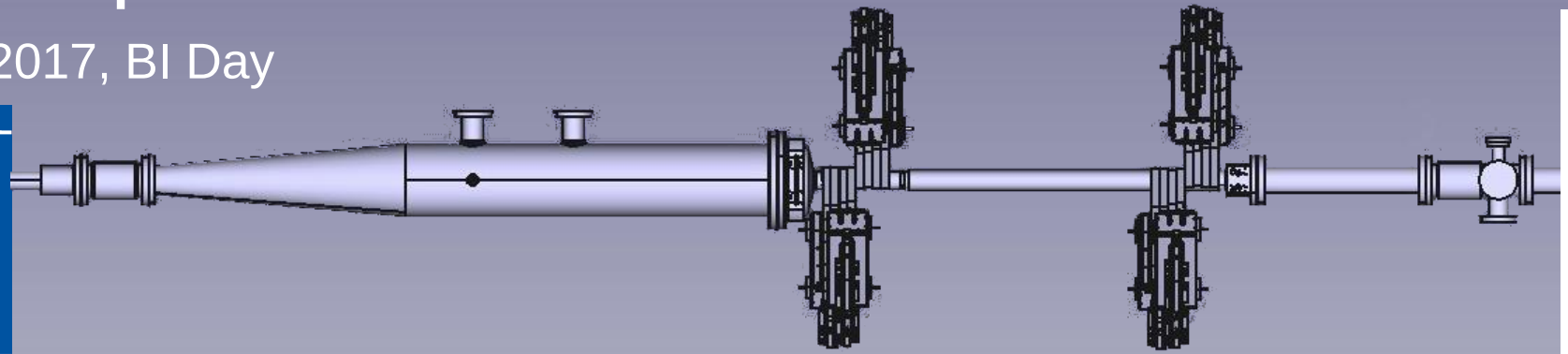
First LHC Transverse Beam Size Measurements with the Beam Gas Vertex Detector

A. Alexopoulos on behalf of the BGV team

June 29, 2017, BI Day



Research supported by the High Luminosity LHC project

The BGV team

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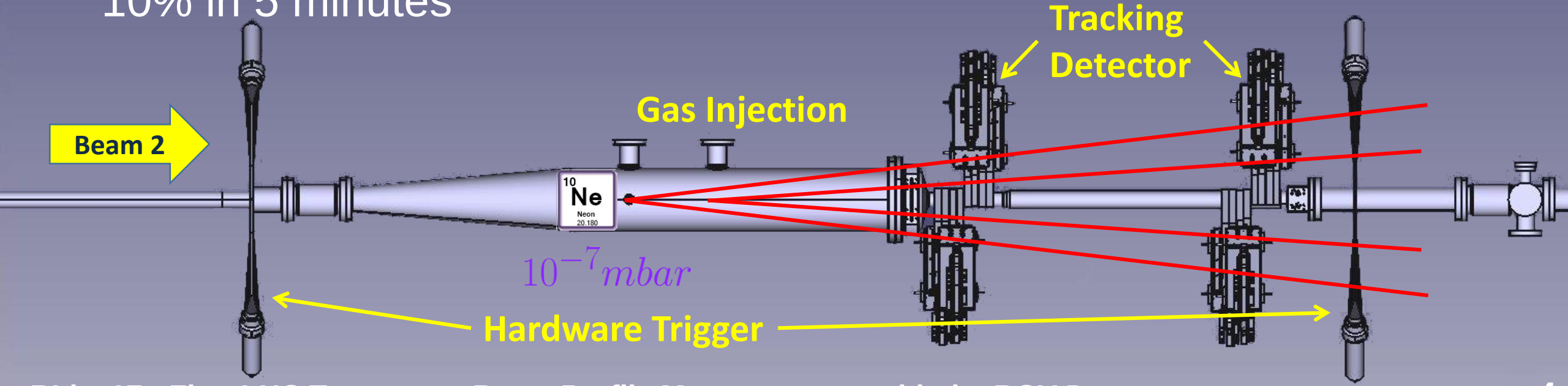
…and significant support by LHCb collaboration & BE-BI community

Outline

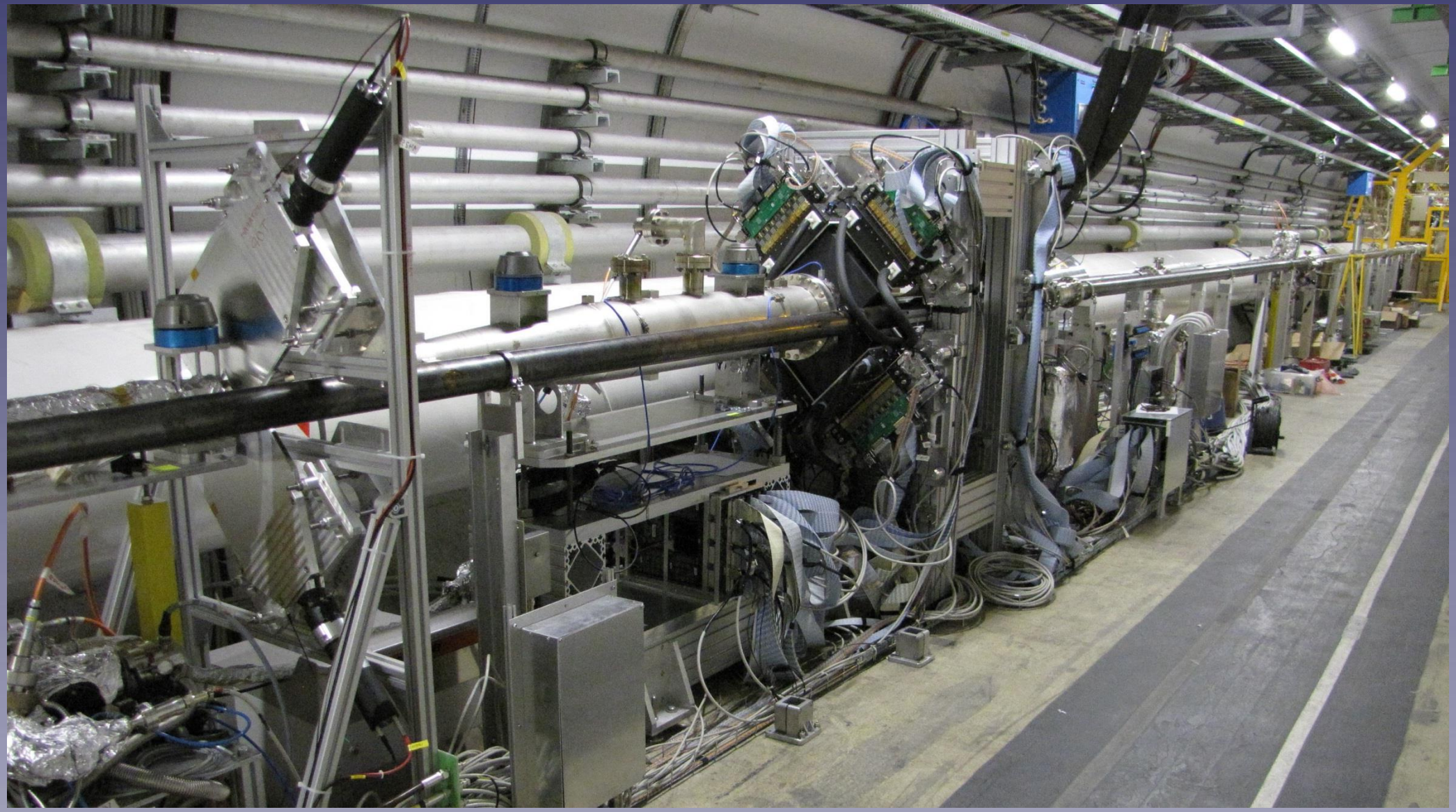
- The BGV Demonstrator
  - Detector Design
  - Readout System
- BGV Data Analysis
  - Analysis Method
  - Results from 2016 LHC Run
- Summary

The BGV Demonstrator

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

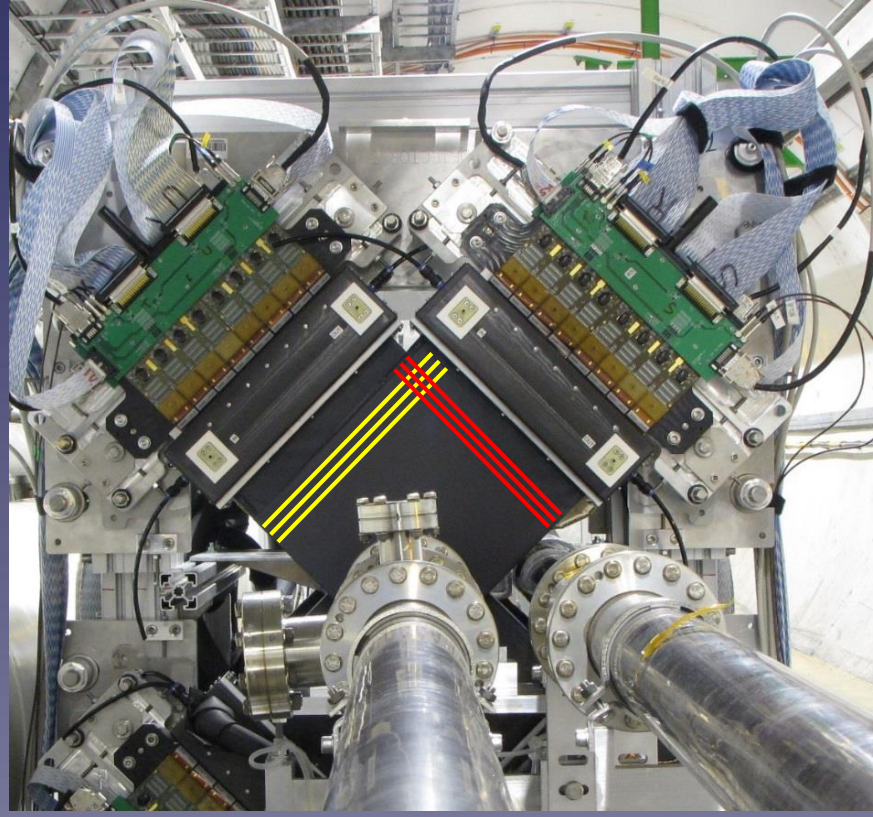


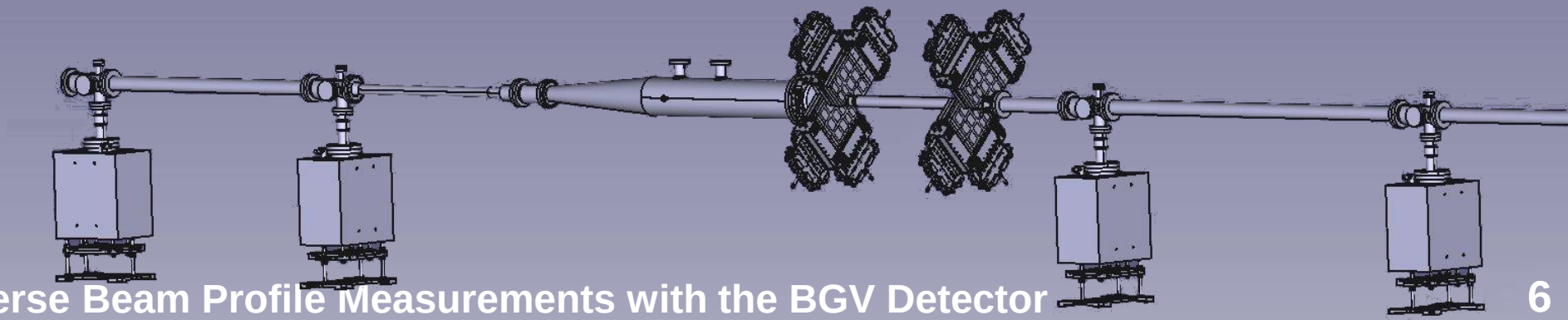
The BGV Demonstrator



Detector Design

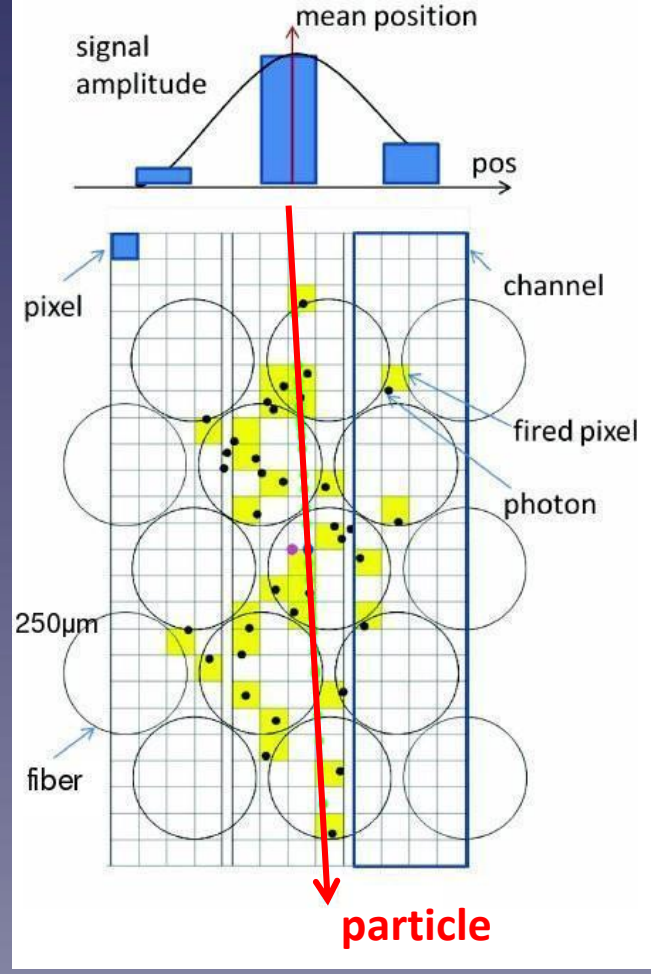
- Tracking Detector
  - Consists of 2 stations (‘near’ and ‘far’)
  - 4 scintillating fiber (SciFi) modules per station
    - Each pair of modules is perpendicularly placed
    - Module read out by 16 Silicon Photo Multipliers (SiPMs) of 128 channels each

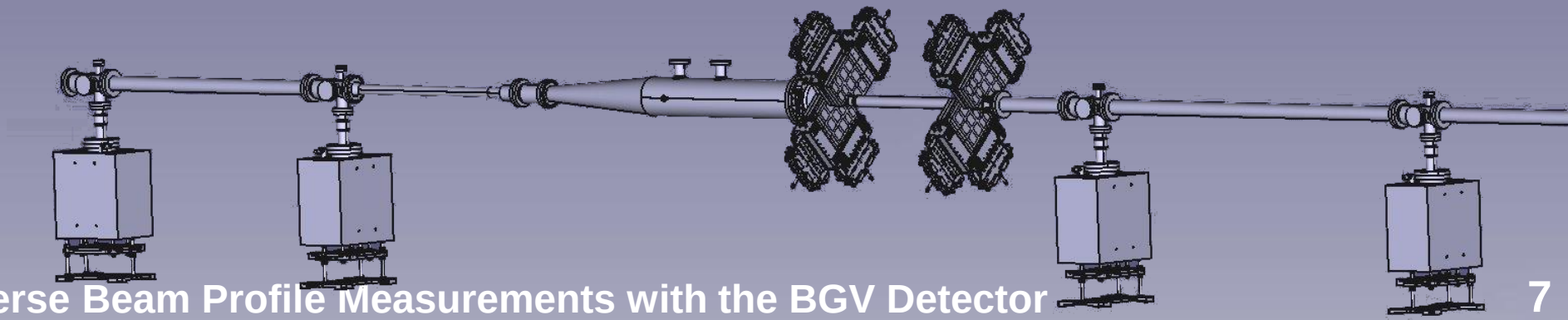




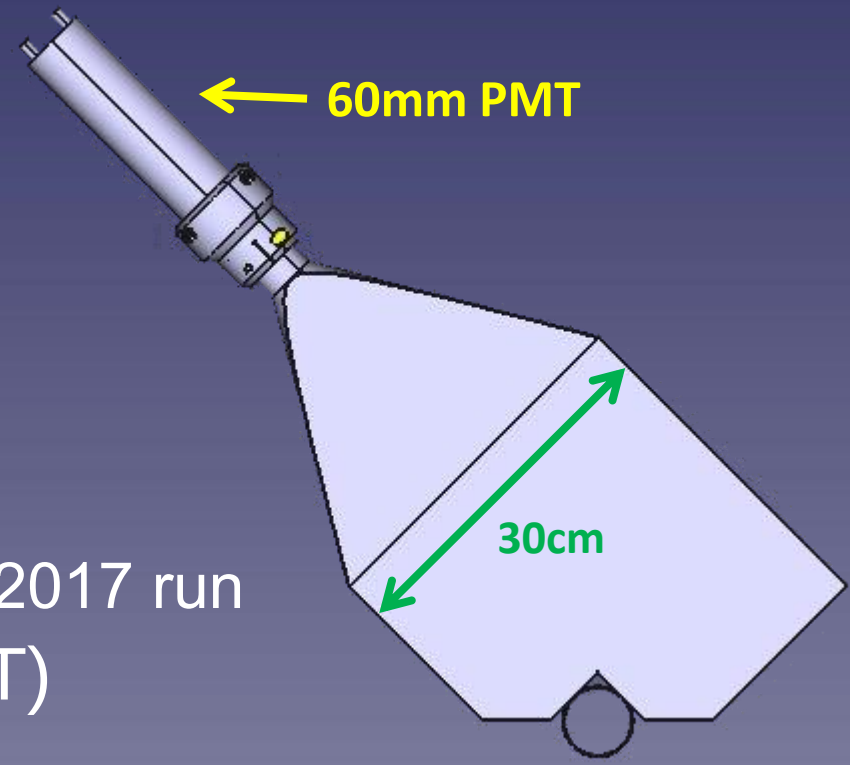
Detector Design

- Tracking Detector
  - 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

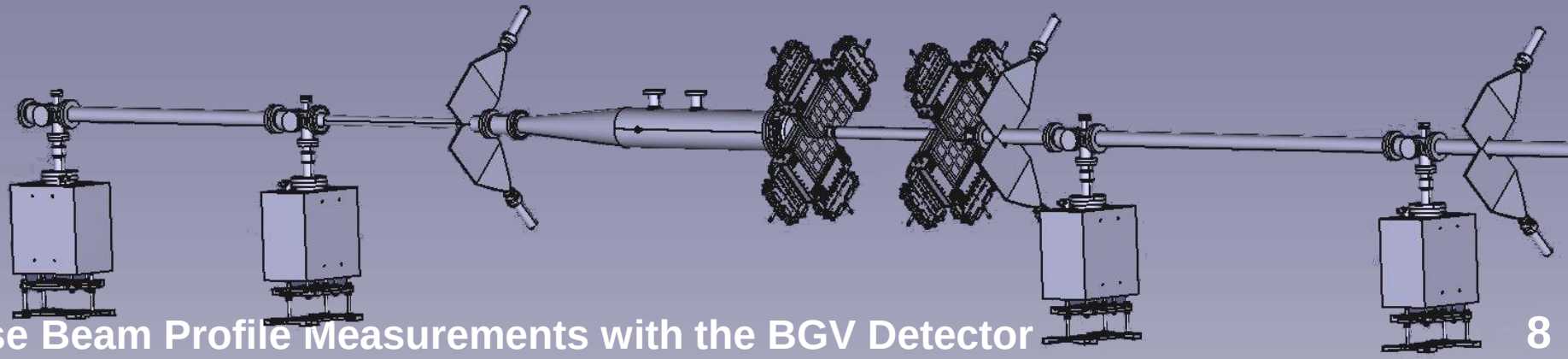




Detector Design



- 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)
  - Combination of all signals is used as trigger



Readout System

LHC Tunnel

Hardware Trigger

Analog Front-End

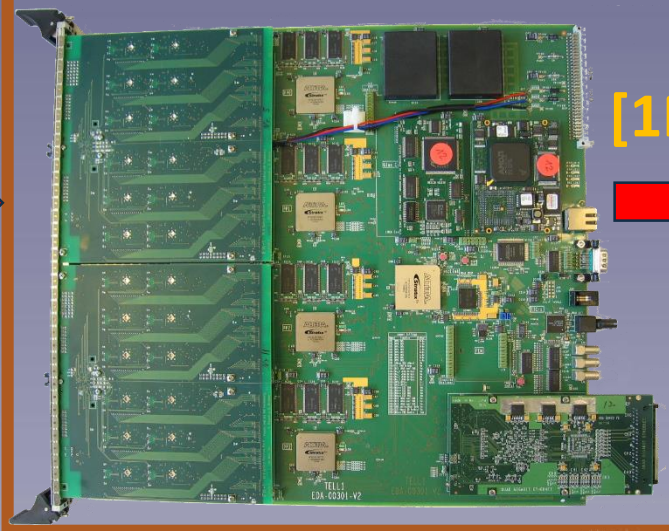
[40MHz]

60m

LHC Alcove

Digitization

- ❑ Data corrections
- ❑ Zero-suppression
- ❑ Cluster recognition



[1MHz]

CPU Farm

- ❑ Track reconstruction
- ❑ Vertex localization
- ❑ Beam size determination

Outline

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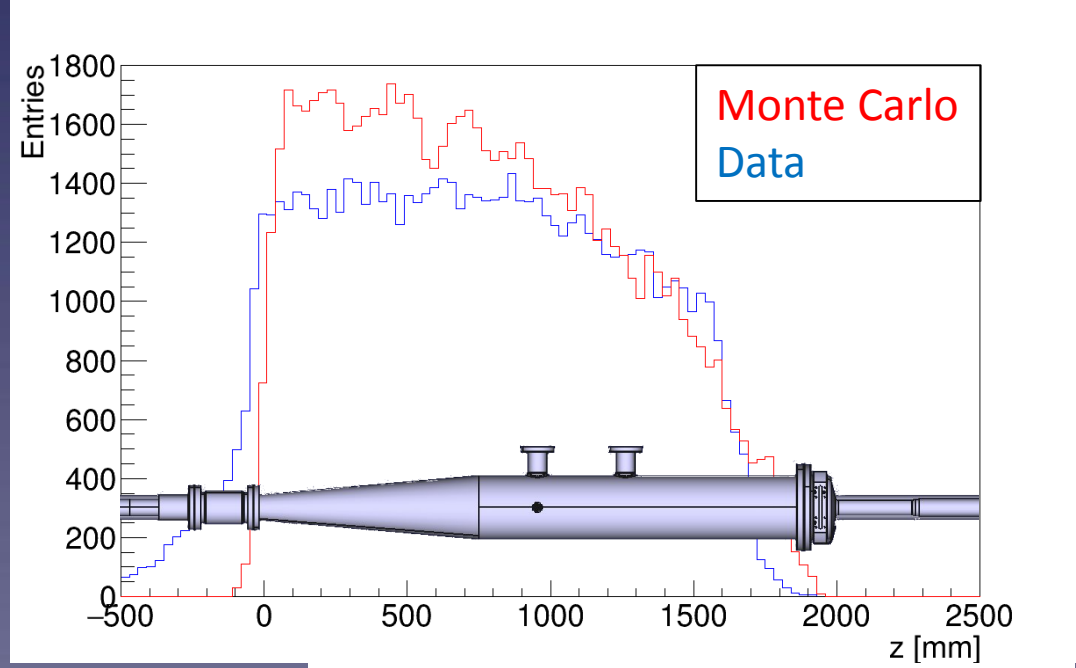
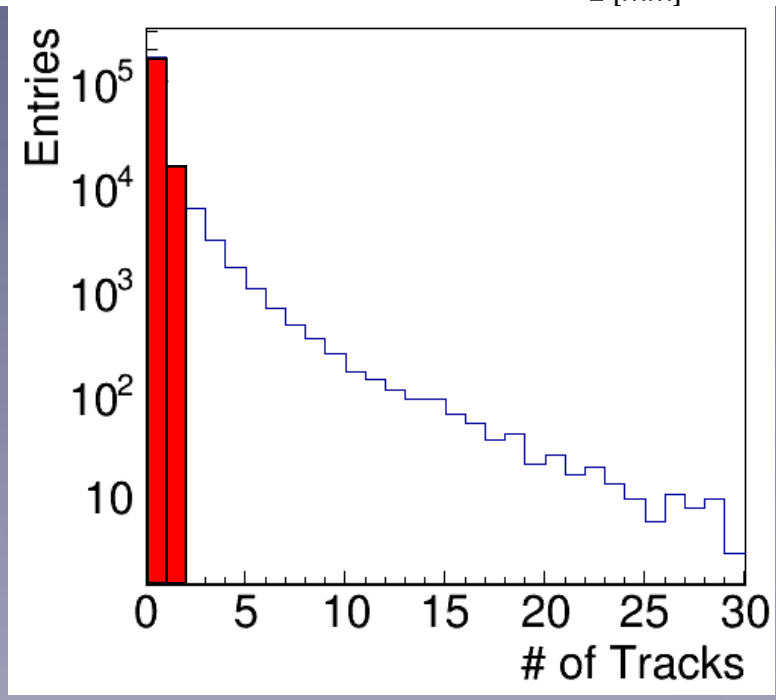
- BGV Data Analysis
  - Analysis Method
  - Results from 2016 LHC Run
- Summary

BGV Data analysis

- Triggering issues
  - In 2016 the majority of the events did not contain any “reconstructible” tracks
  - Reduced statistics
  - The distribution of the points of closest approach to the z-axis for the reconstructed tracks matched the simulation

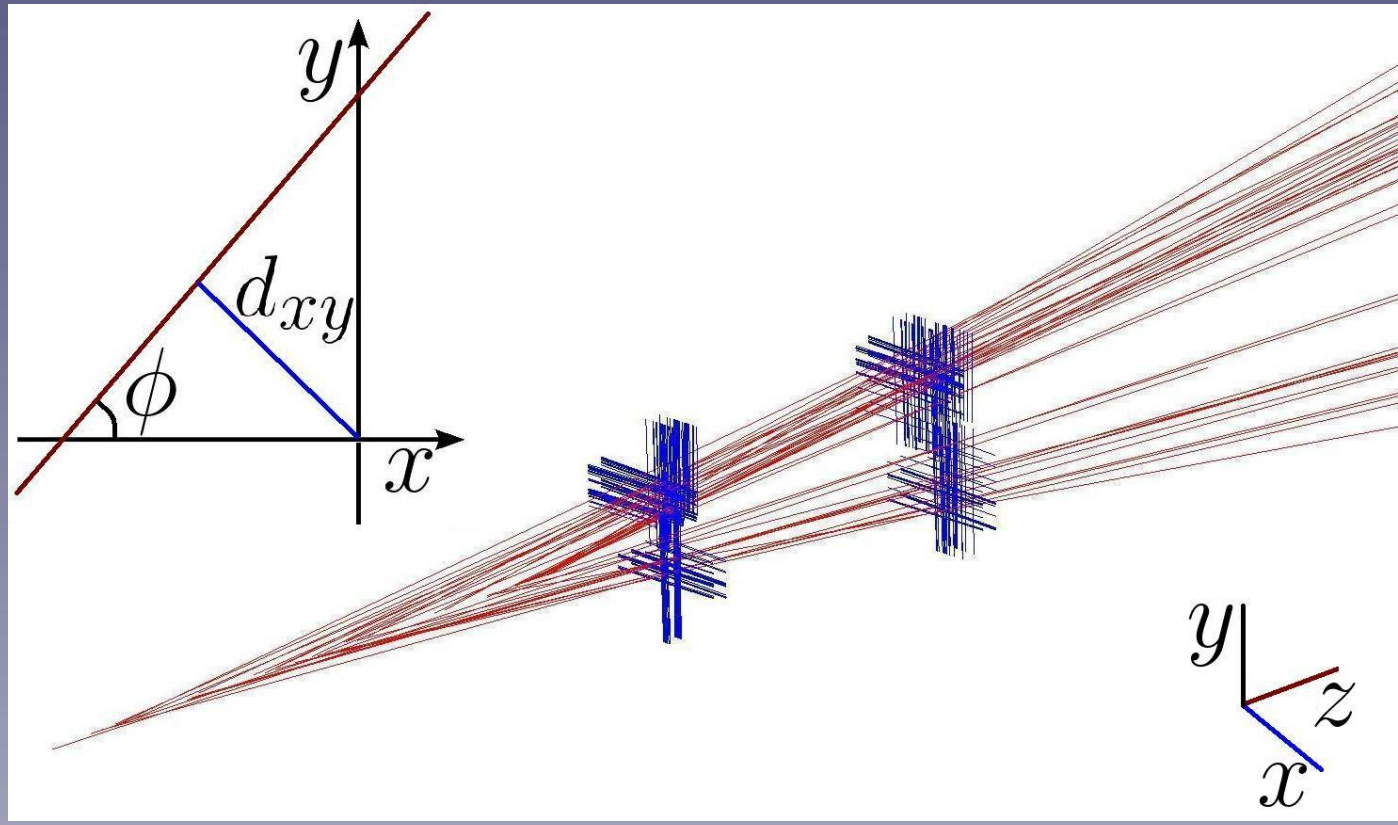




Analysis Method

- 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

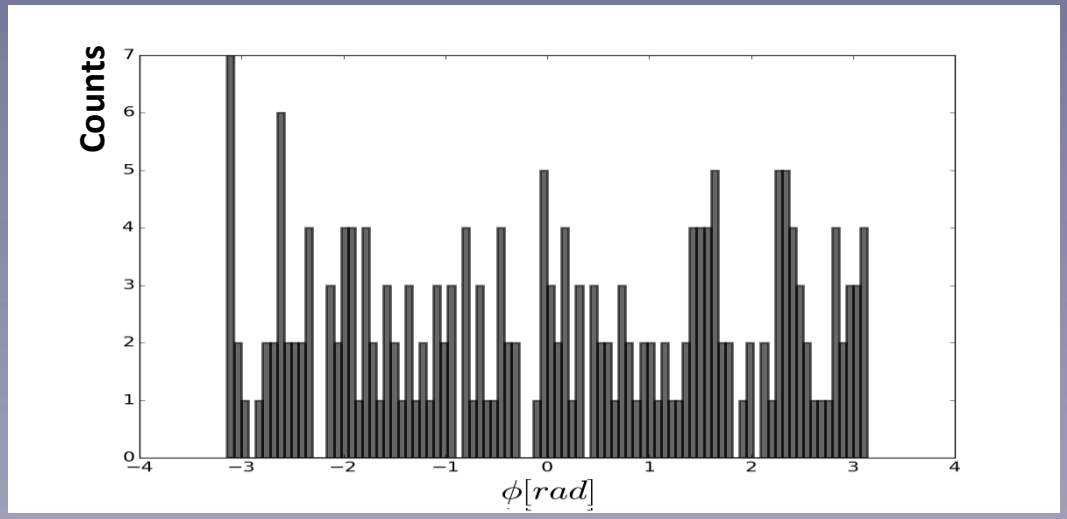
Use tracks & impact parameter correlations to measure beam position and size

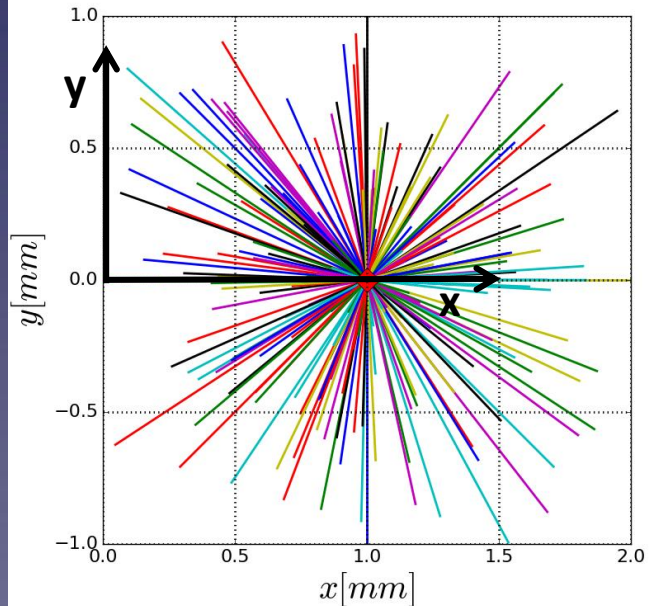


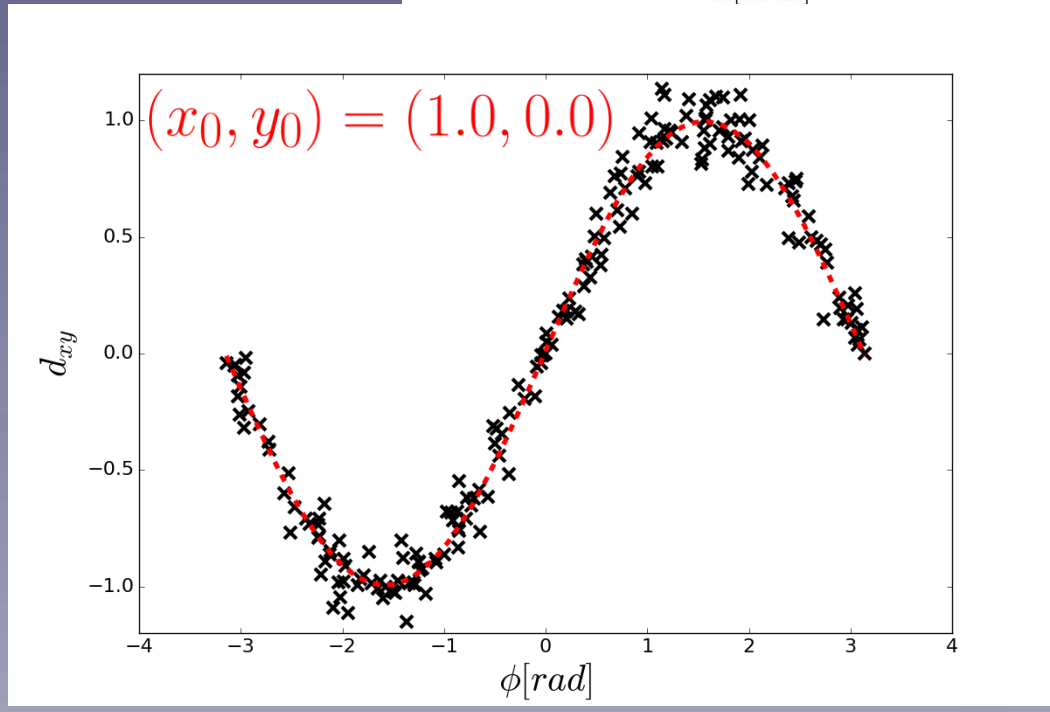
Analysis Method

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

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





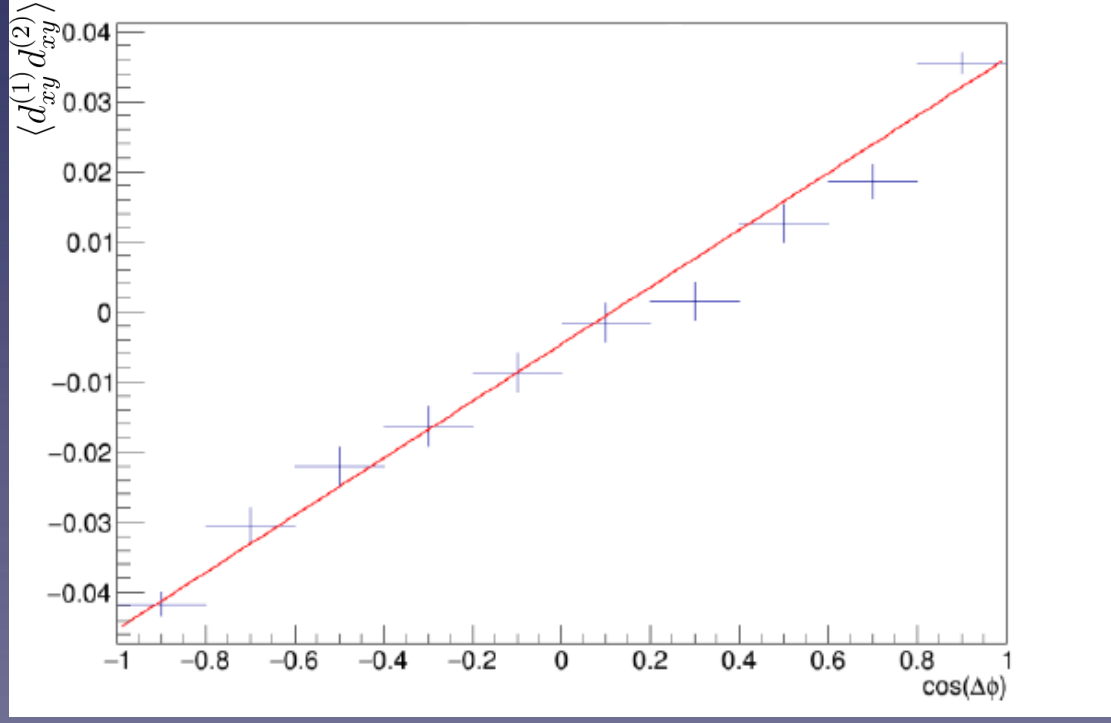


Analysis Method

- 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

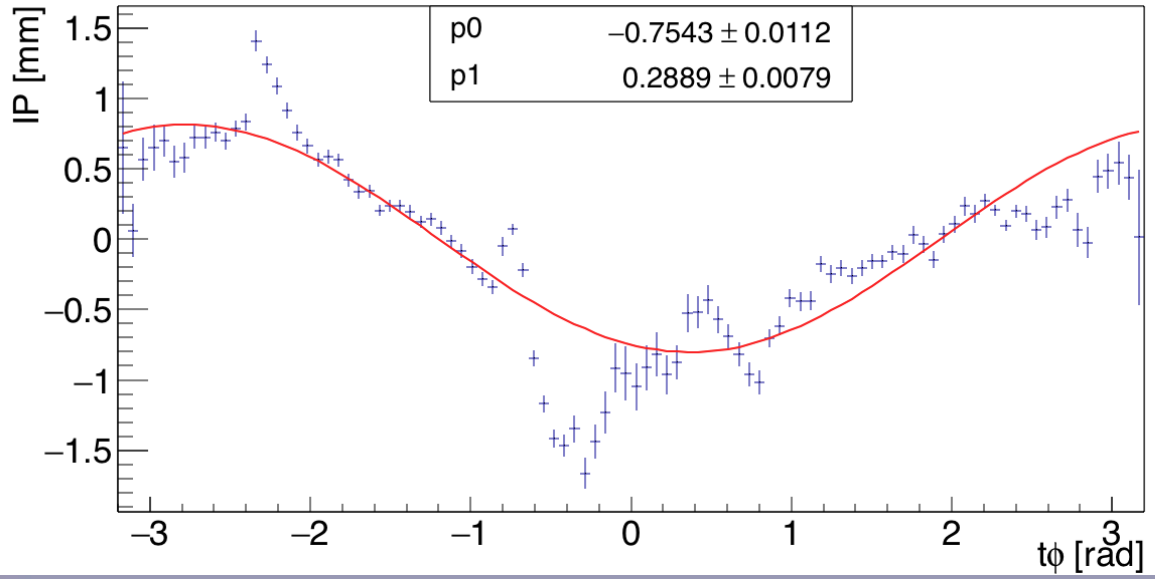
Initial results with limited statistics

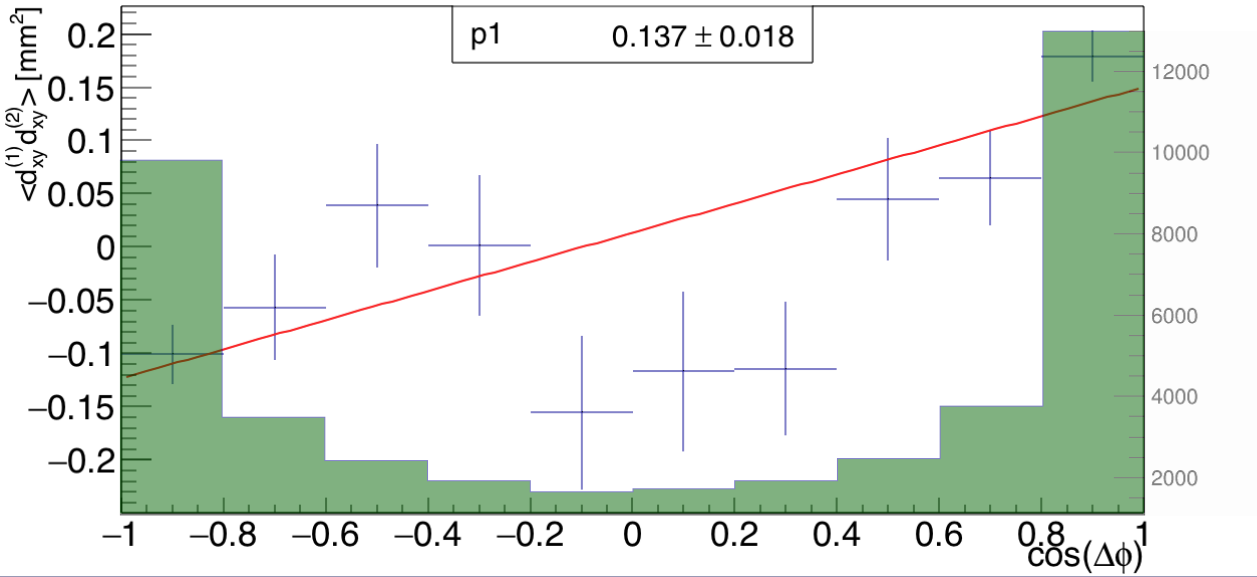
Beam position

$$(x, y) = (-0.79mm, 0.29mm)$$

Beam Size

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





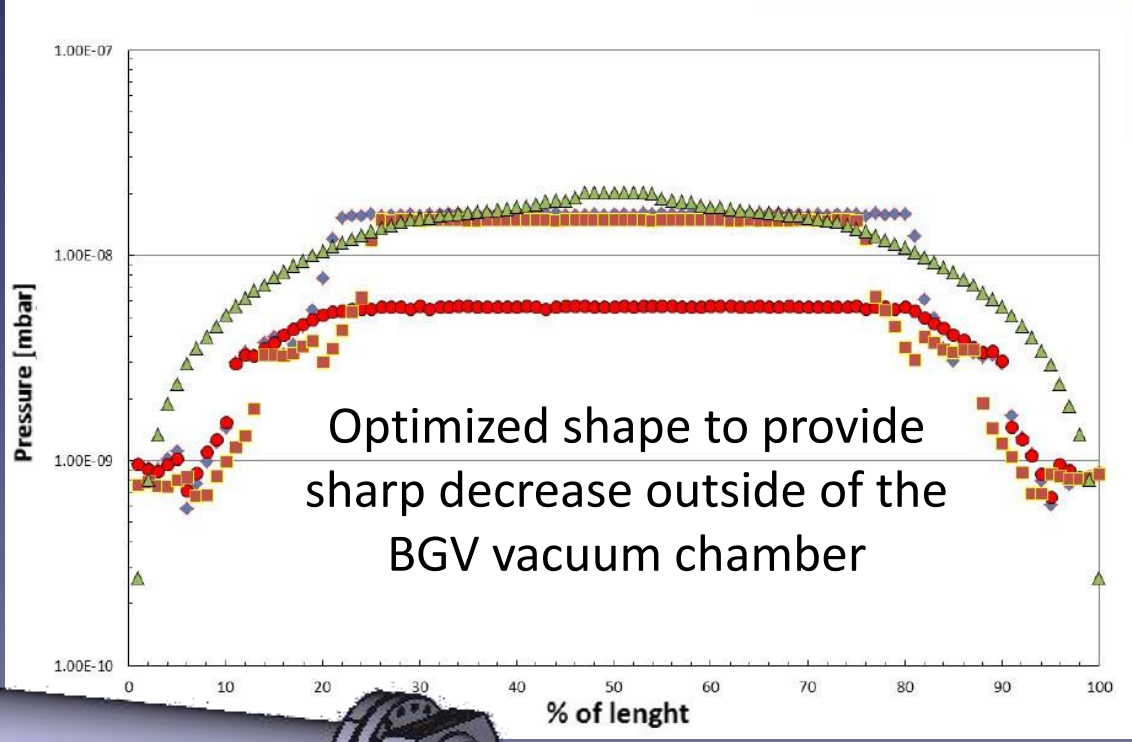
Summary & Outlook

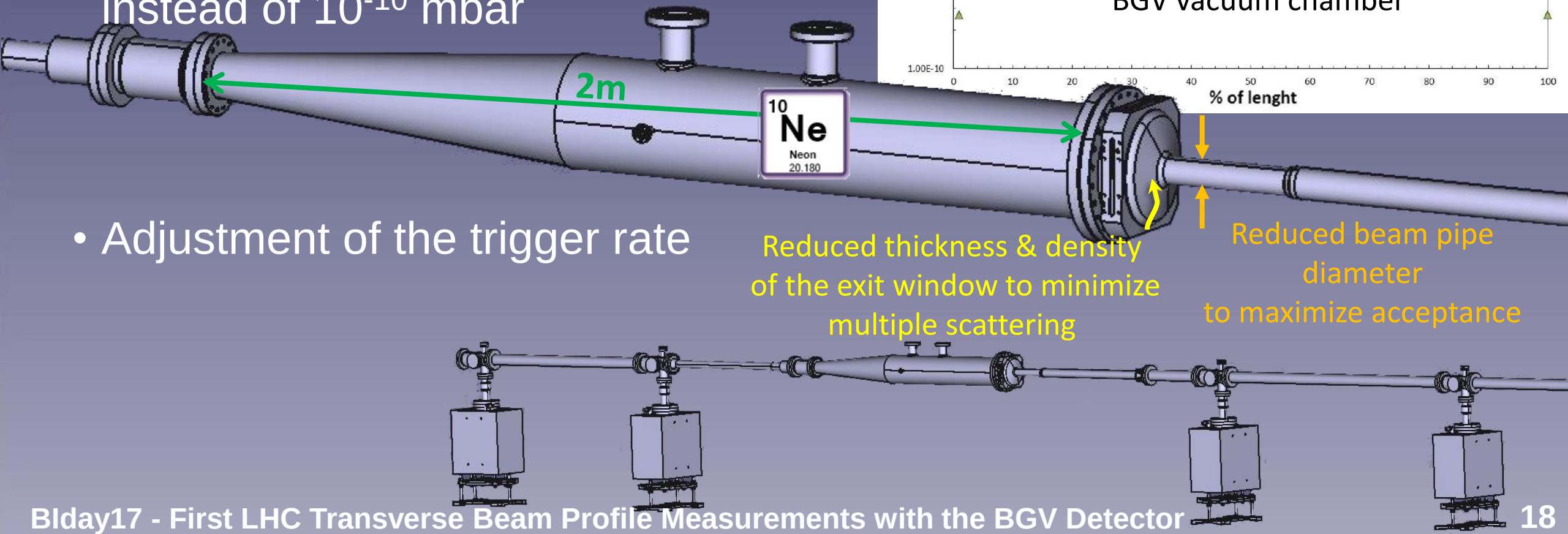
- First commissioning steps were successfully completed
- Transverse beam profile measured with 0.13mm statistical error
  - Not yet allowing for a full comparison with other instruments
- Several enhancements for 2017:
  - Zero-suppression in the read-out FPGAs ➡ Increase statistics (100x)
  - Trigger upgrade ➡ Improve the event selection
  - Cross-calibration with other LHC instruments

Backup Slides

Detector Design

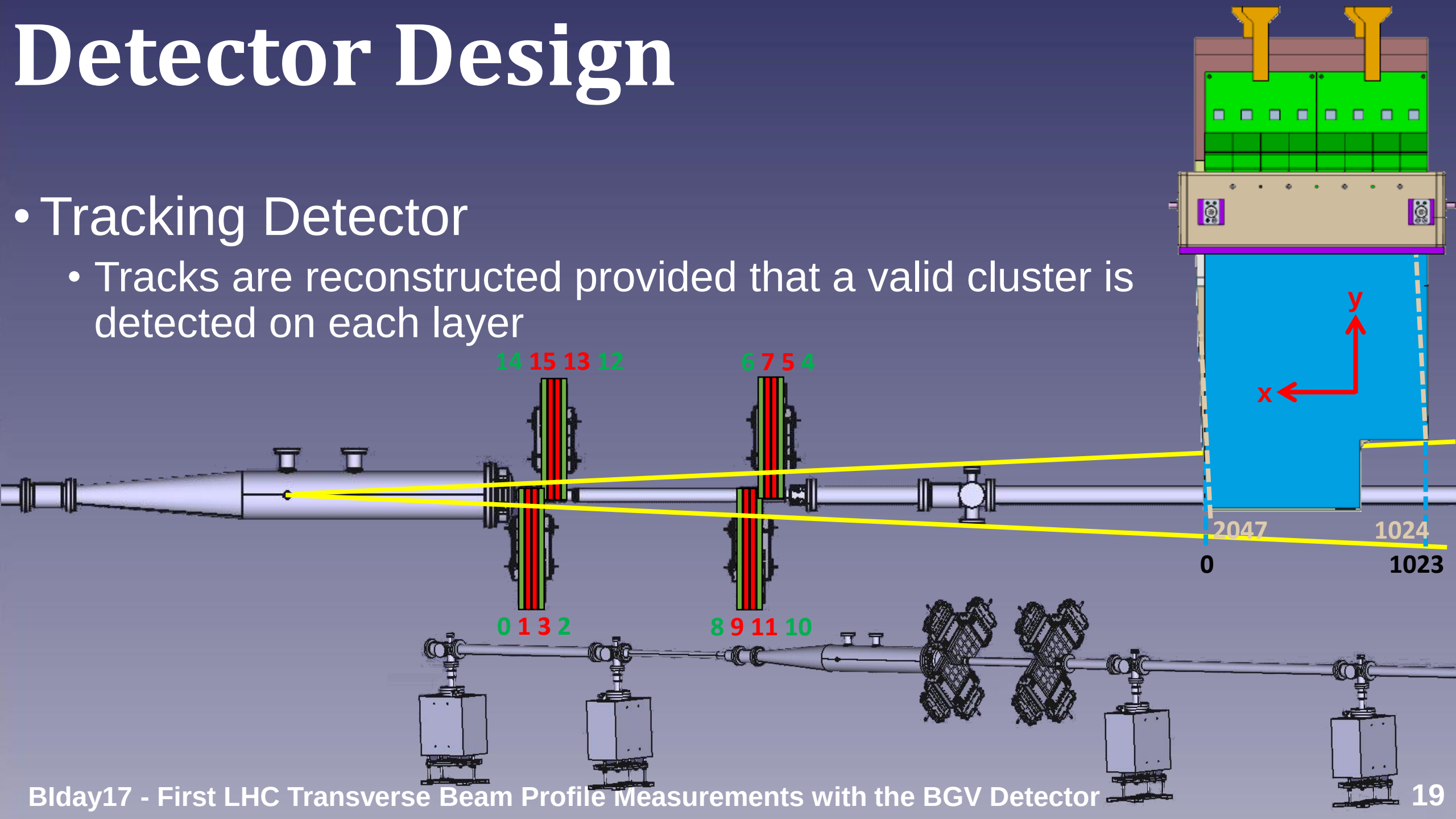
- Gas Target
  - Pressure bump up to 10^{-7} mbar instead of 10^{-10} mbar
  - Adjustment of the trigger rate





Detector Design

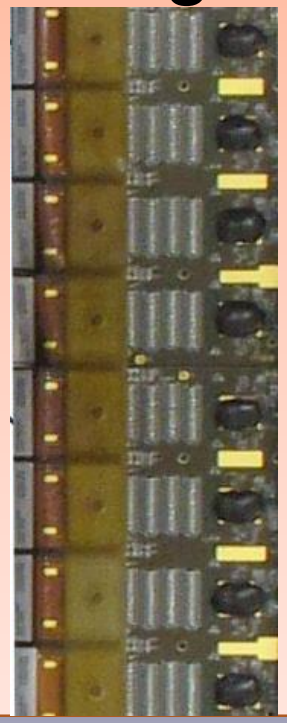
- Tracking Detector
  - Tracks are reconstructed provided that a valid cluster is detected on each layer

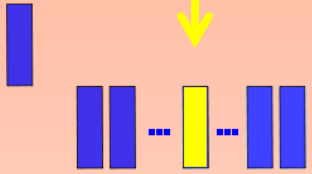


Readout System

LHC Tunnel

Analog FE





25ns

RPT

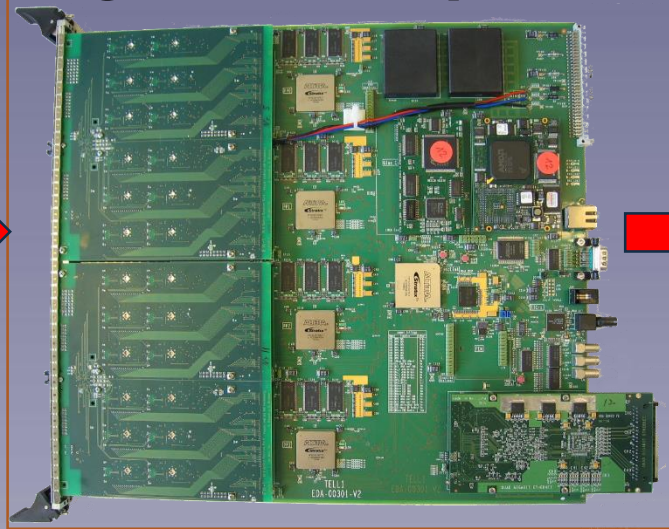
60m

L0 Latency

Hardware Trigger

Readout Manager (ODIN)

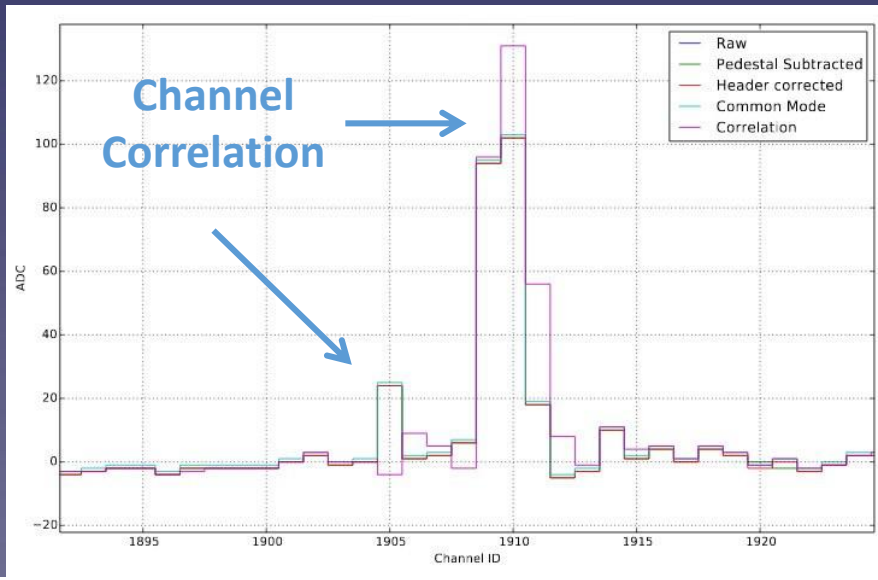
Digitization (TELL1)

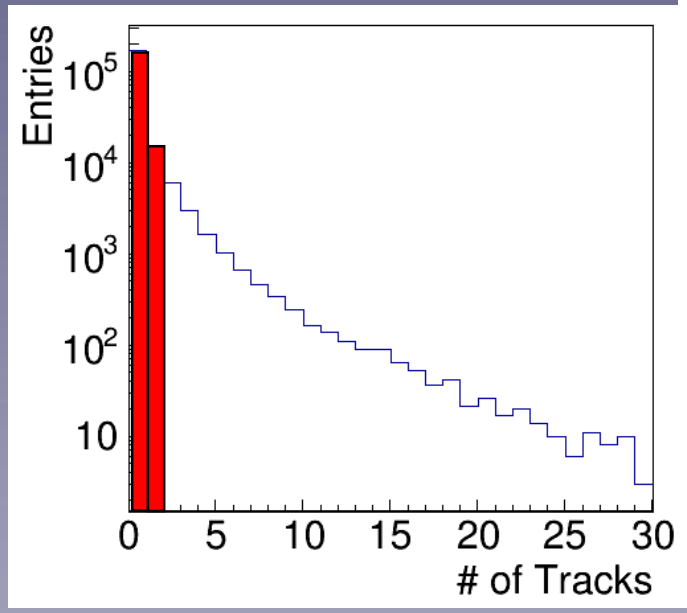


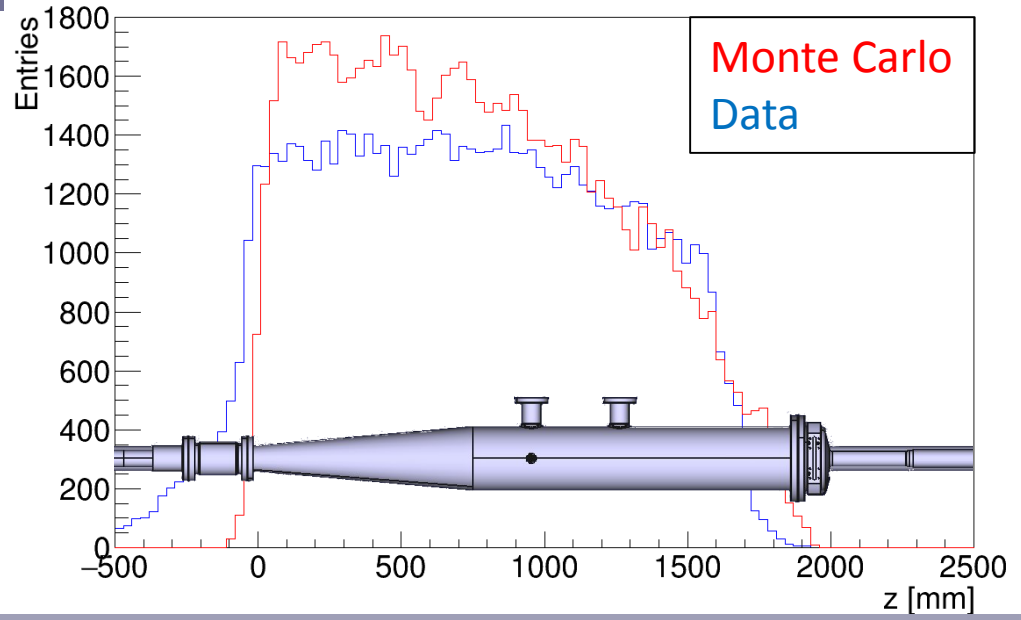
CPU Farm

BGV Data analysis

- Data corrections
  - Pedestal subtraction
  - Common mode noise suppression
  - Channel correlation
- Data Metrics
  - Track Multiplicity
  - POCA z-distribution
  - Pseudorapidity…

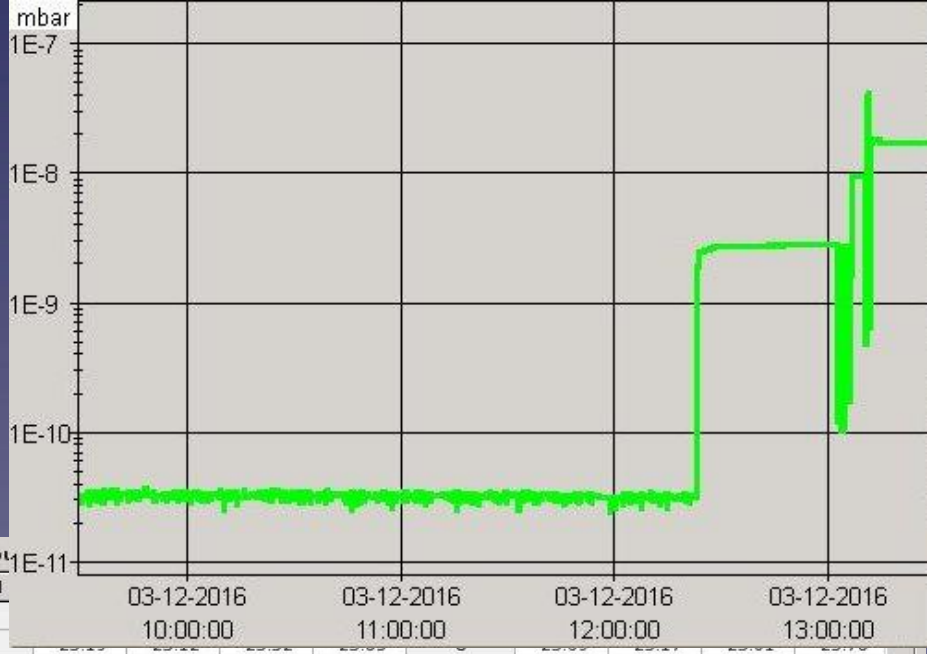






LHC 2016 Run Results

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



Temperature Readou

Module	Frontend								
U-TOP	R								
	T								
U-BOTTOM	R	-24.12	-24.08	-24.98	-25.42	S	-25.38	-25.00	-25.02	-25.01
	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	
PROTON-NUCLEUS PHYSICS	1	4.14E+12	4.31 MJ	Pb82	540	6.50 Z TeV	03-12-2016 13:28:51
Inj. scheme: 100_200ns_540Pb_684p_513_224_162_20inj	2	1.80E+13	18.8	Proton	684		
2016-12-03 08:22:20 (now: physics 540Pb/684p)							