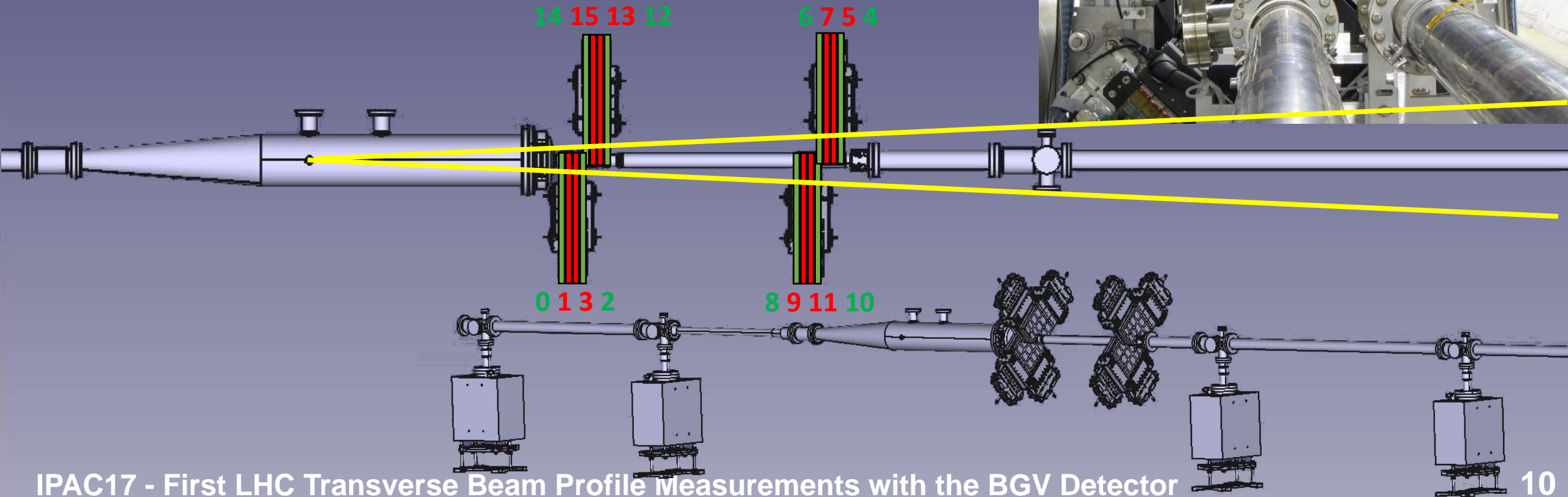
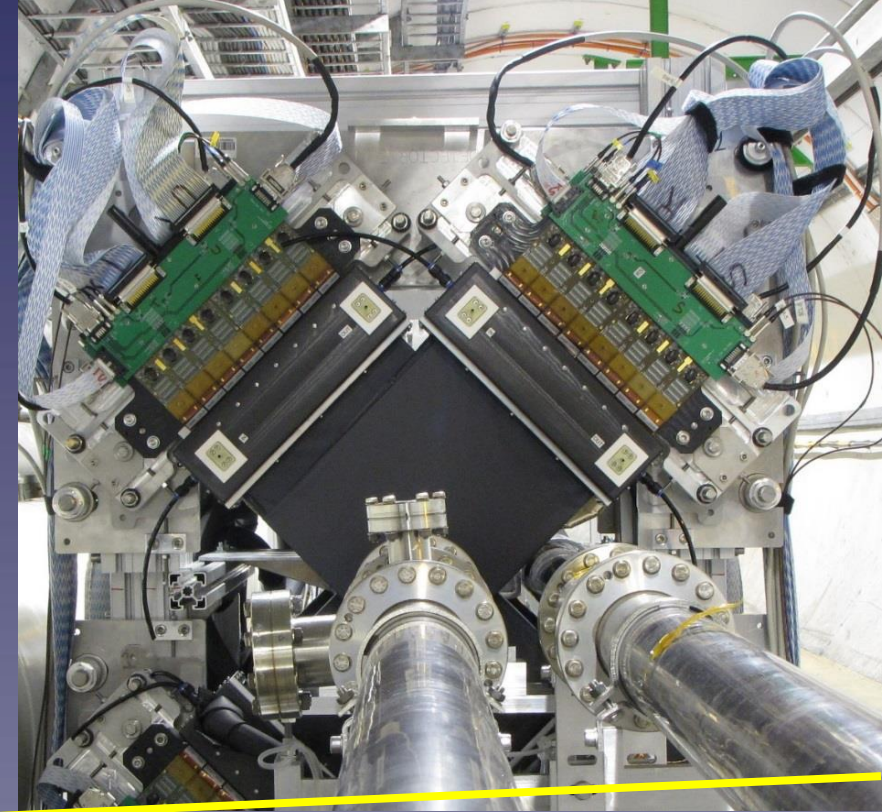
- Tracking Detector

- Fibers of 250 μ m diameter, 4 or 5 fiber layers per mat
- Photons are generated in the fibers & detected by several pixels of the SiPM
- The signal of each channel is the sum of all fired pixels within the channel
- The crossing point is calculated as a weighted mean of the cluster's channels



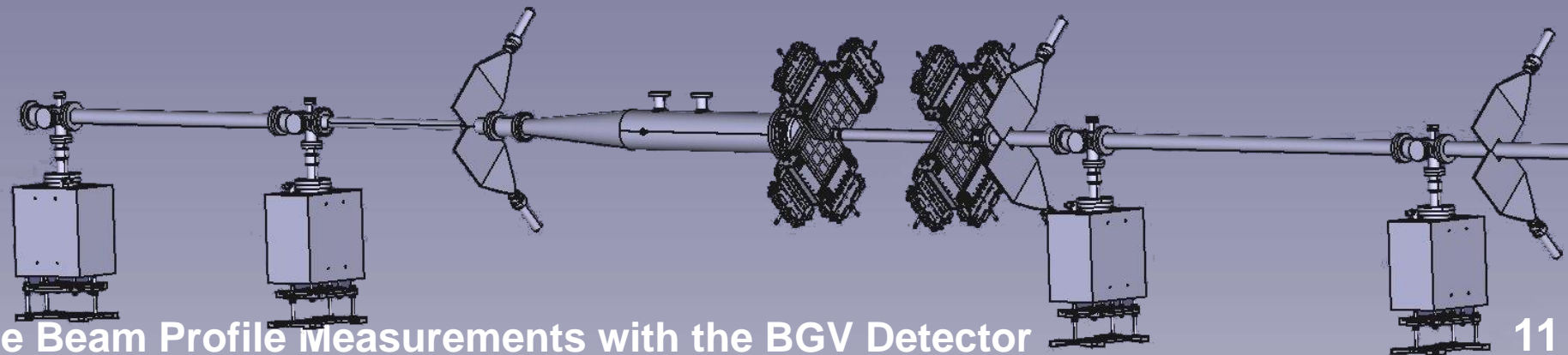
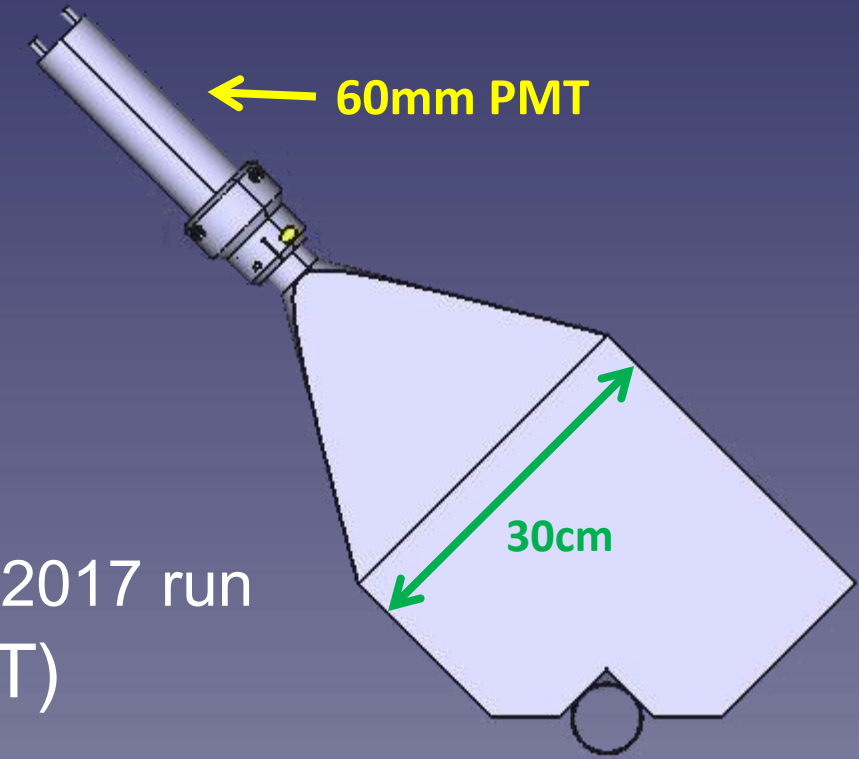
Detector Design

- Tracking Detector
 - Tracks are reconstructed provided that a valid cluster is detected on each layer



Detector Design

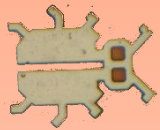
- Hardware Trigger
 - Based on scintillator plates
 - Three stations, 'veto', 'signal', 'confirm'
 - 'confirm' station to be commissioned during LHC 2017 run
 - Read out through Photomultiplier Tubes (PMT)
 - Coincidence of all signals is used as trigger



Readout System

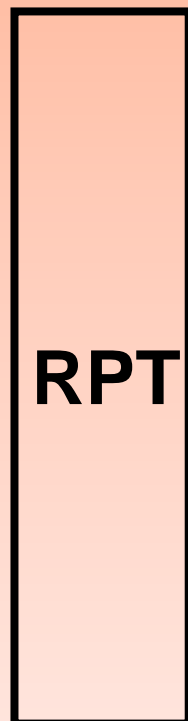
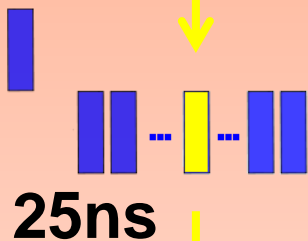
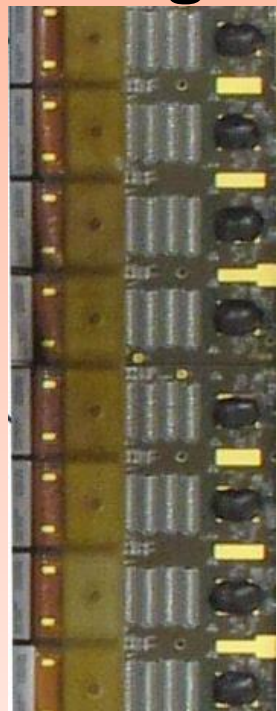


LHC Tunnel



Analog FE

L0 Latency



60m

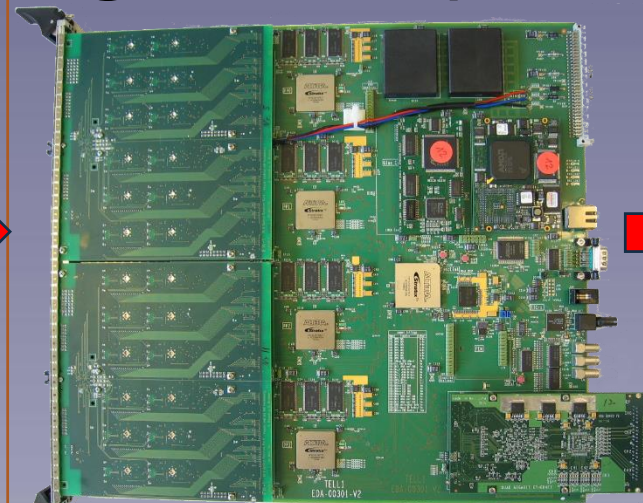
Hardware Trigger

Readout Manager (ODIN)



Digitization (TELL1)

CPU Farm



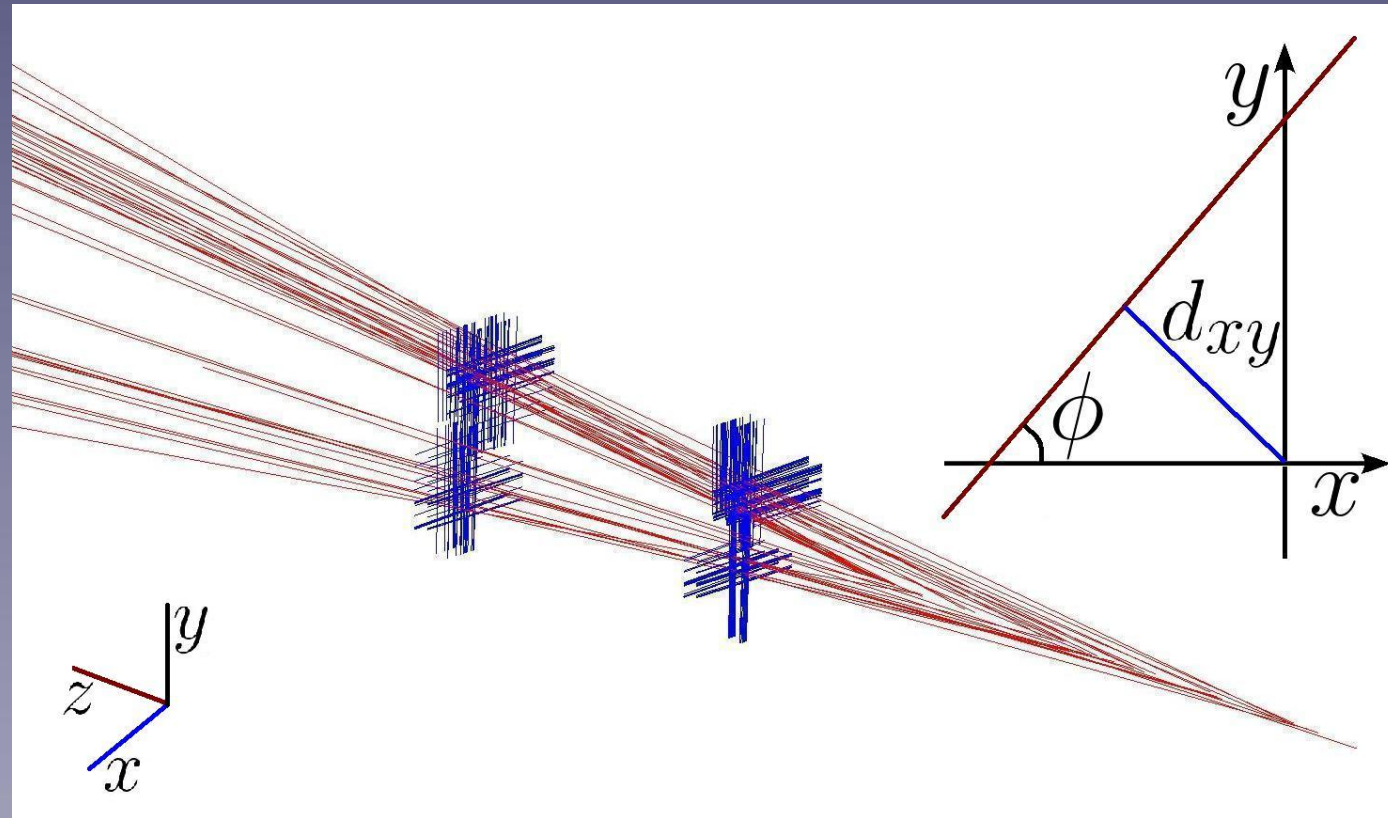
Outline

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Analysis Method

- Impact parameter d_{xy}
 - Distance of closest approach of reconstructed tracks to the z-axis
- Azimuthal angle ϕ
 - Angle between the x-y projection of the track & the x-axis

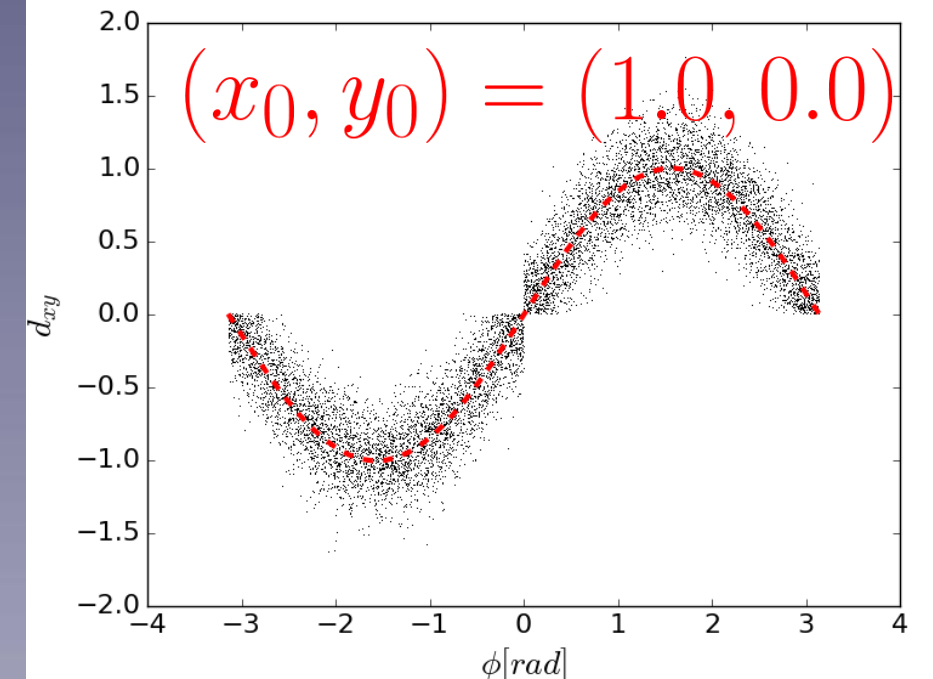
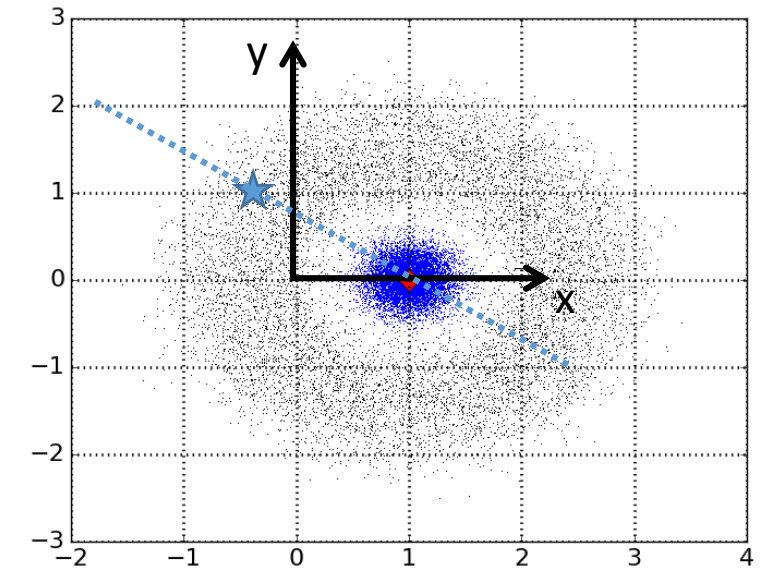
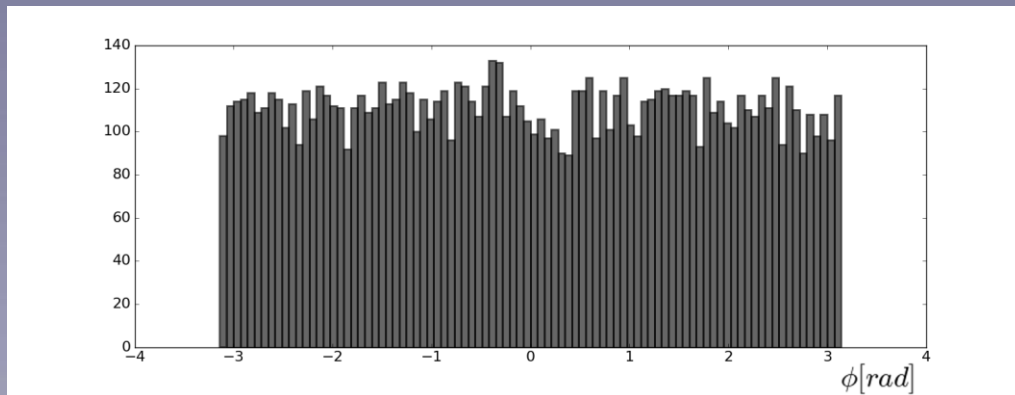
Use tracks & impact parameter correlations to measure beam position and size



Analysis Method

- Beam Position
 - Using the impact parameter to azimuthal angle correlation, the position can be calculated as:

$$d_{xy} = x_0 \sin(\phi) - y_0 \cos(\phi)$$

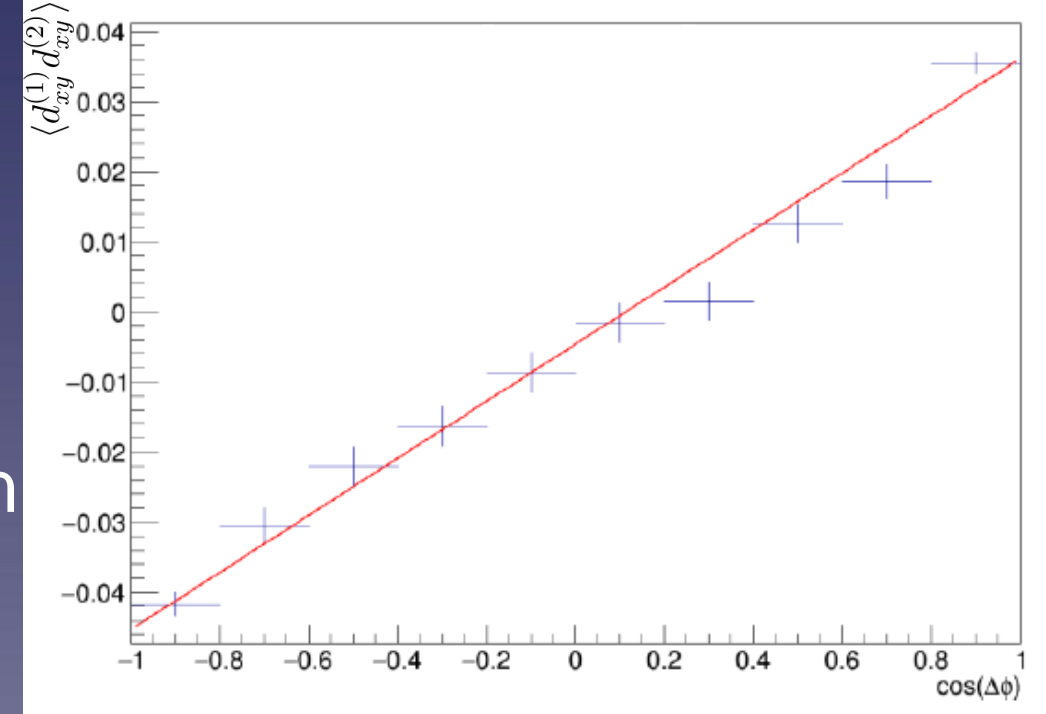


Analysis Method

- Beam Size
 - Using the impact parameter correlation of tracks produced by a beam-gas interaction the beam size is measured as:

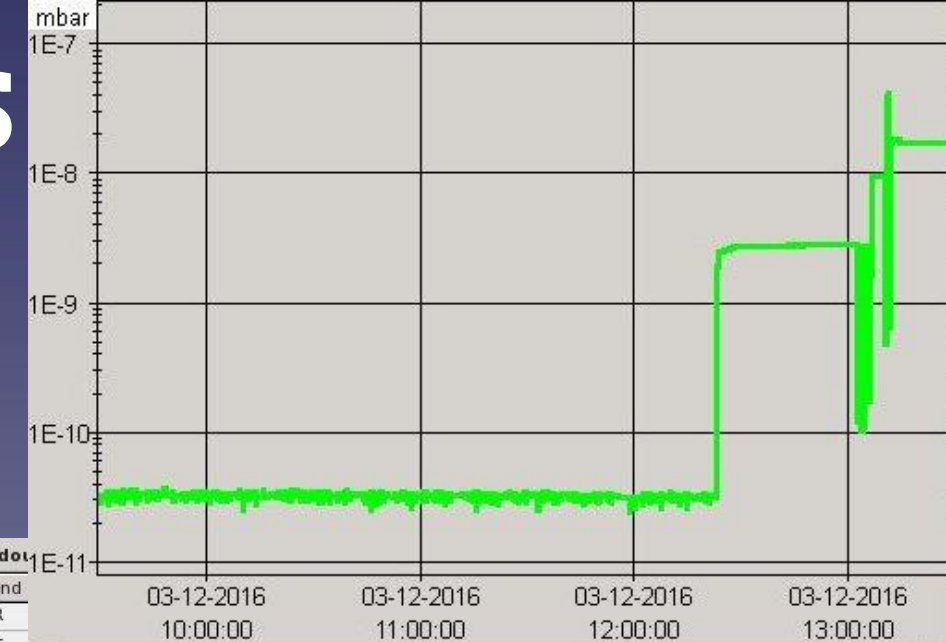
$$\langle d_{xy}^{(1)} d_{xy}^{(2)} \rangle = \sigma_{beam}^2 \cos(\phi_1 - \phi_2)$$

- Assuming that $\sigma_x = \sigma_y$ at BGV location (optics)



LHC 2016 Run Results

- Results from fill 5570
 - Beam properties
 - Energy : 6.5 TeV
 - Intensity : (B2) 1.8×10^{13} / 684p
 - Gas Pressure : 6.0×10^{-8} mbar
 - SiPMs Temperature: -25°C
 - Acquisition duration of ~5 minutes
 - Trigger rate <1kHz

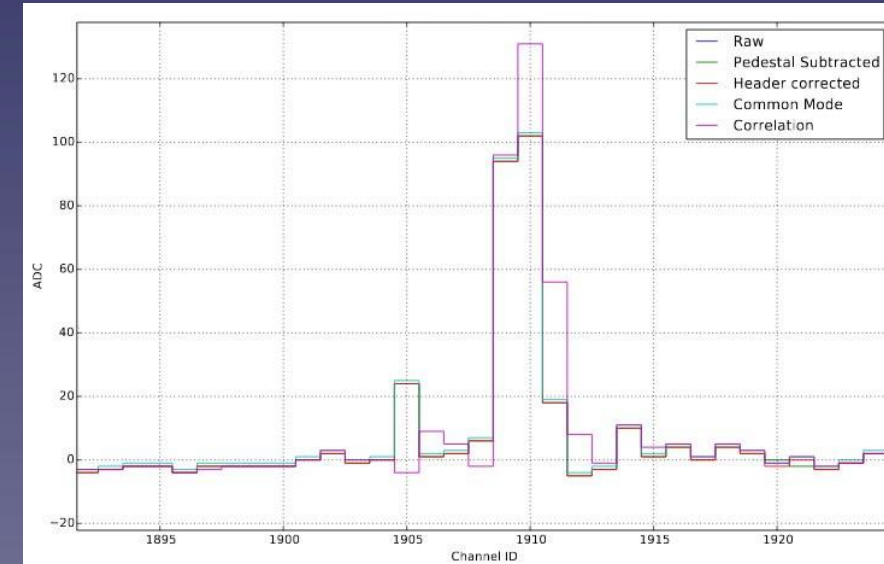


Temperature Readout										
Module	Frontend	03-12-2016 10:00:00		03-12-2016 11:00:00		03-12-2016 12:00:00		03-12-2016 13:00:00		
U-TOP	R									
	T	-24.12	-24.08	-24.98	-25.42	S	-25.38	-25.00	-25.02	-25.01
U-BOTTOM	R	-24.81	-25.24	-25.79	-26.51	U	-26.66	-26.12	-26.01	-26.73
	T	-24.81	-25.24	-25.79	-26.51	U	-26.66	-26.12	-26.01	-26.73
U-QRL	R	-25.31	-25.68	-26.29	-26.83	S	-26.85	-26.42	-26.26	-26.33
	T	-24.39	-24.01	-24.67	-25.36	U	-25.37	-25.27	-25.06	-25.15
U-PAS	R	-25.50	-25.68	-25.76	-25.81	S	-25.36	-25.12	-24.90	-24.95
	T	-24.39	-24.49	-25.22	-25.54	U	-25.53	-25.14	-24.69	-25.02
D-TOP	R	0.00	0.00	0.00	0.00	S	0.00	0.00	0.00	0.00
	T	0.00	0.00	0.00	0.00	U	0.00	0.00	0.00	0.00
D-BOTTOM	R	0.00	0.00	0.00	0.00	S	0.00	0.00	0.00	0.00
	T	0.00	0.00	0.00	0.00	U	0.00	0.00	0.00	0.00
D-QRL	R	-24.38	-24.41	-25.05	-25.53	S	-25.61	-25.31	-25.32	-25.27
	T	-24.86	-25.76	-26.19	-26.66	U	-26.59	-26.05	-25.71	-26.35
D-PAS	R	-23.97	-23.86	-24.69	-25.42	S	-24.87	-24.97	-24.87	-25.09
	T	-25.46	-24.91	-25.12	-25.70	U	-25.11	-24.97	-24.85	-24.93

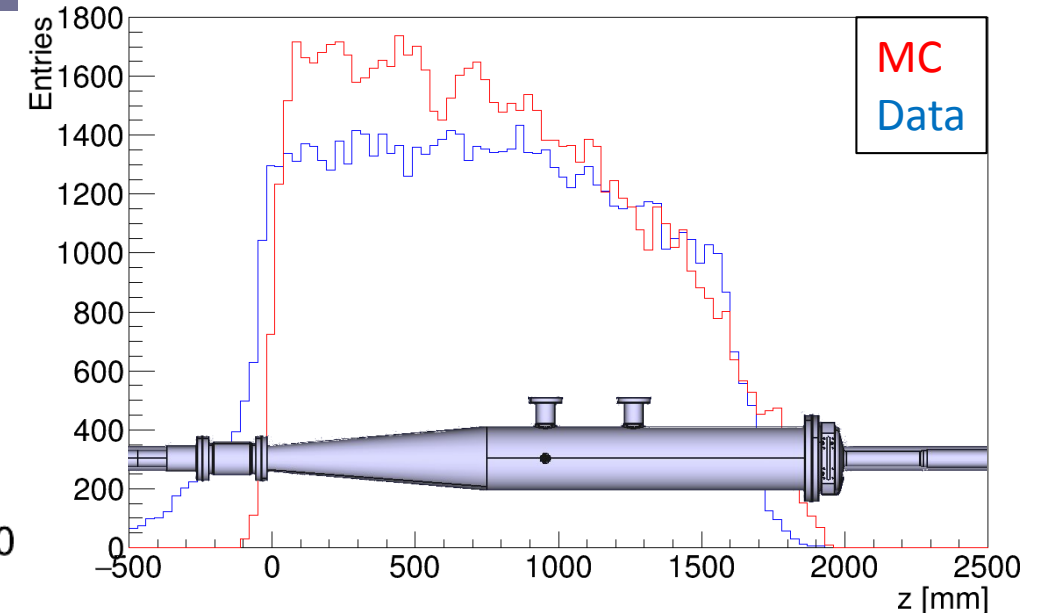
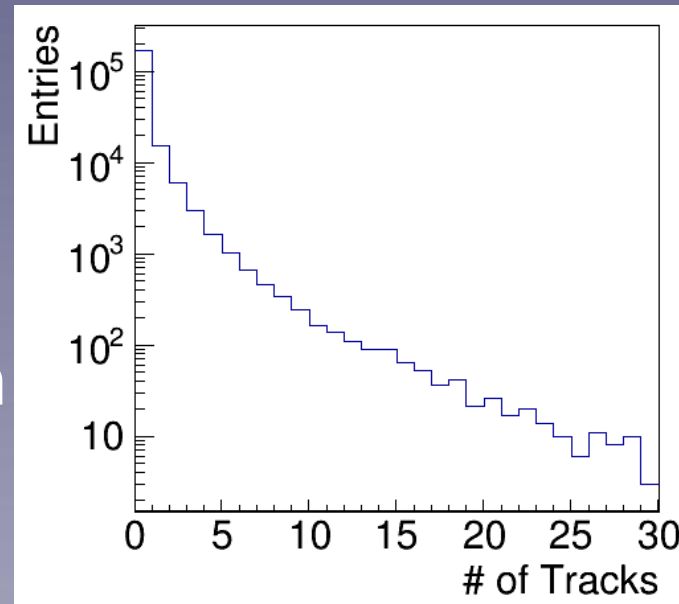
LHC FILL NUMBER: 5570 STABLE BEAMS SINCE 05h 23m	Beam	Intensity	Stored E	Particle	Bunches	Beam Energy	03-12-2016 13:28:51
PROTON-NUCLEUS PHYSICS	1	4.14E+12	4.31 MJ	Pb82	540	6.50 Z TeV	
Inj. scheme: 100_200ns_540Pb_684p_513_224_162_20inj	2	1.80E+13		Proton	684		
2016-12-03 08:22:20 (now: physics 540Pb/684p)							

LHC 2016 Run Results

- Data corrections
 - Pedestal subtraction
 - Common mode noise suppression
 - Channel correlation



- Data Metrics
 - Track Multiplicity
 - POCA z-distribution
 - Pseudorapidity



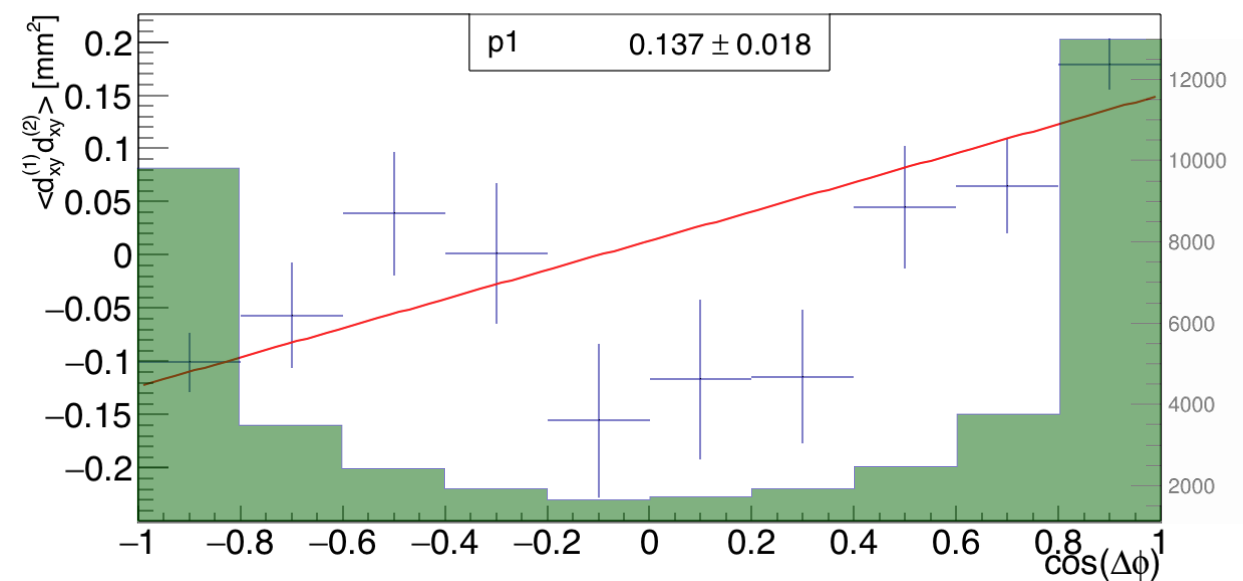
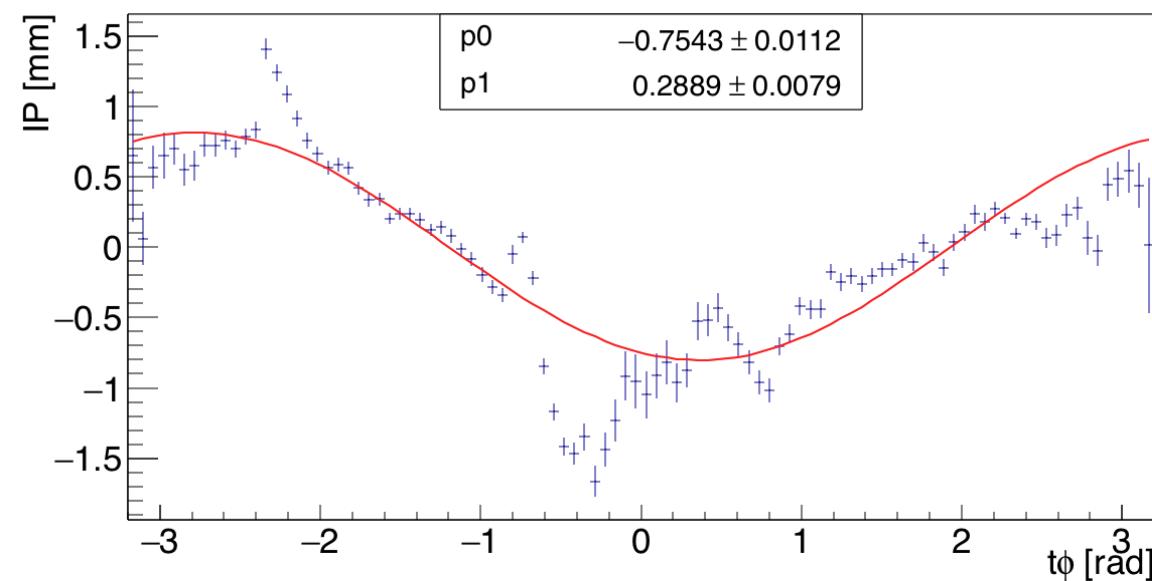
LHC 2016 Run Results

Beam position

$$(x, y) = (-0.79\text{mm}, 0.29\text{mm})$$

Beam Size

$$\sigma_{beam} = 0.37\text{mm} \pm 0.13\text{mm}$$



Summary & Outlook

- First commissioning steps were successfully completed
- Transverse beam profile measured with 0.13mm statistical error
 - Not yet allowing for a full comparison with other instruments
- Several enhancements:
 - Zero-suppression in the read-out FPGAs → Increase statistics (100x)
 - Trigger upgrade → Improve the event selection
 - Cross-calibration with other LHC instruments