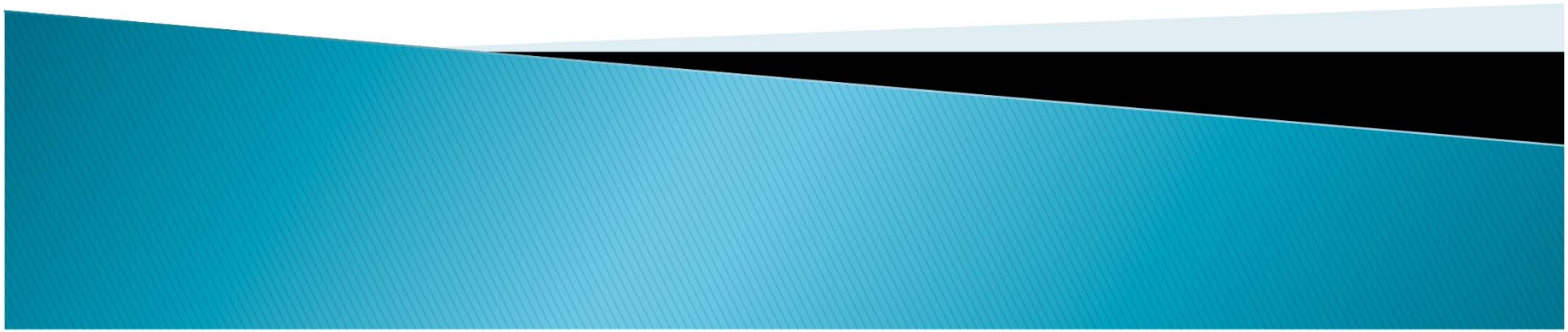
TOF System Performance: Calibrations & Time Resolutions

Frank Geurts
Rice University



Outline

- Time-of-Flight in STAR
  - start & stop detectors in Run 9
- Time-of-Flight Calibration
  - upVPD
  - Barrel TOF
  - preliminary Run-9 results (500Gev & 200GeV)
- Calibration History & Requirements
  - Calibration Cross-verification
- Noise Rates & Discriminator Threshold
- Summary

TOF in Run9

Based on Multi-gap Resistive Plate Chambers (MRPC)

- various prototypes since Run 3.
- timing electronics based on CERN's HPTDC chip

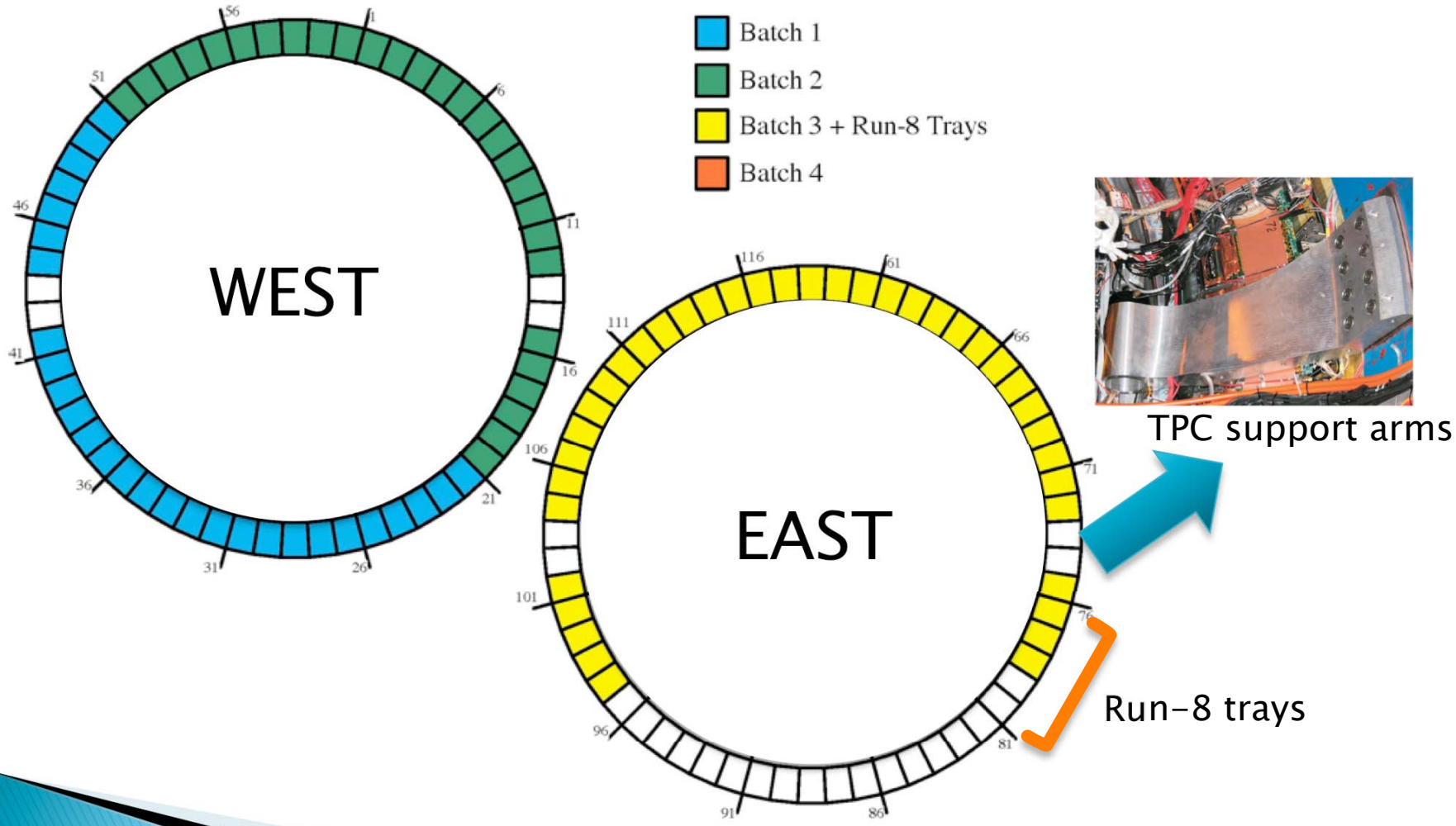
Significant increase in scale:

- Run 8: 5 trays (4%)
- Run 9: 86 out of 120 trays (72%)
- Run 10: 120 trays (100%)

Run 9 experience:

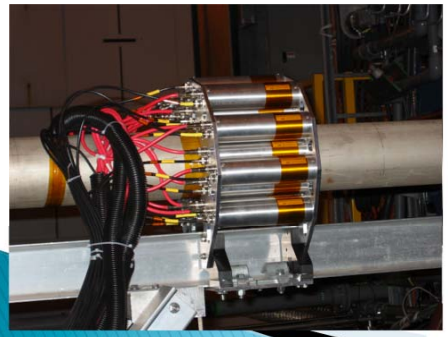
- stable running, TOF participated in nearly all runs;
- 3 dead channels out of 16,128;
- 2 trays disable during run
- average noise rate per channel is less than 10 Hz.

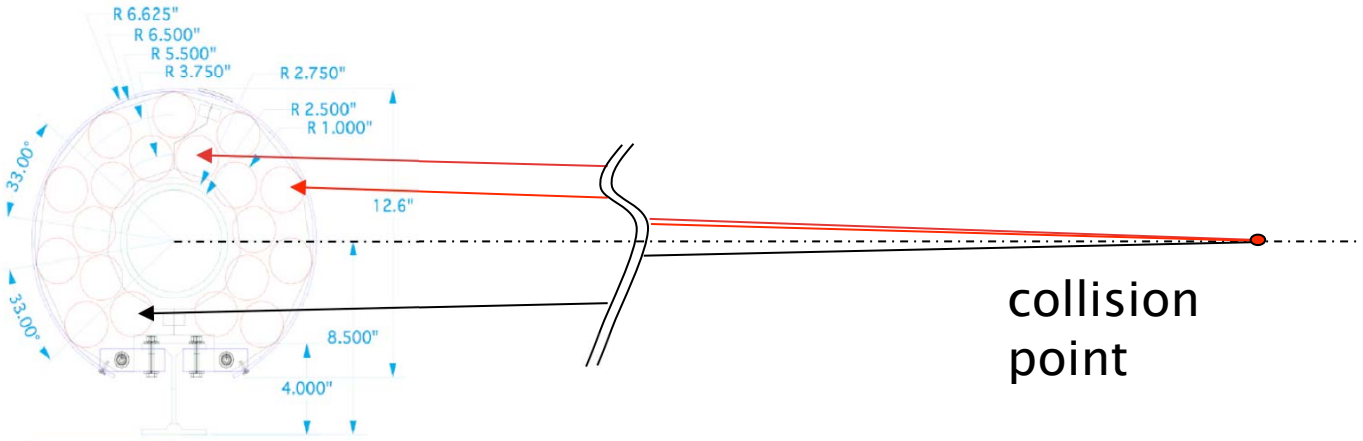
Run 9 TOF trays



Start Side: the upVPD

- upVPD replaced pVPD (Run8):
  - both based on scintillator and fast PMTs
  - uses similar timing electronics as TOF
  - upgrade involves increase in #channels from 6 to 38 channels (east + west)
- STAR $|Z|=570cm$ and $4.24 < |\eta| < 5.1$





TOF Calibrations

- Integral Non-Linearity (INL)
- Trigger timing window

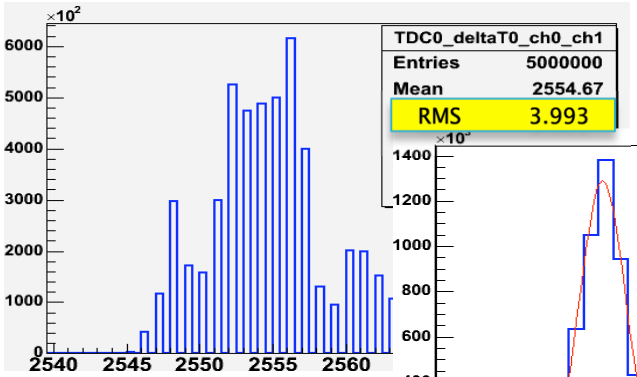
- Start-side calibration upVPD
  - signal slewing, T vs. Time-over-Threshold (TOT)
- Stop-side calibration Barrel TOF
  - TOF T0
  - signal slewing (T vs. TOT)
  - MRPC cell signal propagation (T vs. Z_{local})
  - tray alignment calibration

Integral Non-Linearity Calibration

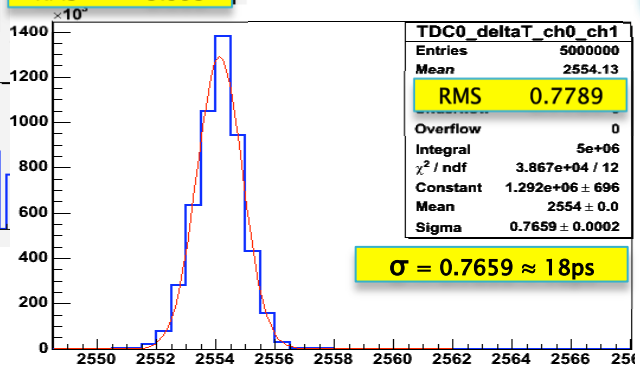
Jing Liu

HPTDC integral non-linearity (INL):

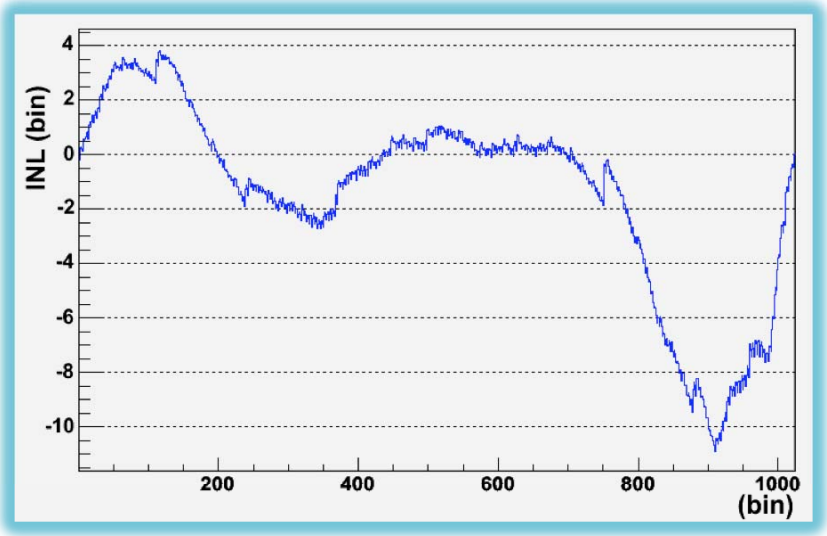
- periodicity 1024 bins (25ns)
- calibration data collected on testbench
- expect no change, but will monitor



no INL applied



INL applied



- INL correction determined for all TOF HPTDC channels
- Full TOF Barrel: 120x192 = 23k TDC channels
- 1024 bins/channel at 2byte precision
- In Offline Database
- Applied by StBTofHitMaker

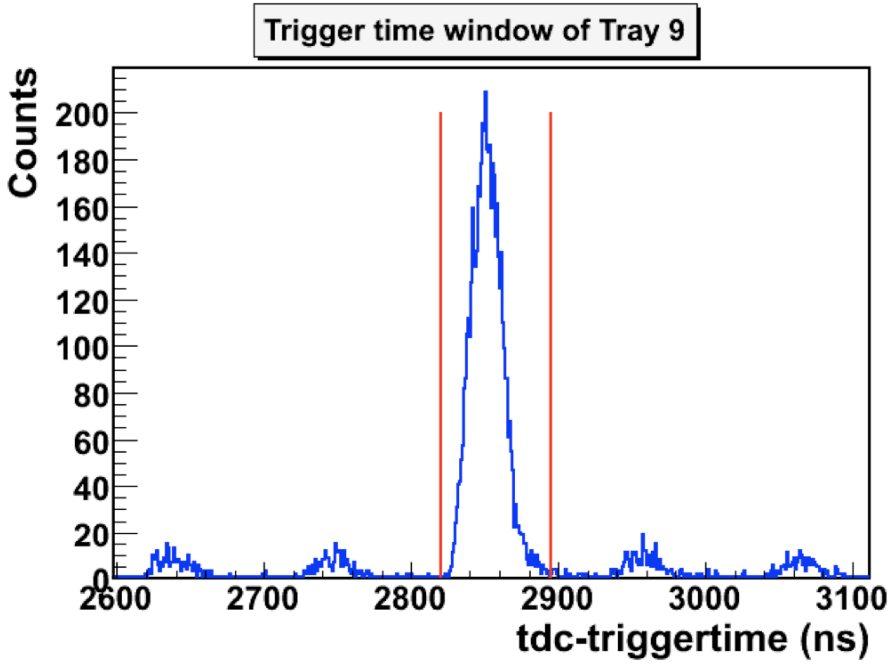
Trigger Timing Window

Xiaoping Zhang
Yi Zhou

- HPTDC timing information is based on a free running clock
  - determine optimal window for trigger timing
  - timing affected by *e.g.* firmware changes

Final trigger timing window checked for Run 9 (500GeV and 200GeV)

- based on Fast-Offline data
- one parameter per tray,
- ready for database
- Applied by StBTofHitMaker



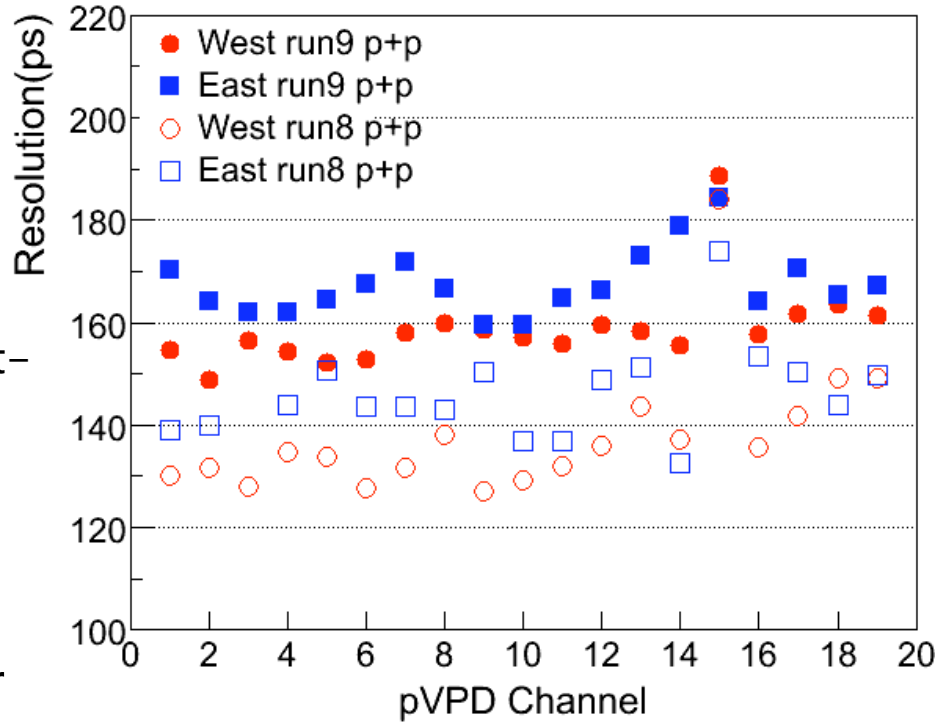
upVPD Calibration

Zebo Tang
Xiaoping Zhang

- Preliminary Calibration of Run 9
  - based on Fast-Offline production
  - 500 GeV: ~3M events; 200 GeV: ~6.8M events.

- Separate East & West Calibration
- Iterative process
- Low multiplicity in upVPD is an issue
  - not all events will have a start-time

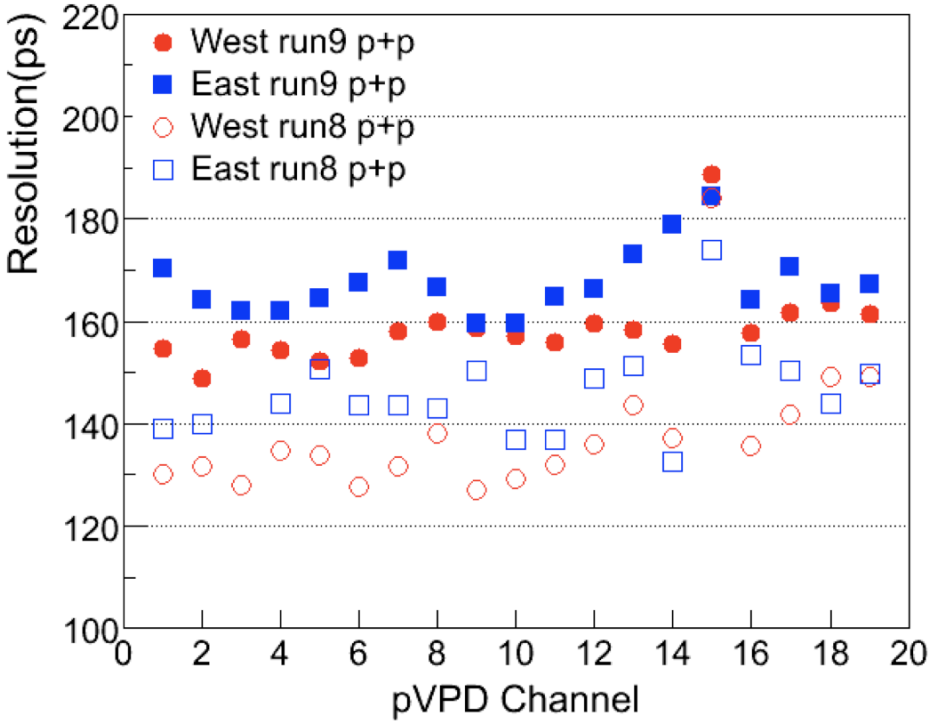
- Calibration constants ready for database (500GeV)
  - 200GeV in progress
- Applied by StBTofCalibMaker



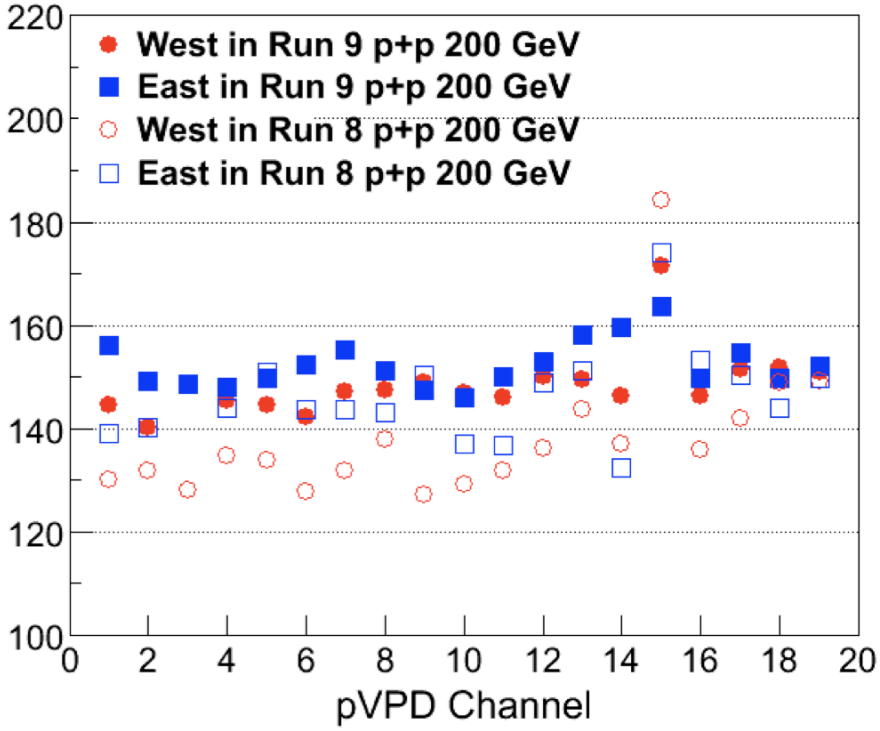
upVPD Calibration (cont'd)

Xiaoping Zhang

500GeV p+p



200GeV p+p



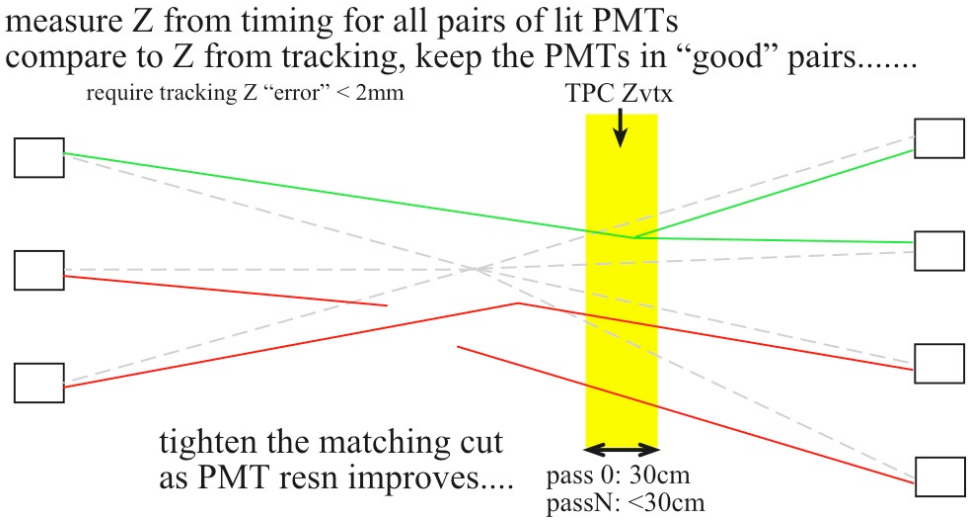
- 200GeV preliminary results based on recent calibration performed on subset of fast-offline data (days 132-152)

upVPD Calibration (cont'd)

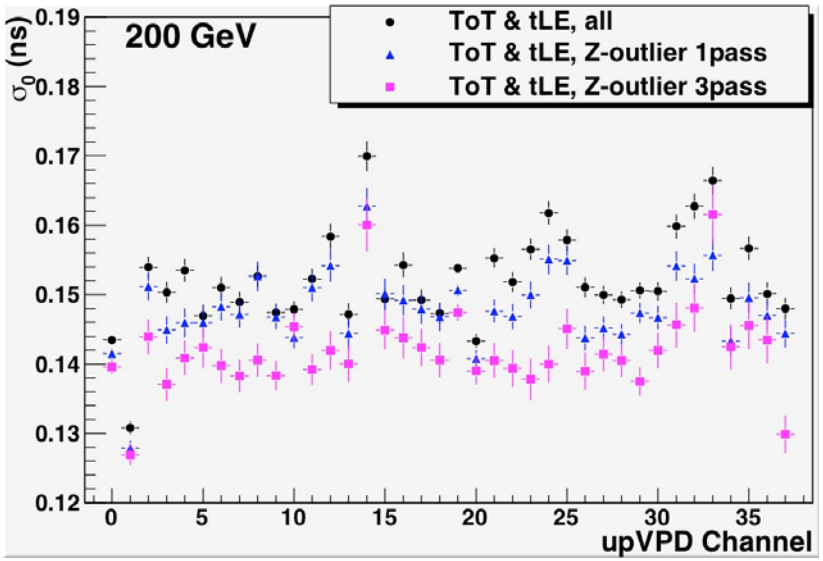
Bill Llope

Alternative approach in upVPD calibration

- less sensitive to "outliers", *e.g.* potentially resulting from additional vertices.



Promising first results:



Resolution per channel ~140ps
➔ upVPD start resolution < 100ps
(for 1.AND.1)

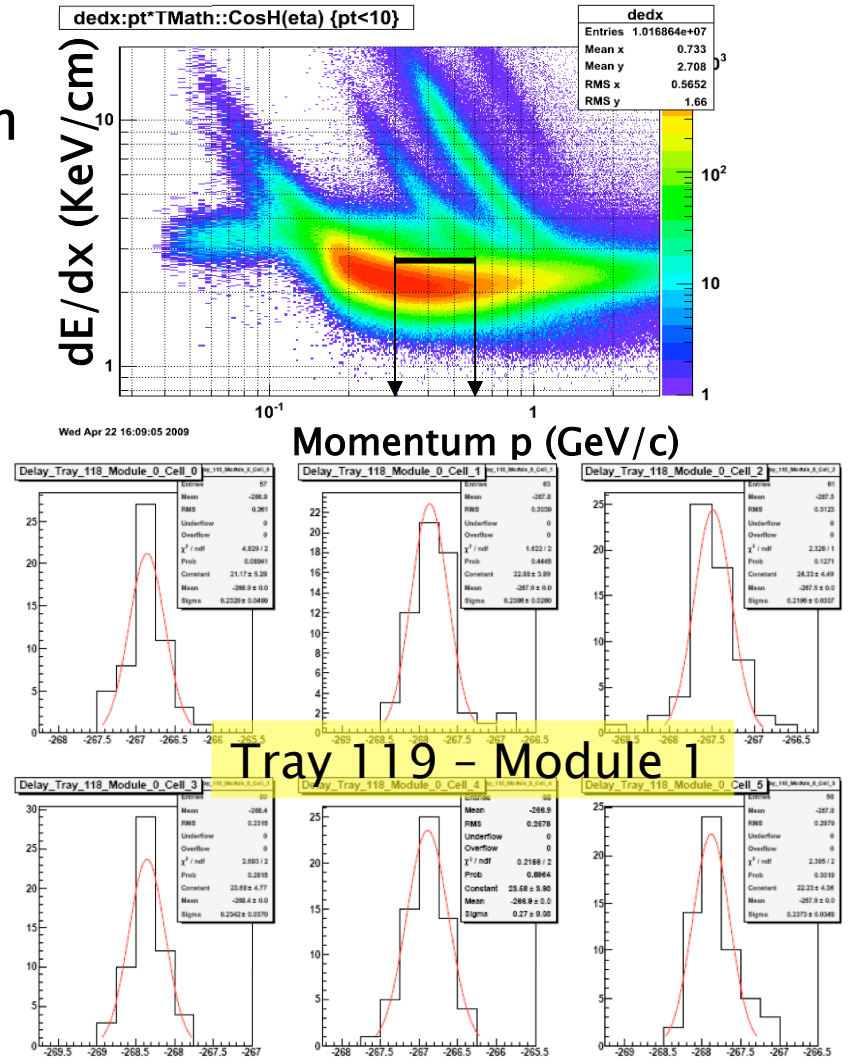
Barrel TOF Calibration

Zebo Tang

- Use a clean π sample, either from TPC dE/dx (and momentum cuts) or a pre-calibrated TOF in the next iterations

- T0 Calibration:
  - compensate for differences in cable lengths and signal transition times.
  - shifts the mean of $TOF_{measured} - TOF_{expected}$ to 0
  - determined channel by channel, *i.e.* per MRPC cell

  - Parameters done for 500GeV
    - Ready for database
    - 200 GeV in progress
  - Applied in StBTofCalibMaker

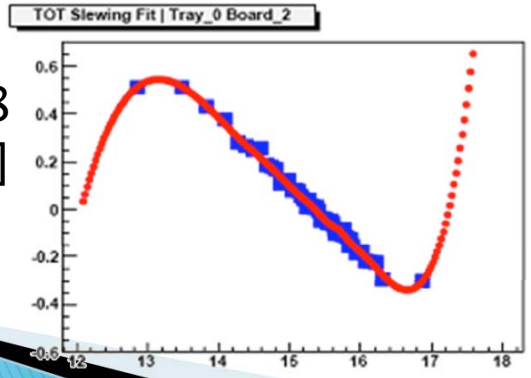


Barrel TOF Calibration (cont'd)

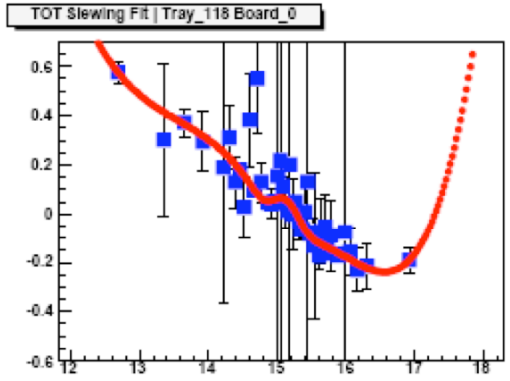
Slewing Correction

- compensates for correlation between signal timing and signal height.
  - time-over-threshold is proportional to signal height; based on a trailing edge timing measurement in addition to the leading edge
- use spline fits, and store its shape, *i.e.* bin values
- pp (500GeV): difficult to get enough statistics
  - corrections were performed per TDIG board (4 MRPCs, 24 channels)
  - Preliminary set ready for database, applied by StBTofCalibMaker
  - 200GeV data: first sample done, verification in progress

Run-8
[pp 200GeV]

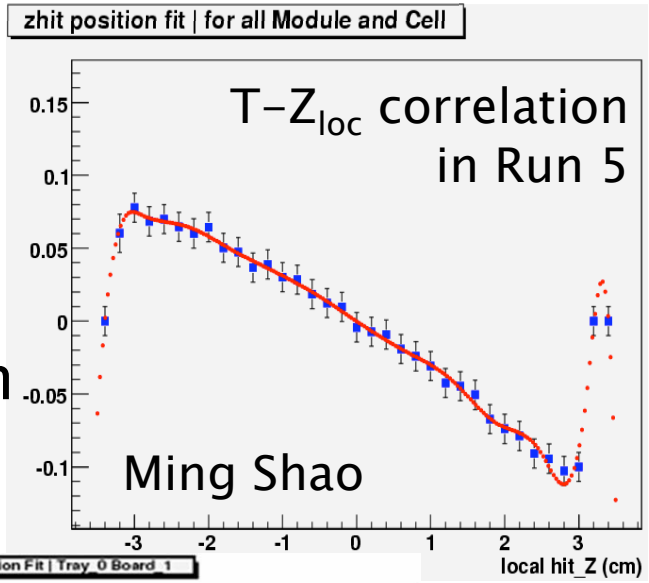


Run-9 [500GeV]
3M events

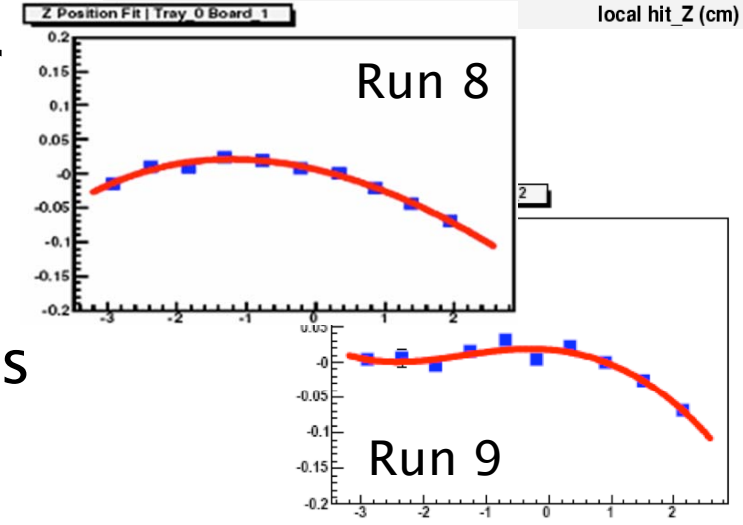


Barrel TOF Calibration (cont'd)

- Local Z-hit position correction
  - Expect a Z_{hit} dependence as signal propagation on the pick-up pads can be 40-50ps/cm
  - No strong dependence observed in Run 8 and 9; not yet understood.



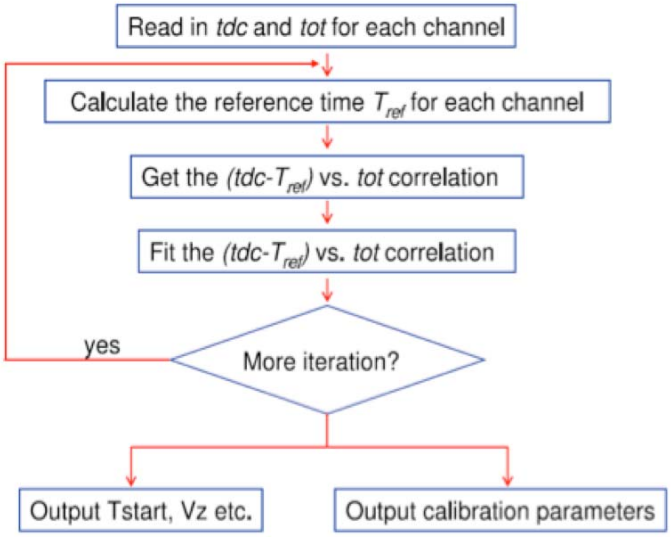
- Corrections are available for Run 9 p+p
  - 500GeV: ready for database, applied by StBTofCalibMaker
  - 200GeV: verification in progress



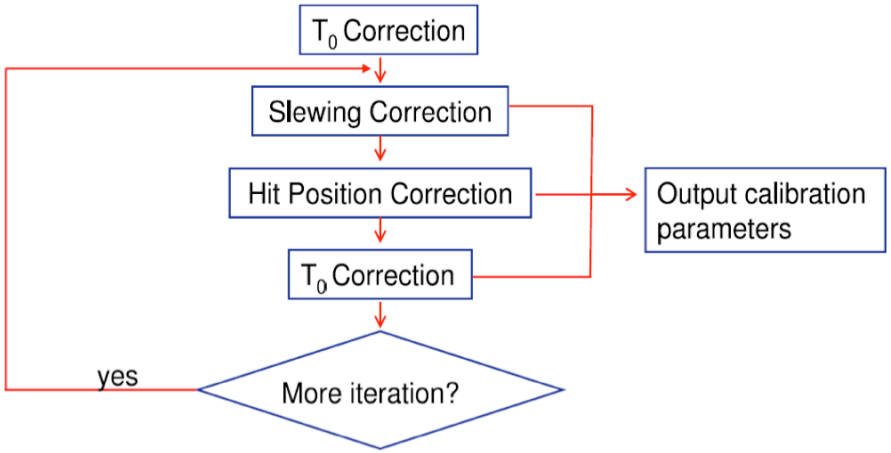
TOF Calibration Procedures

- procedures involve several iterations
  - *e.g.* using a slew-corrected timing to improve T_{ref} or T0 timings

start-side calibration

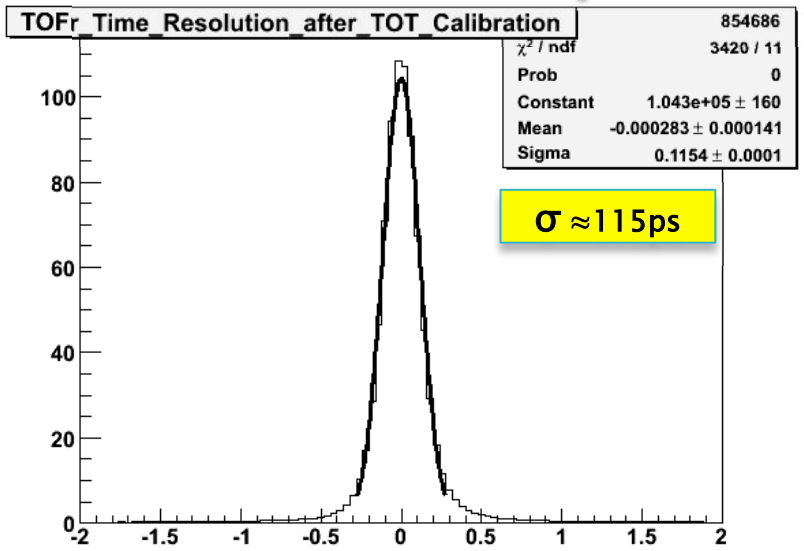


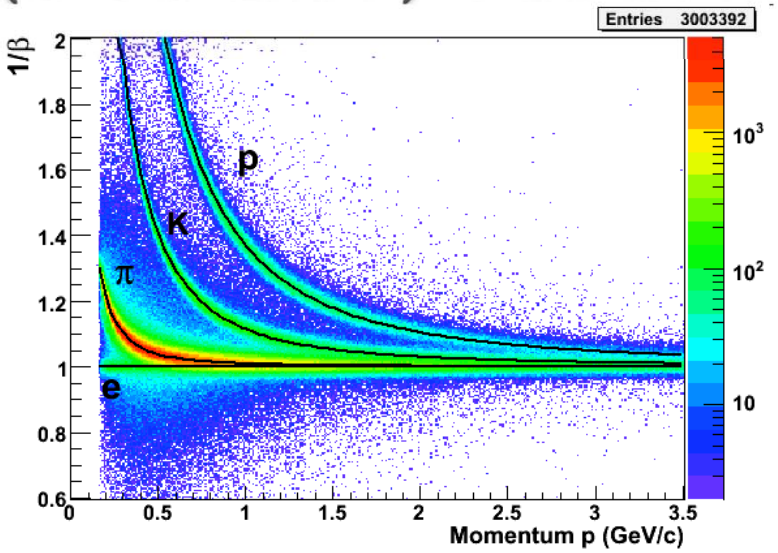
stop-side calibration

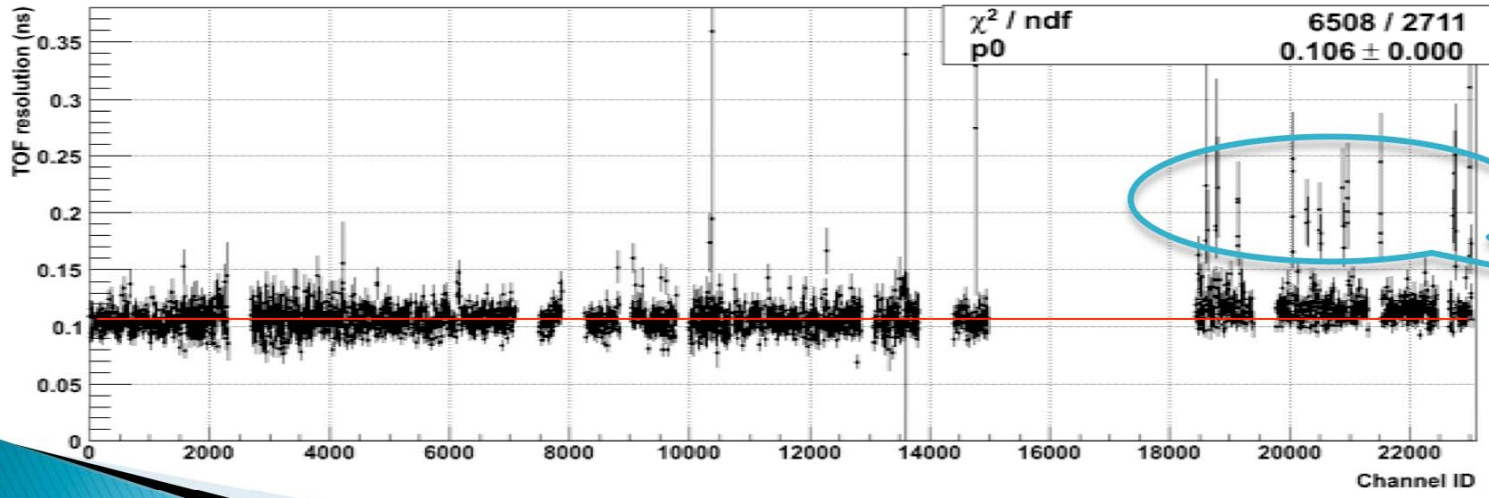


- once a large statistical sample is available determine the tray alignment calibration

Preliminary Run 9 (500GeV) results



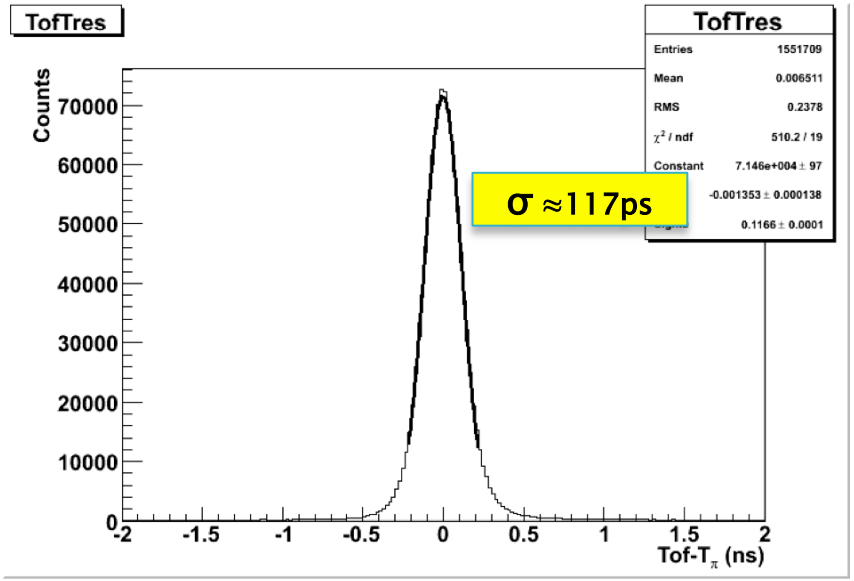


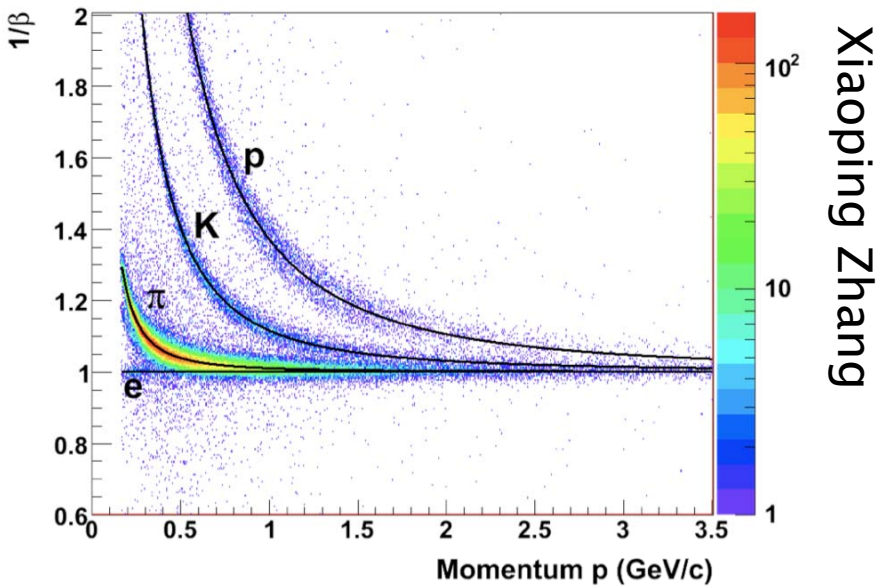


ToT fit failures

Zebo Tang

Preliminary Run 9 (200GeV) results





Xiaoping Zhang

- Preliminary 200GeV data based on subset of Fast-Offline data
- Near-future detailed studies on threshold and magnet field polarity
- Pending STAR production with final TPC calibrations (Sept.'09)

History of Calibration Results

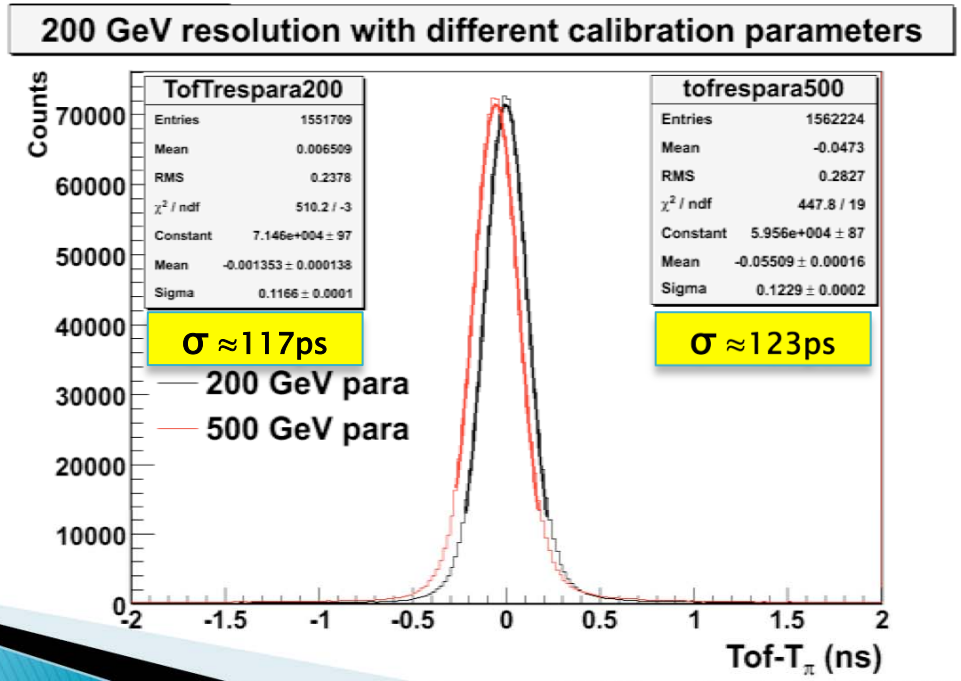
Operation condition			Time Resolution (ps)		
			Start time	Overall	Stop time
Run III	200GeV d+Au		85	120	85
	200GeV p+p		140	160	80
Run IV	62GeV (Au+Au)		55	105	89
	200GeV (Au +Au)	FF/RFF	27	86	82
		HF	20	82	80
Run V	200GeV Cu+Cu (ToT)		50	92	75
	62GeV Cu+Cu (ToT)		82	125	94
Run VIII	200 GeV d+Au(ToT)		NA	NA	NA
	200 GeV p+p(ToT)		*83*	*112*	*75*
Run IX	*500 GeV p+p (preliminary)*		*85*	*115*	*78*
	200 GeV p+p (preliminary)		*90*	*117*	*74*

Calibration Requirements

Collisions [MinBias]	$<dN_{ch}^{raw}/d\eta>$ STAR Collab. Phys.Rev. C79 034909 (2009)	×1/4 (pure π) ×80% (match) ×2 (Δη)	Useable hits per channel	Slewing Correction 10k/{ch,mod,brd)			T0 500/ch
				channel-by-channel	mod-by-mod	board-by-board	
p+p	2.4	0.96	4.2e-5	240M	40M	10M	12M
d+Au	10.2	4.1	1.8e-4	56M	9.3M	2.3M	2.8M
Au+Au	200	80	3.5e-3	2.9M	0.5M	0.12M	0.15 M
Au+Au (0-10%)	515	206	8.9e-3	1.2M	0.2M	0.05M	0.06 M

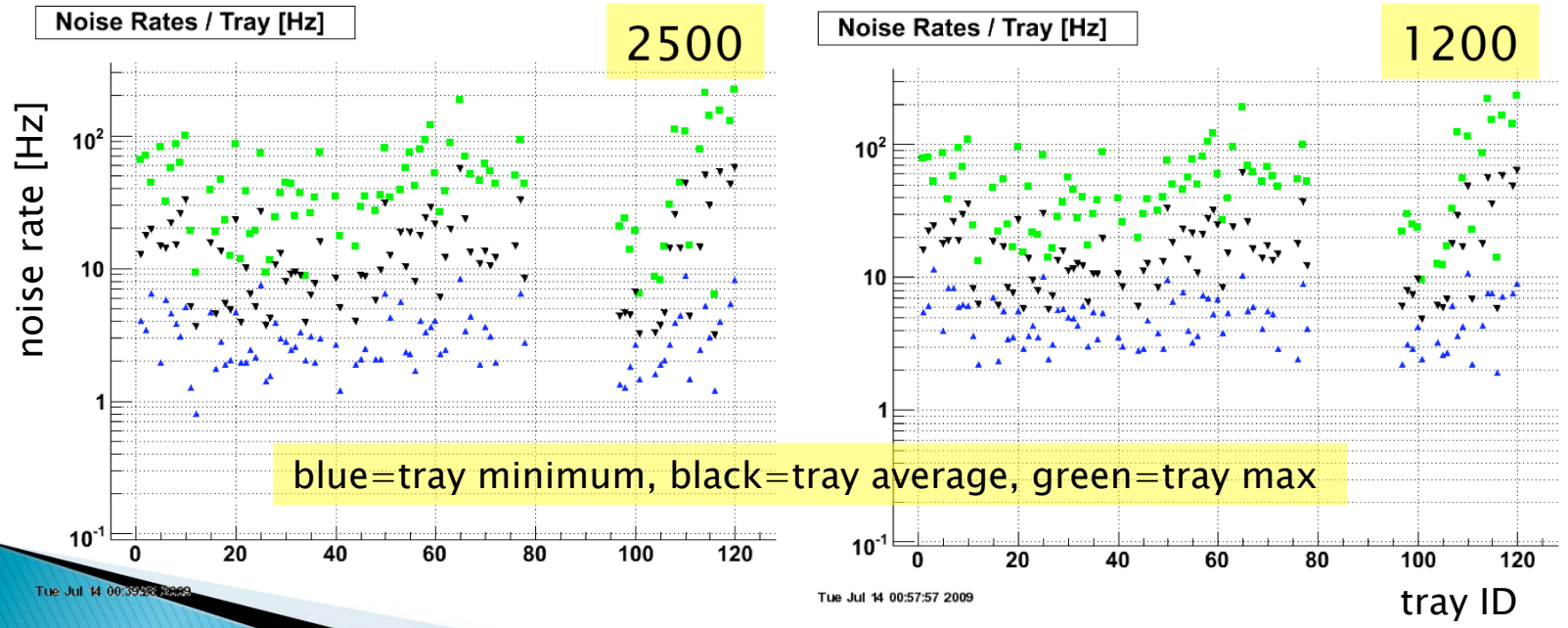
Cross-verification of Calibration

- Significant statistics requirements effect turn-around time for prompt TOF PID
  - application of “online” PID
- Cross-verification of p+p calibration parameters
  - apply 500GeV calibration on 200GeV data sample



TOF Noise Rates and Thresholds

- Run-9 (200GeV): two discriminator thresholds
  - high threshold (2500≈50mV): day 113-161
    - STAR field polarity change RFF ➔ FF on day 147
  - lower threshold (1200≈24mV): day 162-180
- dedicated noise runs (day 195): only little difference
  - further study effect on calibration and efficiency



Summary

- TOF stable operations during Run 9
  - very useful to verify calibration/production procedures
- TOF calibration: full-steam ahead
    - TOF calibration depends on TPC calibration
  - 500GeV: preliminary calibration, ready for STAR database
  - 200GeV: first preliminary calibration, verification in progress
  - will require a larger data sample
    - verify the effect of the different discriminator threshold settings, verify field polarity change, verify effect of final TPC calibration
- Preliminary p+p results for TOF resolution agree with TOF Project deliverable (100±15ps for Au+Au)
  - expect a significant improvement of start-side resolution in full energy Au+Au
  - expect further improvements by increasing statistics