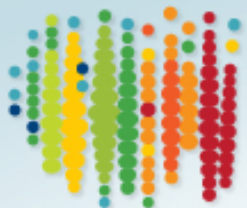


Performance of the new small-strip Thin Gap Chamber for the ATLAS Muon System at the LHC

Alain Bellerive

Canada Research Professor

Carleton University, Ottawa, Canada



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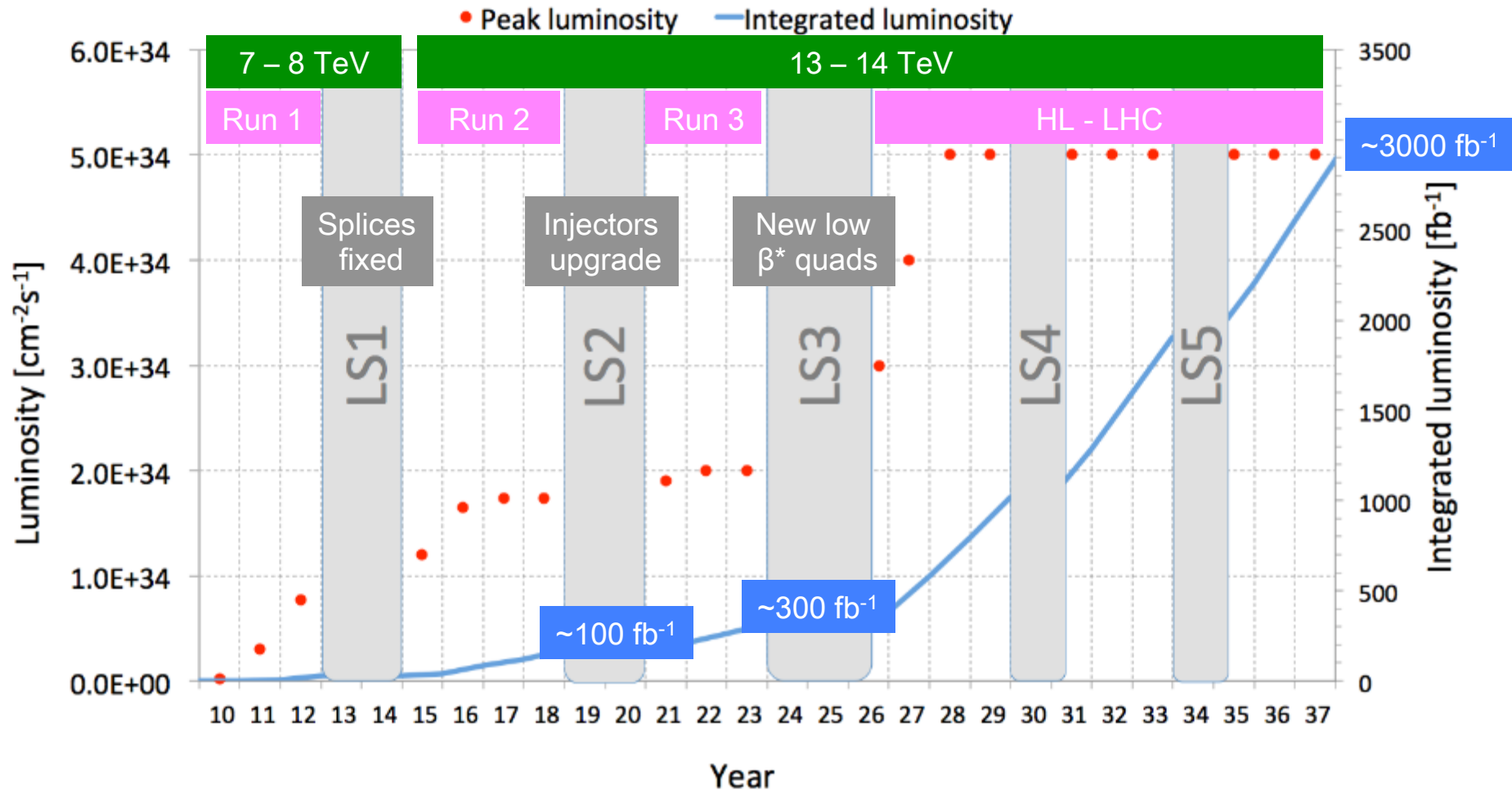
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Outline



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 - Motivation
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- The New Small Wheel (NSW)
- The small-strip Thin Gap Chambers (sTGC)
 - Design of the sTGC
 - Performance & Characterization
 - Digitization Model
- Summary and Conclusion

Motivation: Harsher Conditions at the LHC



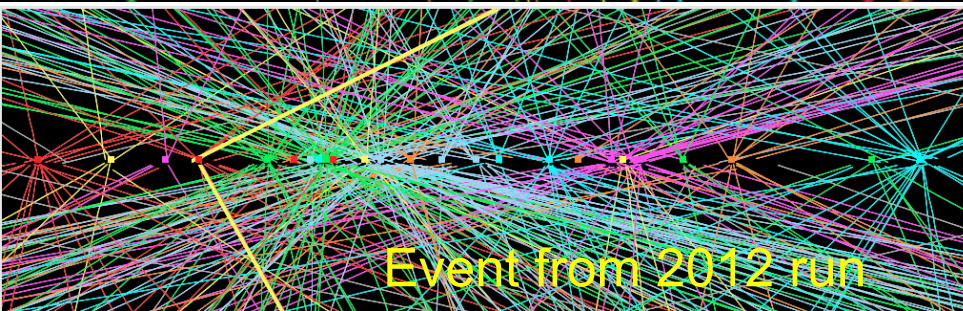
More luminosity + more energy + less bunch spacing
= more Higgs and more of everything else (as well)

Collecting the data for new discoveries



- Collision rate in ATLAS is huge – originally 25 every 50 ns
- In future will be 50-100 every 25 ns

Collisions in one event in ATLAS

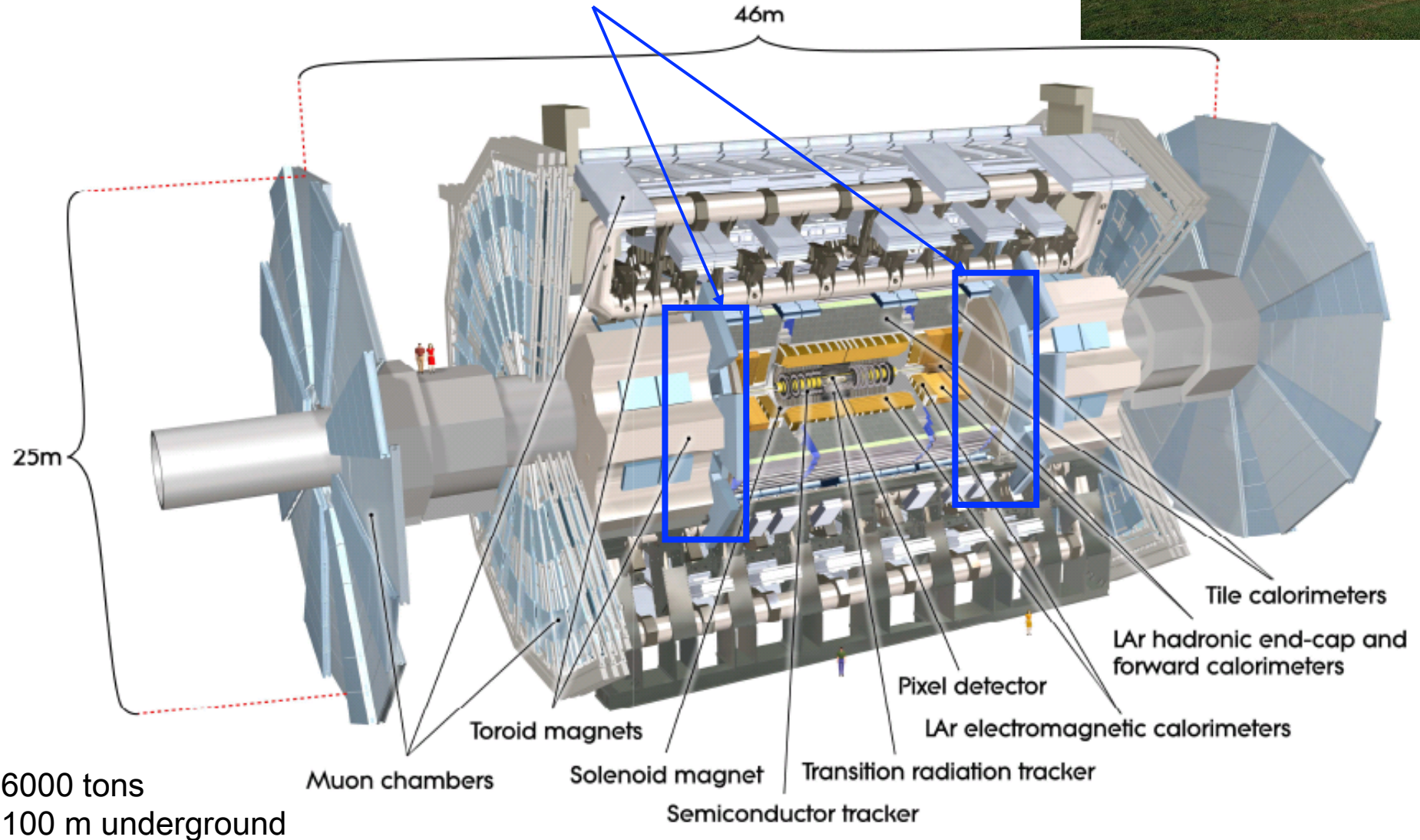


- Need to select rare events with discovery potential
- This is done by the “**trigger**”
- Key trigger selection looks for energetic **muons**
- ATLAS trigger designed for nominal LHC luminosity
- LHC luminosity of 3 – 6 times the original design.
- To collect interesting events we need to enhance ATLAS trigger capability

The ATLAS Detector



New Small Wheel



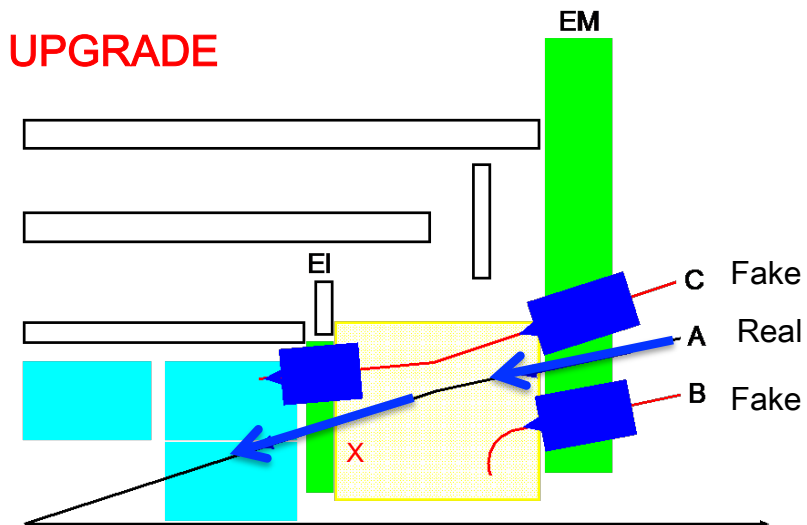
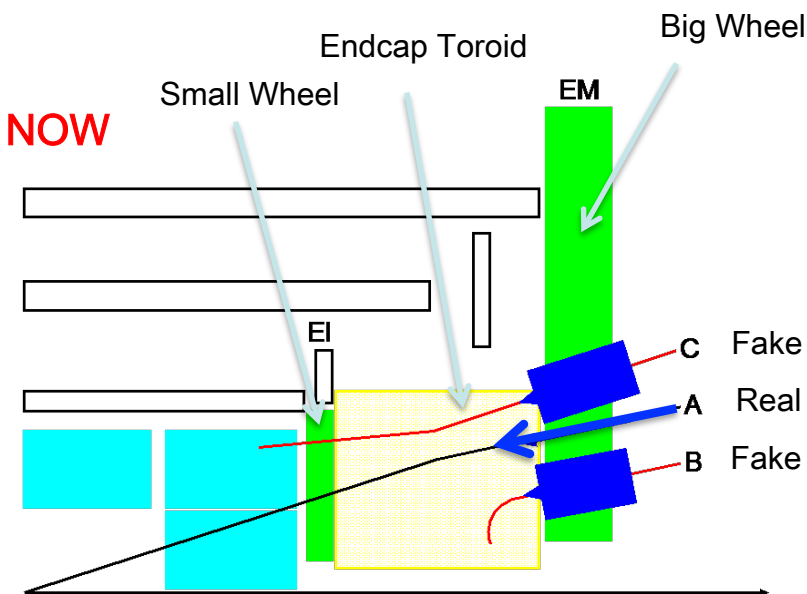
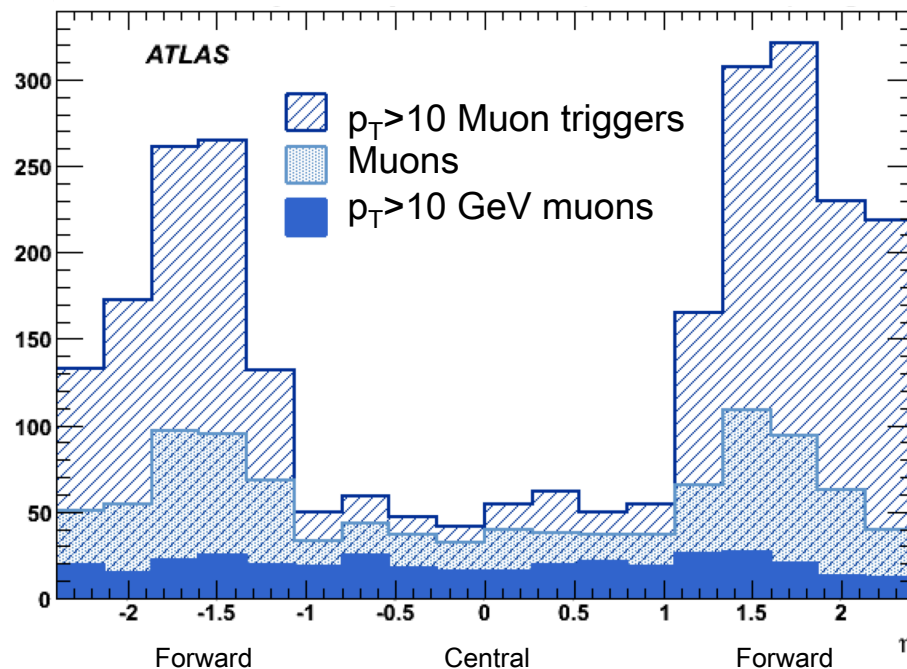
Why a New Small Wheel at ATLAS?



Improved triggering is required given the increase in fake muons

The New Small Wheel will reduce trigger fakes by an order of magnitude at the cost of $\sim 7\%$ of efficiency, while simultaneously improving tracking performance

NSW TDR, CERN-LHCC-2013-006

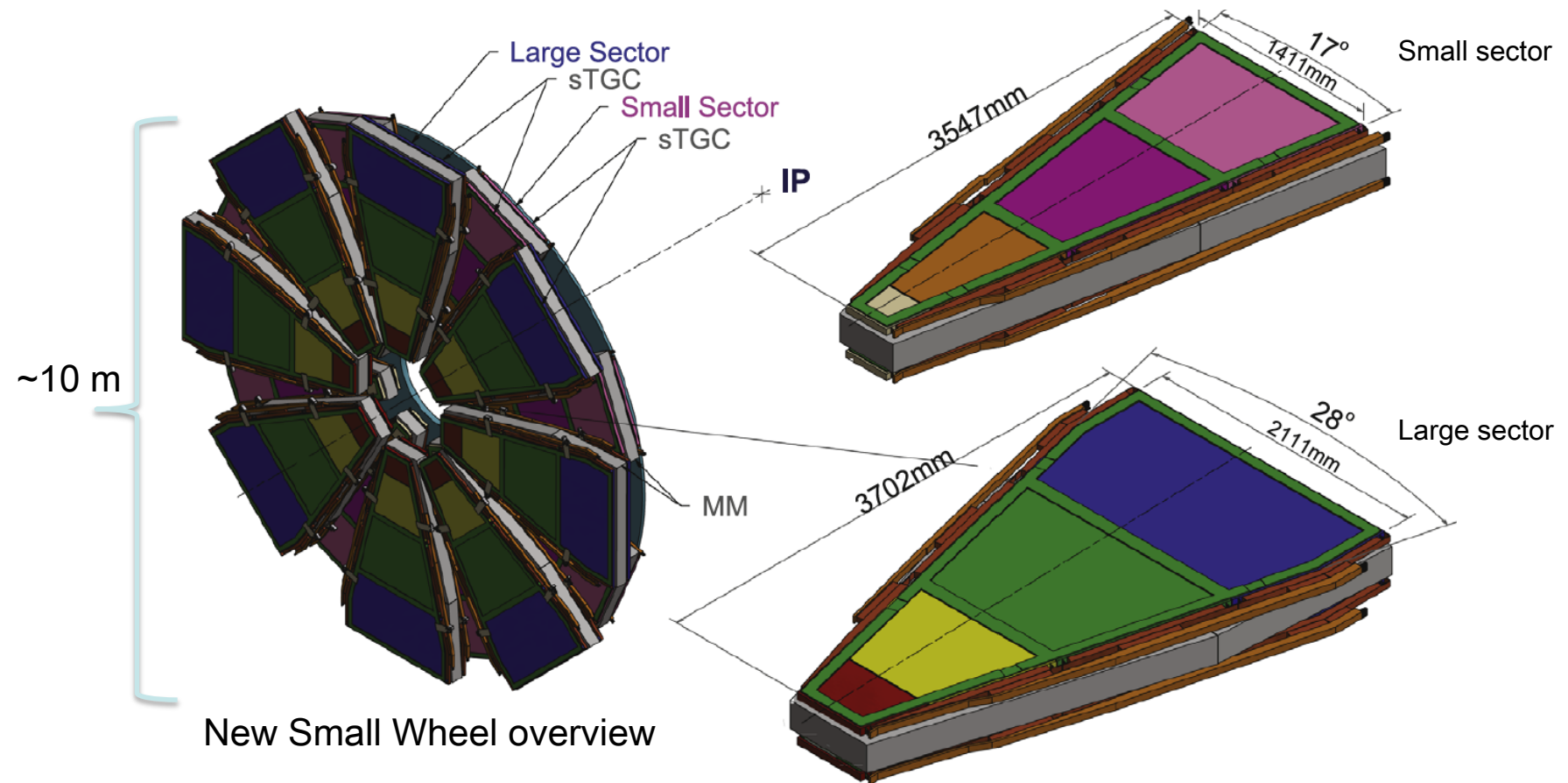


New Small Wheel (NSW) Technologies

The NSW must provide angular resolution of <1 mrad or less to the IP, and so a spatial resolution of <100 μm per point, in <1 μs

To satisfy the requirements, use two separate technologies:

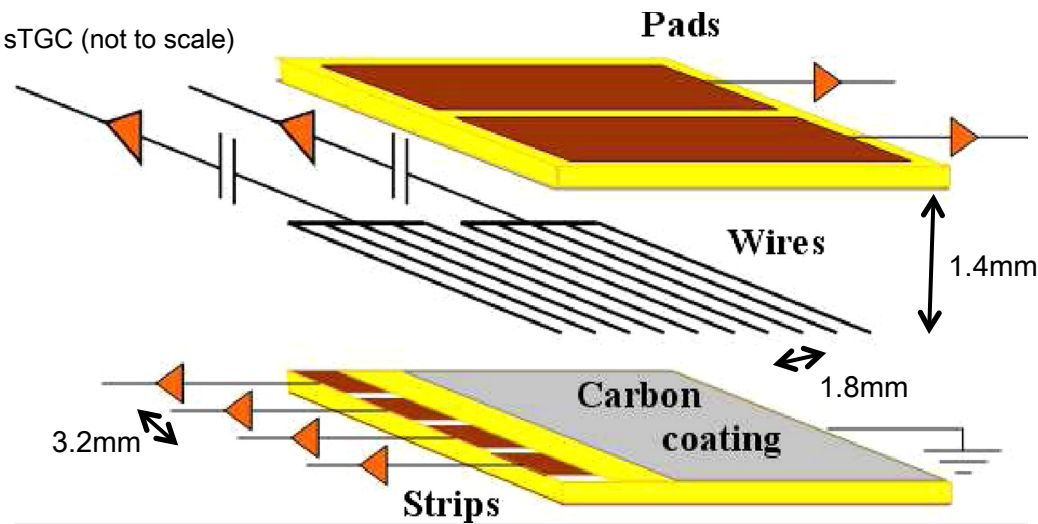
1. sTGC (in color below) as the primary trigger (very fast)
2. MicroMegas (in grey) as the primary tracker (high-resolution)



The small-strip Thin Gap Chamber (sTGC)



sTGC (not to scale)



Gas: n-pentane / CO₂ (45% / 55%)

Anode: wires (at 2900 Volts)

Cathode: pads and strips

Resistive layer: mitigate 10kHz/cm² rate protection against discharge

Pads for triggering

Narrow strips + Wires for tracking

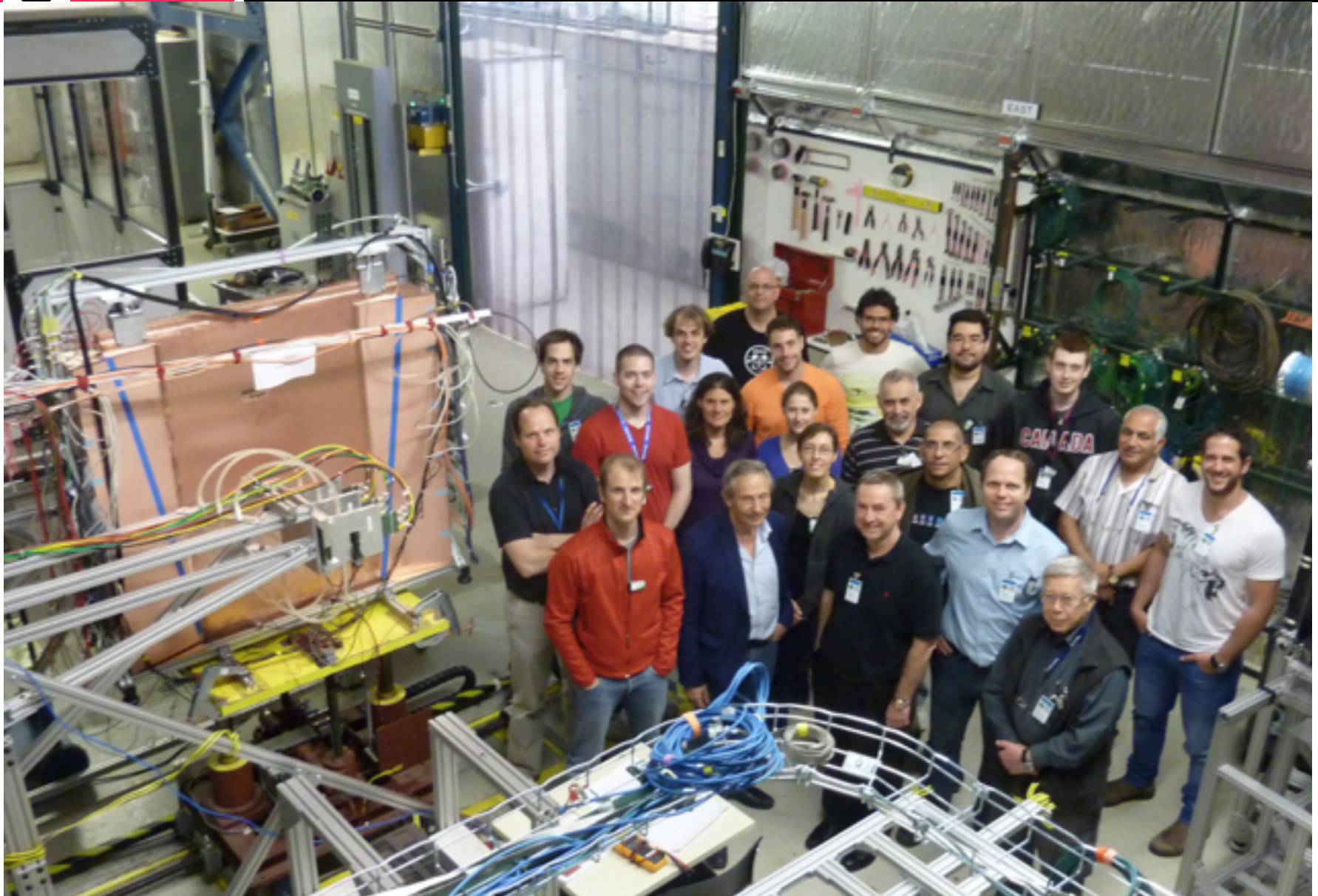
Thin gap wire chambers (cathode-wire distance < wire-wire distance).

Each chamber is composed of 4 sTGC's, and each sector has two sTGC quadruplets (sandwiched around two MicroMega quadruplets)

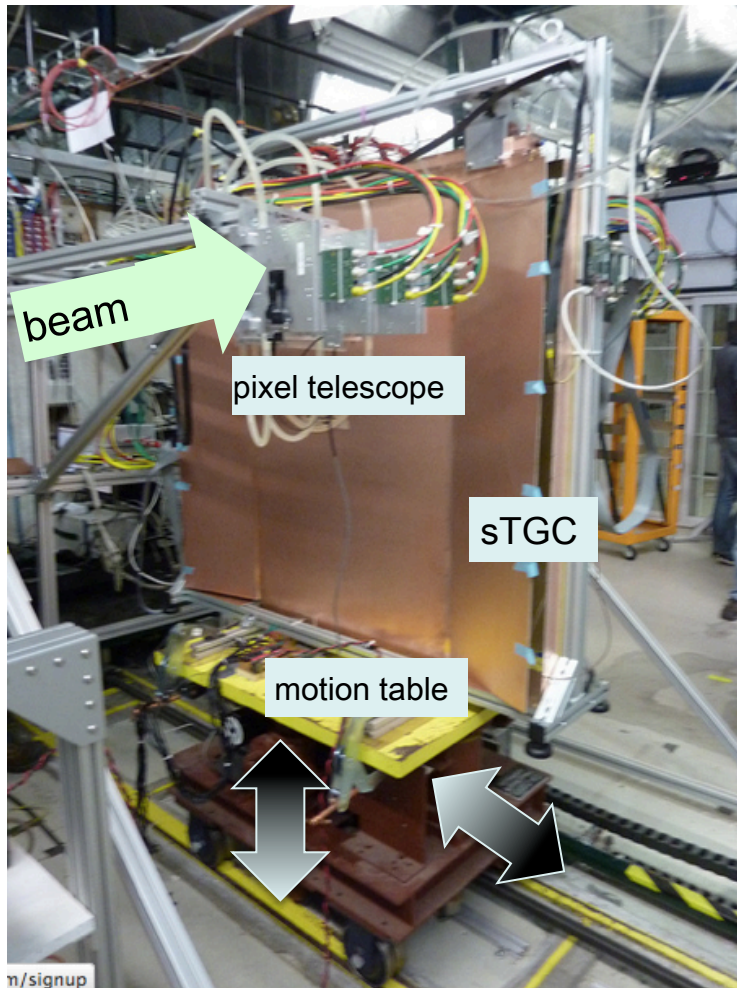
For the NSW, precise construction methods are also essential: the cathode boards must be extremely flat & precisely aligned

- Flatness: RMS < 80 μm
- Strip alignment: parallel to within 100 μm

Testbeam at Fermilab (FNAL)



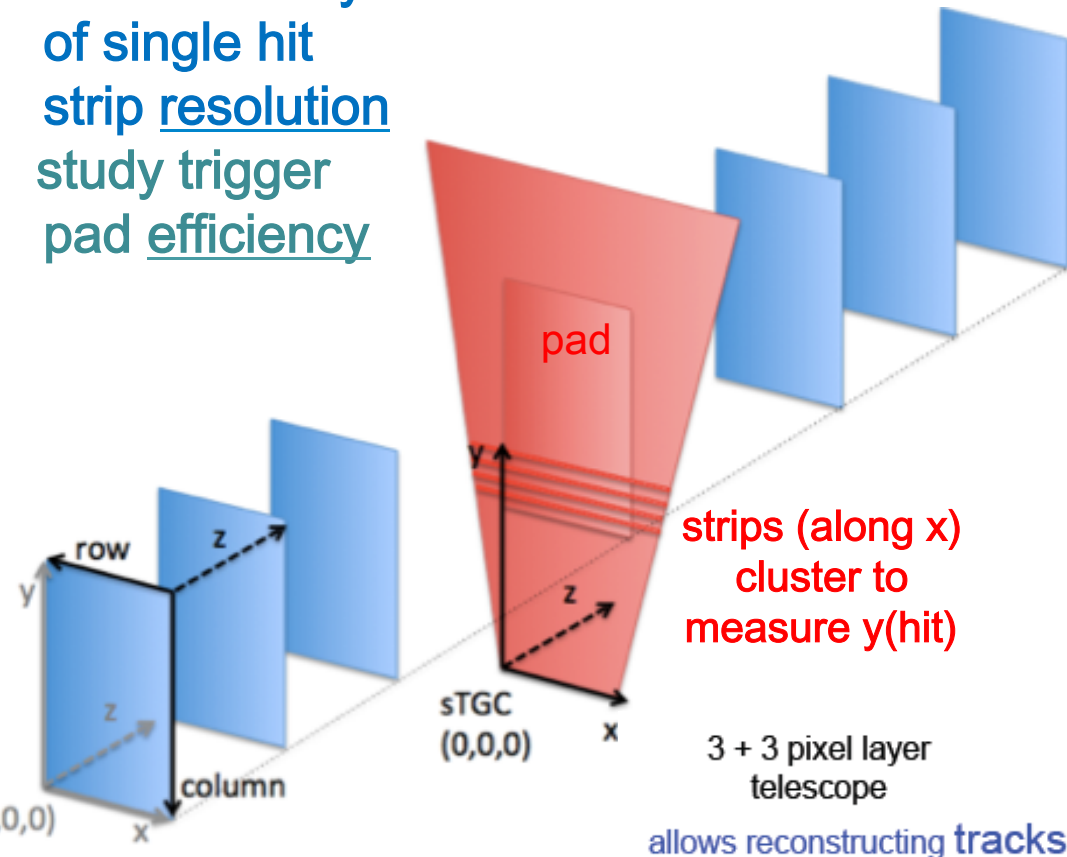
FNAL Experimental Setup sTGC



Remote control motion table

Scan sTGC with pixel telescope ($\sigma \approx 4\mu\text{m}$)

- allow independent measurement of s-shape bias correction and gap alignment
- residual analysis for determination of single hit strip resolution
- study trigger pad efficiency



$$\Delta\theta \approx \Delta y = \sigma = y(\text{sTGC}) - y(\text{pixel})$$



sTGC: hit reconstruction



Distribution of charge

Amplitude on i^{th} strip

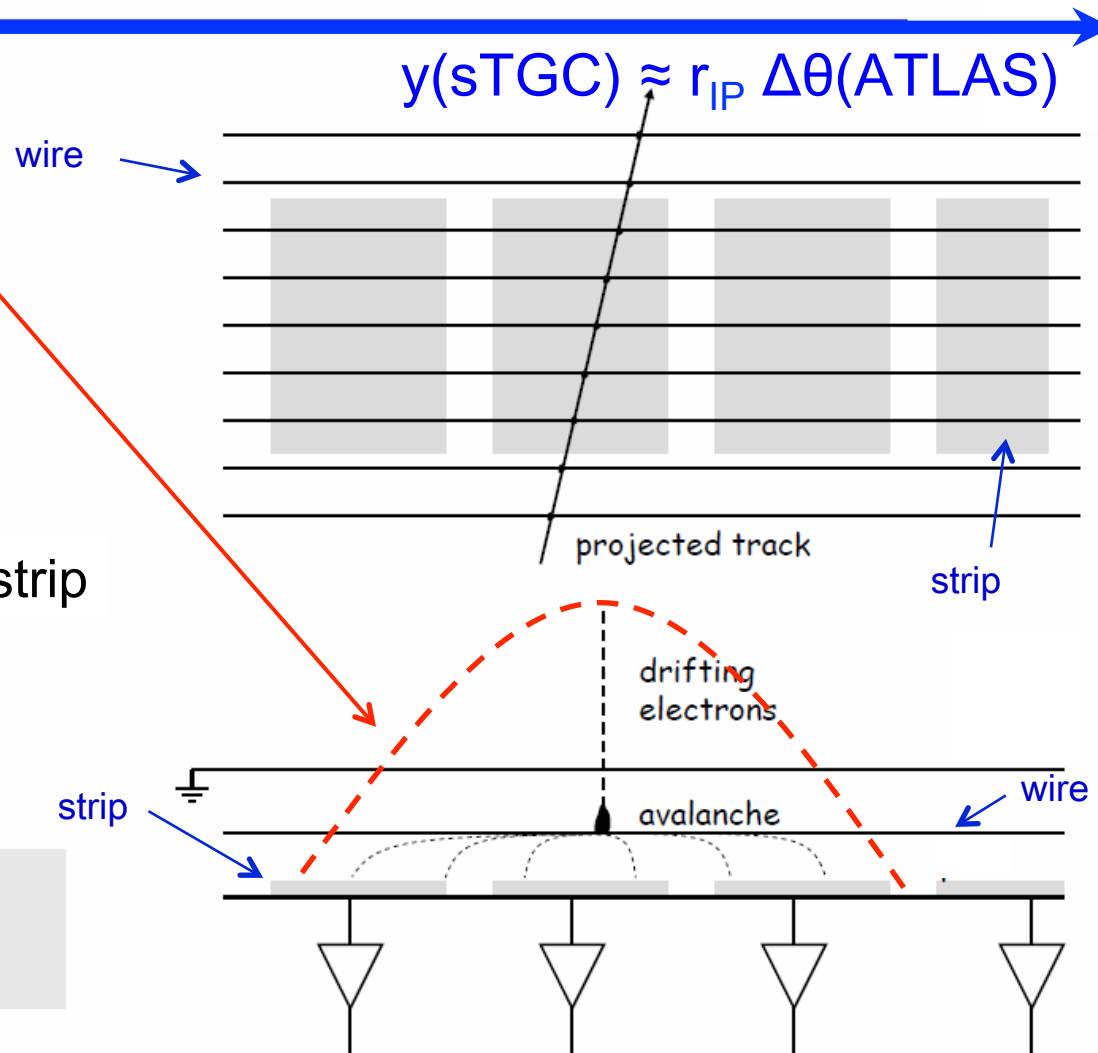
$$A_i = A e^{-(y-y_i)^2 / 2\sigma_{prw}^2}$$

y Hit position

y_i Position of center of i^{th} strip

σ_{prw} Strip response width

- Measure A_i
- Invert equation to get y



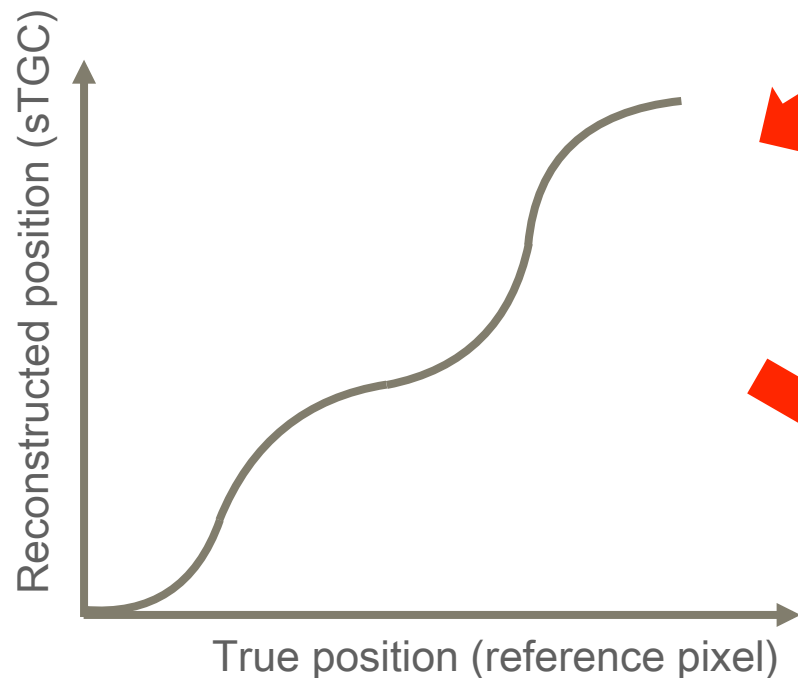
Knowing the reference track with the pixel detector allowed to determine, without assumption, the shape of the “strip” response function

Determination of bias



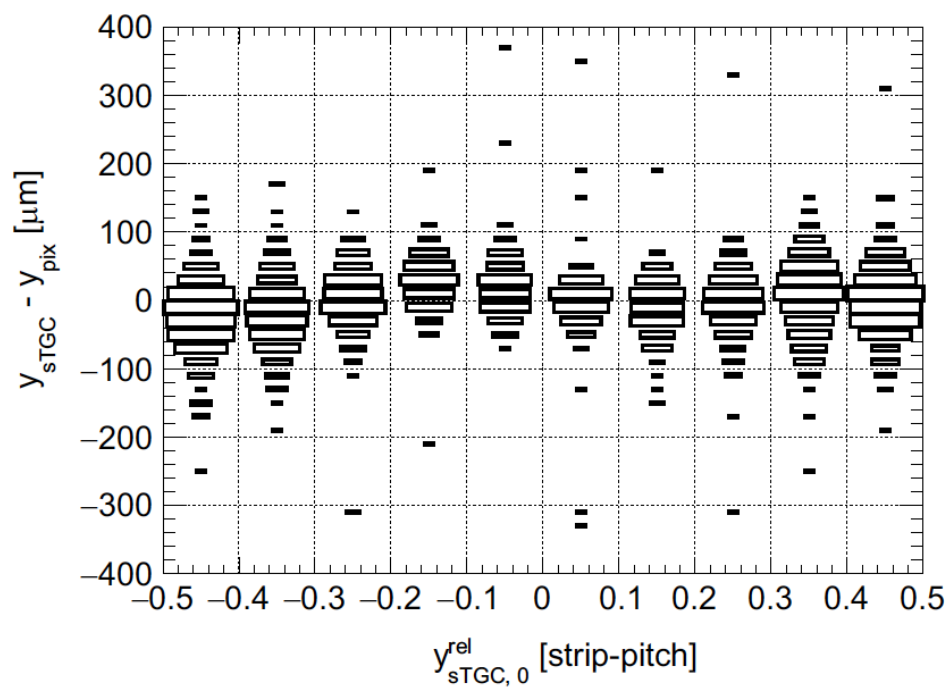
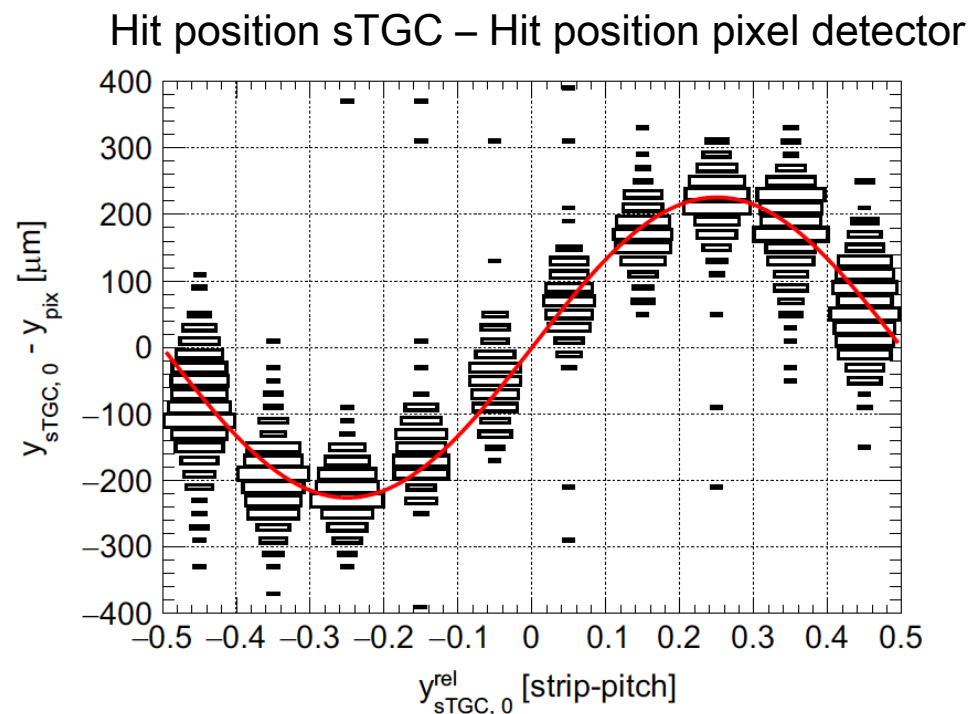
Determination of the track position:

- Pixel detector allowed extrapolation of the position of the hit with a 4 microns precision
- Bias correction parameterized as a sine wave



Intrinsic sTGC bias due to:

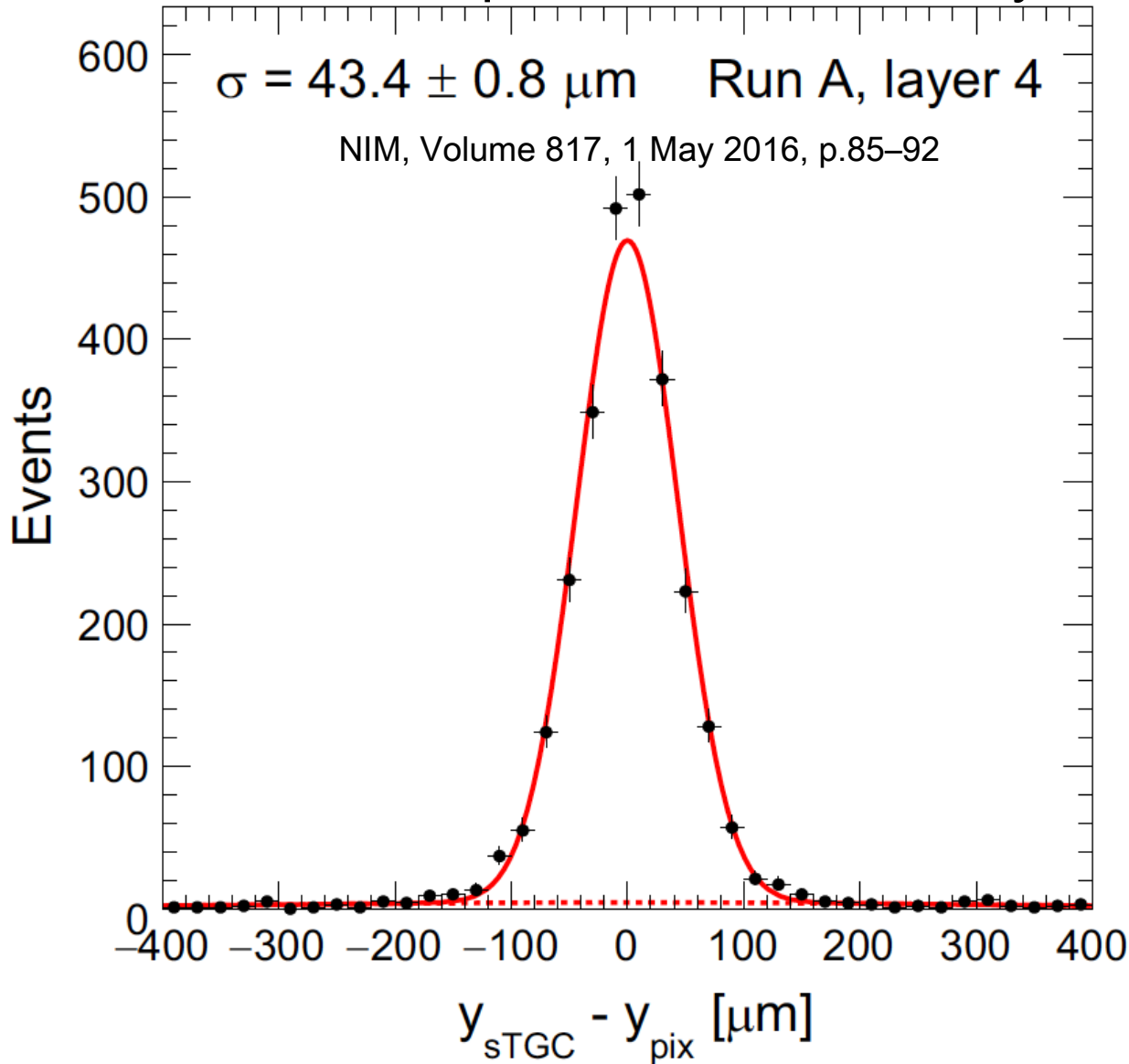
- Collection of charge not continuous since the strips are discrete
- Distribution of charge NOT Gaussian



Single-hit strip spatial resolution: $45 \pm 8 \mu\text{m}$



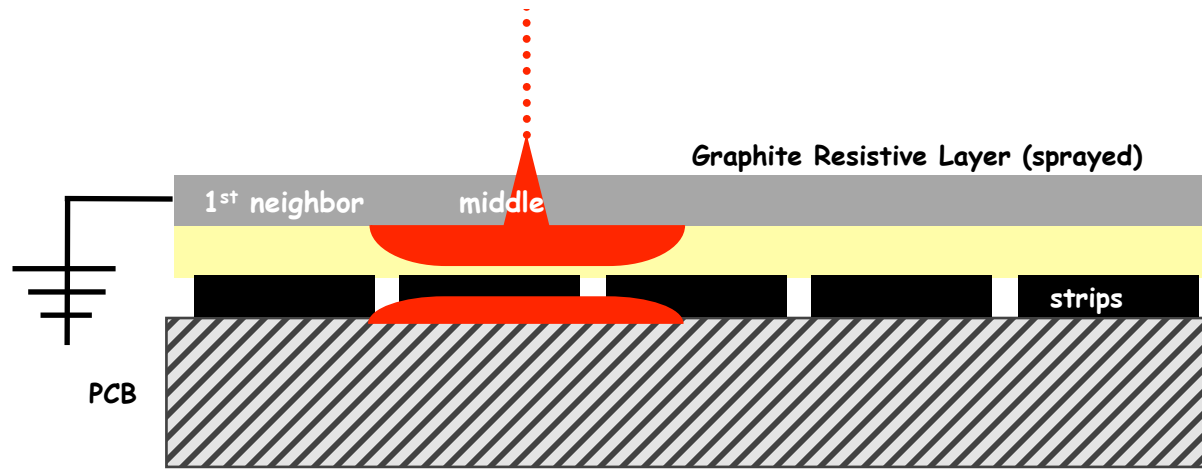
$\sigma = 45 \pm 8 \mu\text{m}$ All runs – All layers



sTGC digitization model (signal simulation)



- Simulation full waveform of signal on strips after VMM electronics
- Study of time delay associated with the resistive layer (carbon coating)
- Investigate pad trigger efficiency
- Detailed trigger simulation (detail see talk X. Meng)
- Optimization track reconstruction optimization (ref: talk H. Herde)

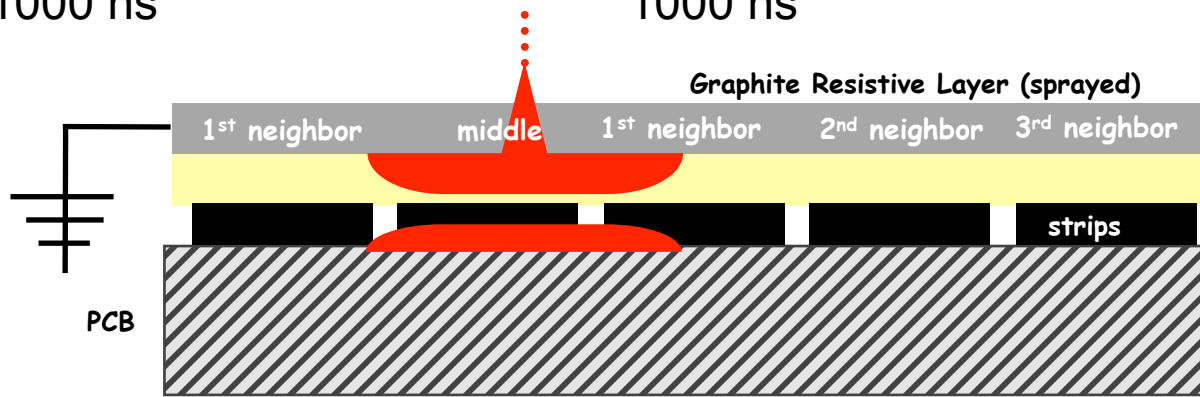
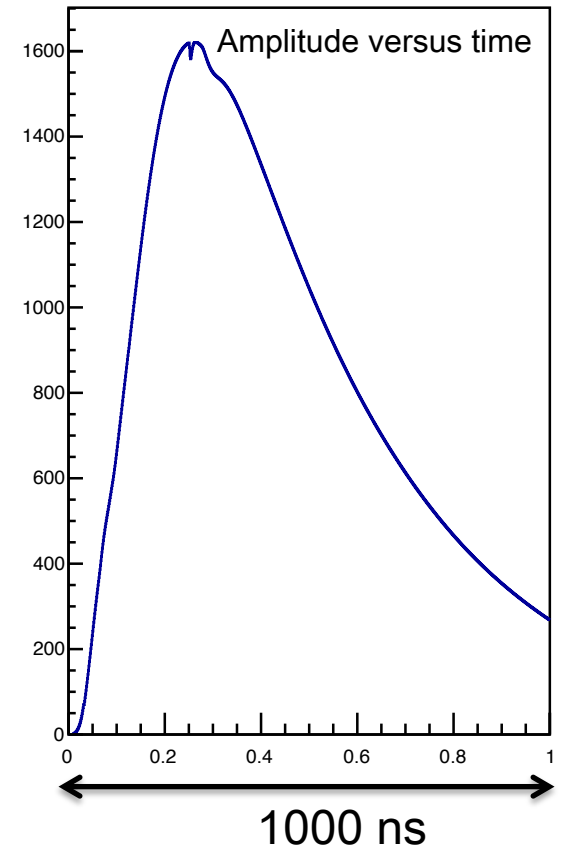
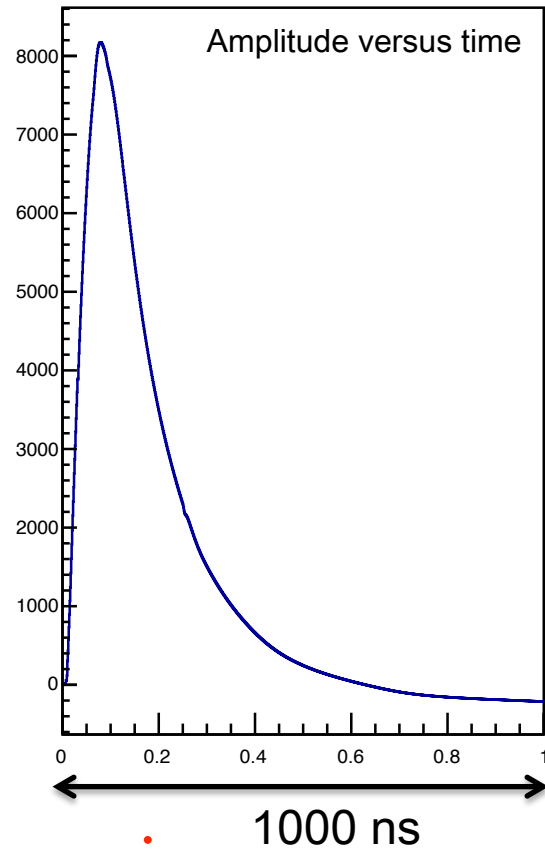
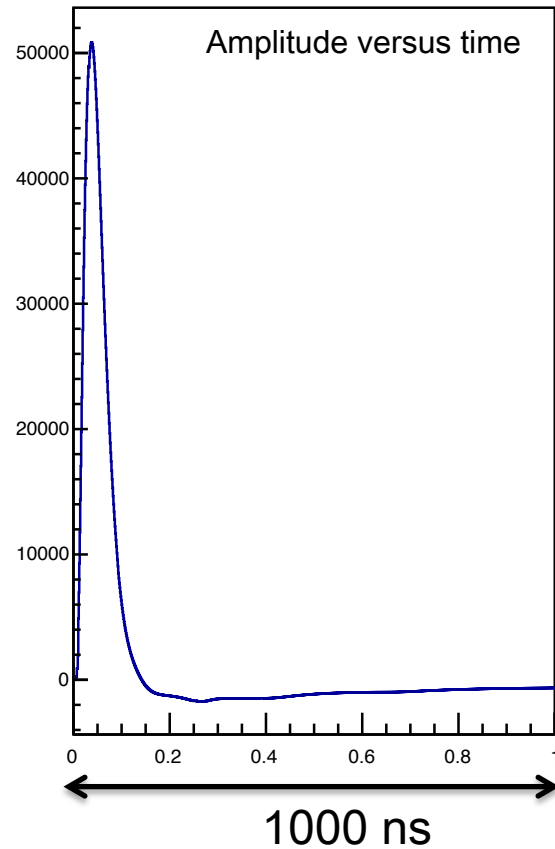


sTGC digitization model (signal simulation)

Strip main (middle)

Strip (1st neighbor)

Strip 2nd neighbor



Summary and Conclusion



- LHC upgrades provide the opportunity to really improve our knowledge of the Higgs boson, the Standard Model and the search for new physics
- However, in its current state ATLAS would be unable to take advantage of these opportunities.
- Upgrade work for construction and installation of the New Small Wheel (NSW) during the next shutdown (LS2) is ongoing
- The first full scale sTGC module meets the specification with single-hit spatial resolution ($\sigma = 45 \pm 8 \mu\text{m}$)
- sTGC digitization simulation for detailed trigger simulation and track reconstruction optimization
- ATLAS Canada is in the middle of a number of important efforts for the future of ATLAS

Extra...



Physics at the Large Hadron Collider (LHC)

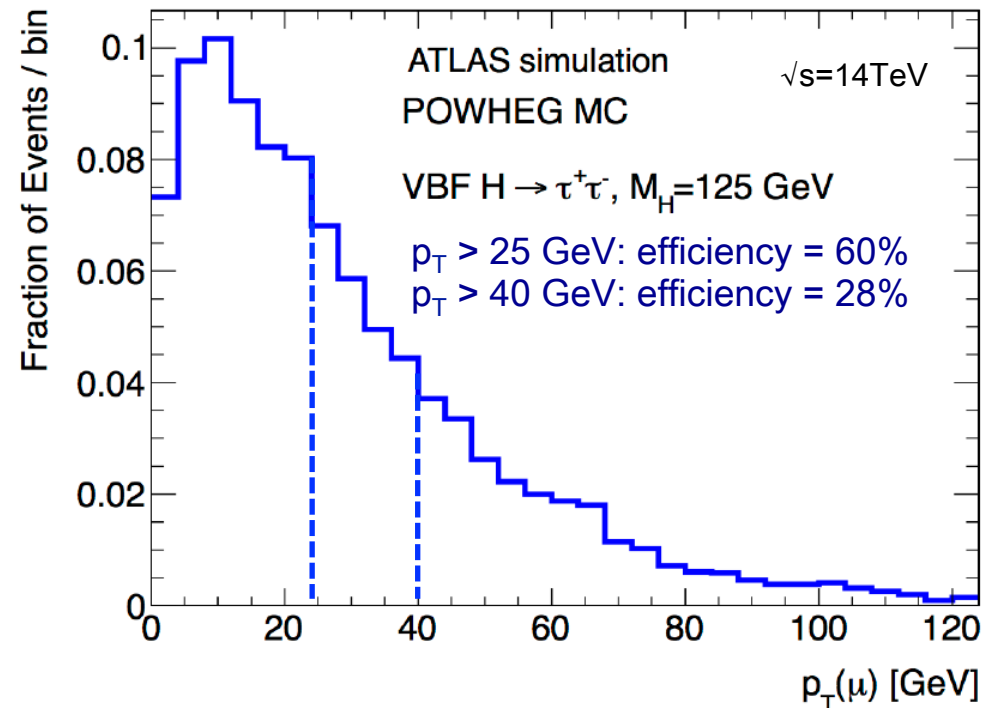


- **Physics at the LHC:** study of the Higgs boson and of the Standard Model, investigate of rare processes, search for new physics like super-symmetry and dark matter
- All these processes are very rare and require lots of energy, so many **high-energy collisions** will be needed to make precision measurements.
- The **energy and number of collisions at the LHC** are largely determined by three parameters:
 - Center-of-mass energy
 - Bunch spacing: accelerators are pulsed, with particles arriving in bunches, rather than continuously. The bunch spacing is the time between two bunches
 - (Instantaneous) Luminosity: essentially measures the rate at which the accelerator produces collisions (collisions/area/time)

Trigger Bandwidth Limitation

- ATLAS subsystems level 1 readout bandwidth (Run3): 100 kHz.
- Allowed level 1 bandwidth for muon triggers: 20 kHz.

- Two options:
 - Reduce number of events with real muons, but miss interesting events!
e.g. Higgs boson
 $H \rightarrow \tau\tau$ with one τ decaying into a muon



- Improve the trigger system: New Small Wheel (NSW)!

<i>Trigger Rate</i>	<i>Muon $p_T > 20 \text{ GeV}$</i>	<i>Muon $p_T > 40 \text{ GeV}$</i>
<i>Without NSW</i>	<i>60 kHz</i>	<i>29 kHz</i>
<i>With NSW</i>	<i>22 kHz</i>	<i>10 kHz</i>