# TOF System Performance: Calibrations & Time Resolutions

Frank Geurts
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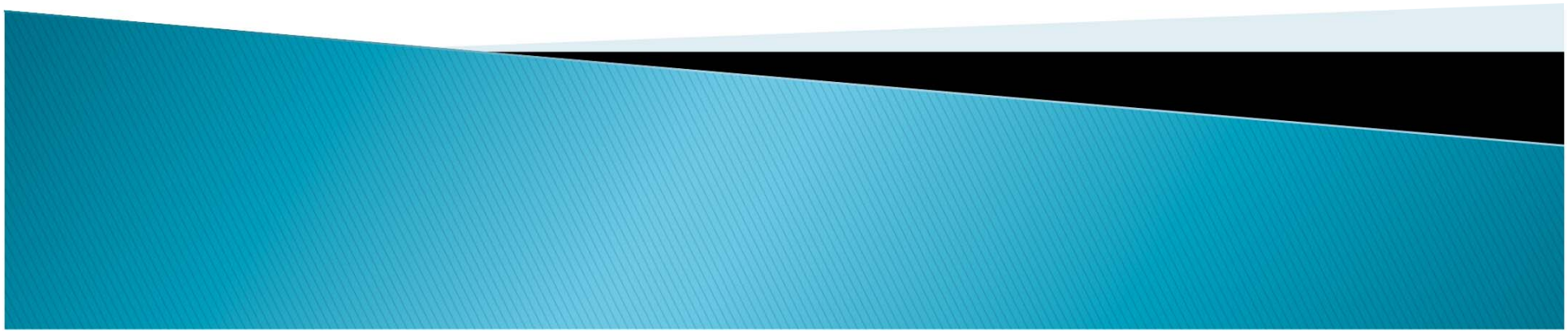


# Outline

- 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
- Summary

# TOF in Run 9

Based on Multi-gap Resistive Plate Chambers (MRPC)

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

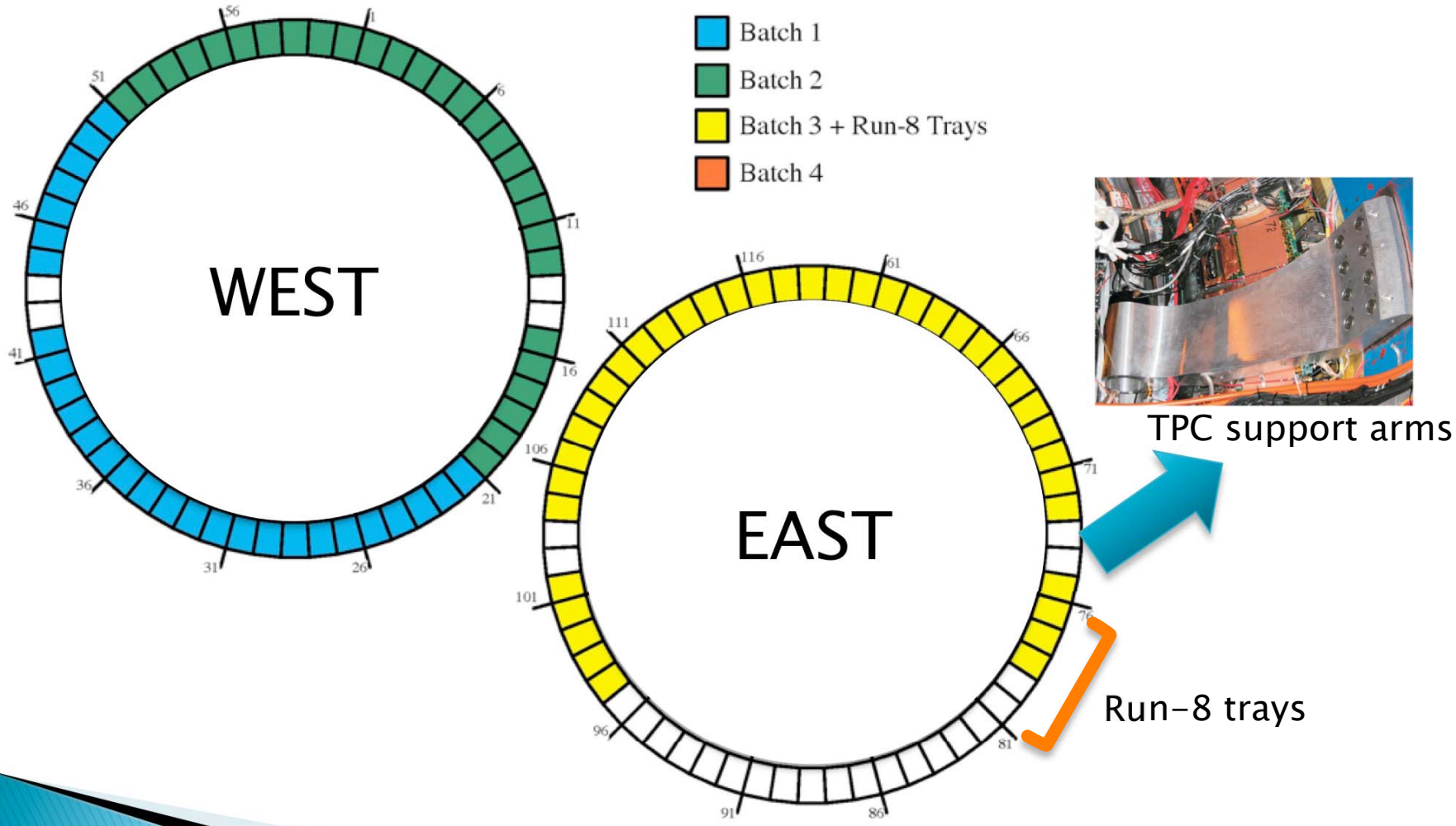
Significant increase in scale:

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

Run 9 experience:

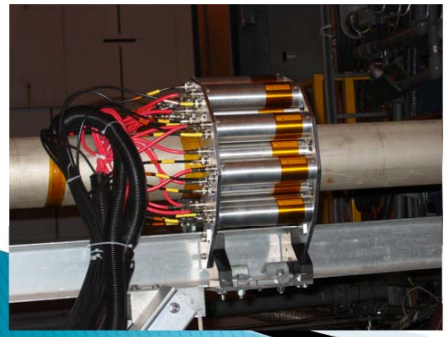
- stable running, TOF participated in nearly all runs;
- 9 dead channels out of 16,512;
- average noise rate per channel is less than 10 Hz.

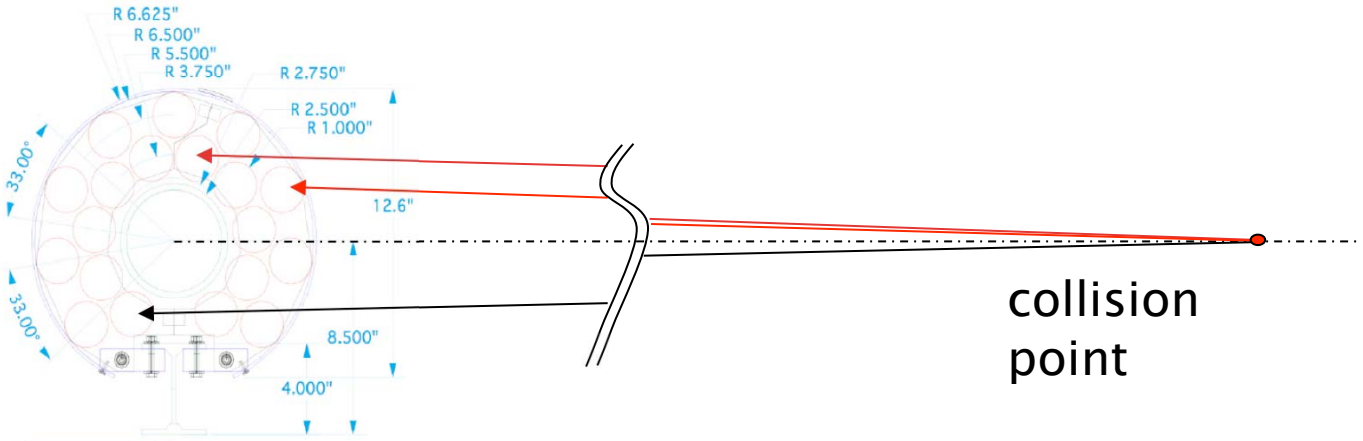
# Run 9 TOF trays



# Start Side: the upVPD

- upVPD replaced pVPD (Run 7):
  - upgrade involves increase in # of channels from 6 to 38 channels (east + west)
  - both based on scintillator and fast PMTs
  - upVPD uses similar timing electronics as TOF
- STAR $|Z|=570cm$ and $4.24 < |\eta| < 5.1$





# TOF Calibrations

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

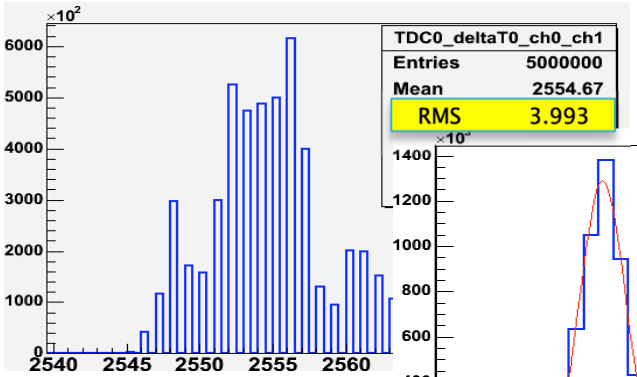
- Start-side calibration upVPD
  - signal slewing, T vs. Time-over-Threshold (TOT)
- Stop-side calibration Barrel TOF
  - TOF T0
  - signal slewing (T vs. TOT)
  - MRPC cell signal propagation (T vs. $Z_{local}$)
  - tray alignment calibration

# Integral Non-Linearity Calibration

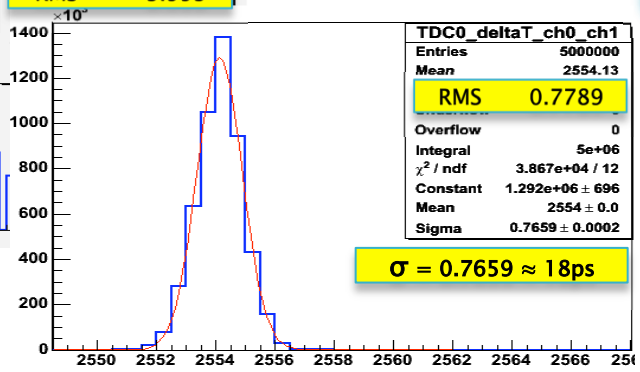
Jing Liu

HPTDC integral non-linearity (INL):

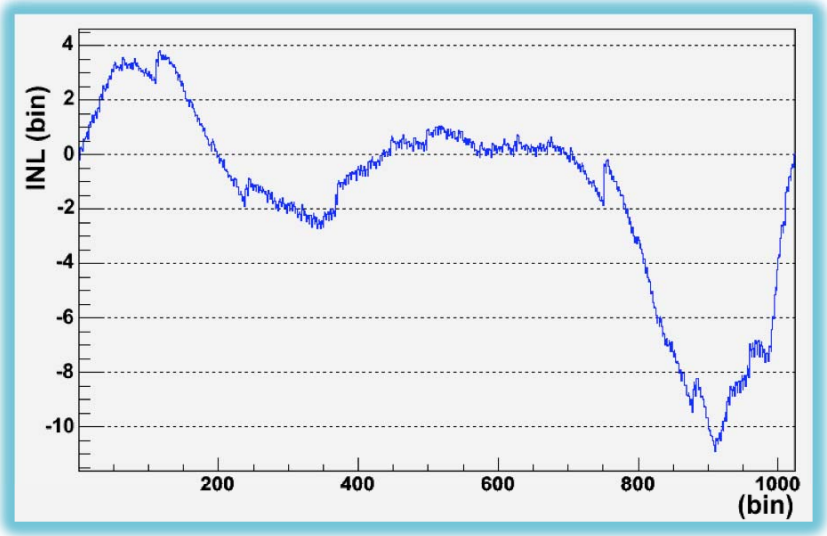
- periodicity 1024 bins (25ns)
- calibration data collected on test bench
- expect no change, but will monitor




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 STAR Offline Database
- applied by offline software

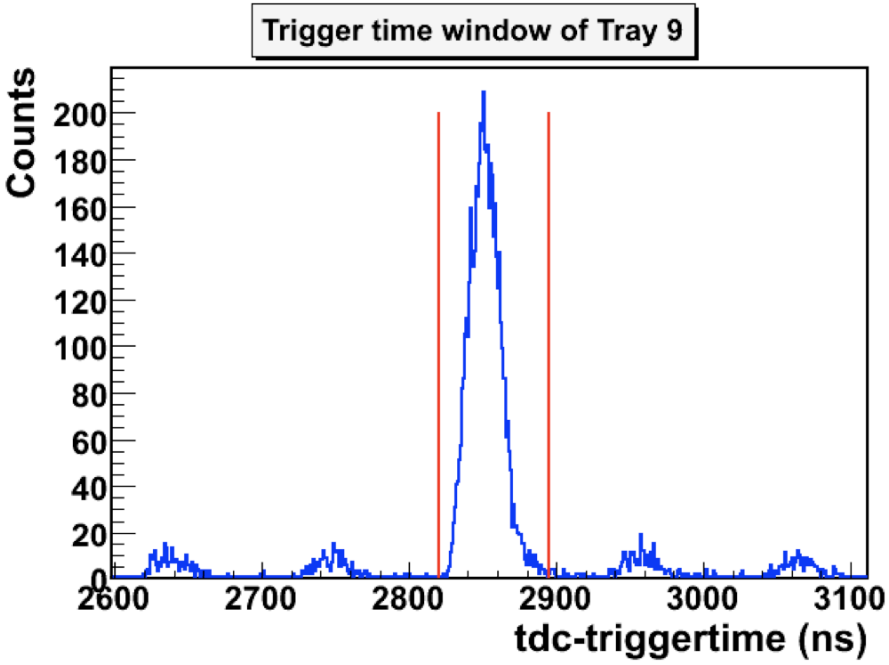
# Trigger Matching Window

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 in offline software

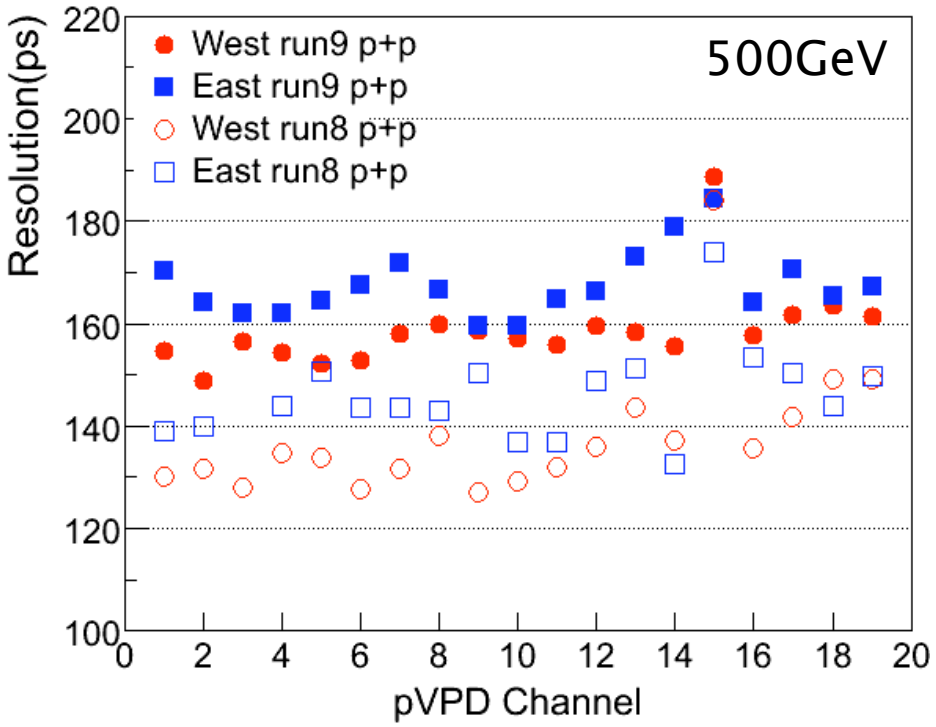


# upVPD Calibration

Zebo Tang
Xiaoping Zhang

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

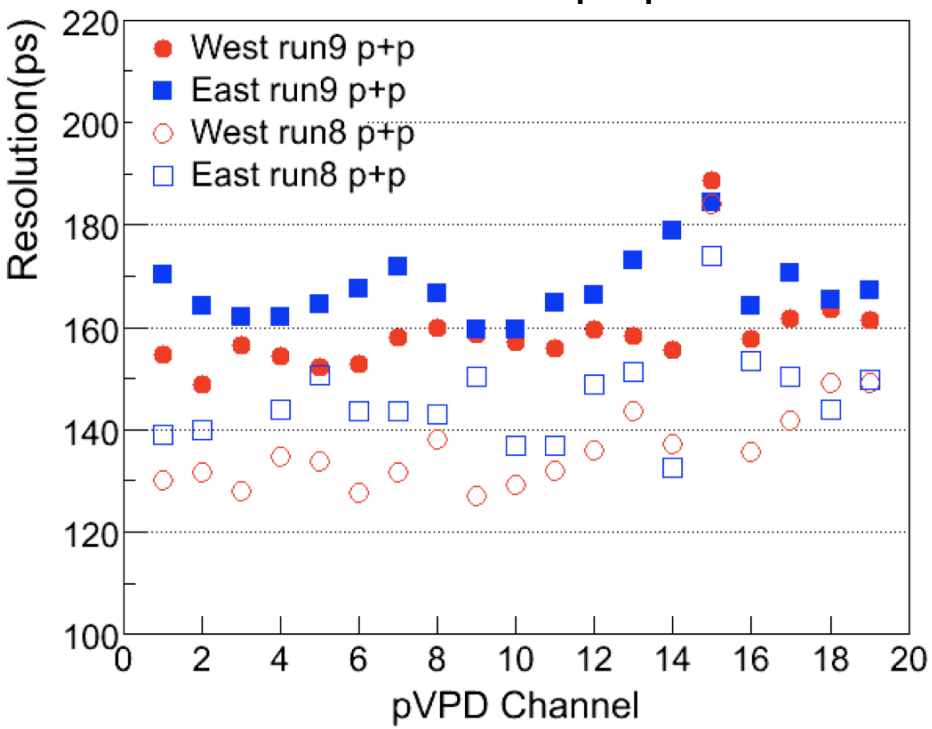
- iterative process
- separate East & West Calibration
- low multiplicity in upVPD is an issue
  - not all events will have a start-time
- calibration constants ready for database (500GeV)
  - 200GeV in progress
- applied in offfline production (StBTofCalibMaker)



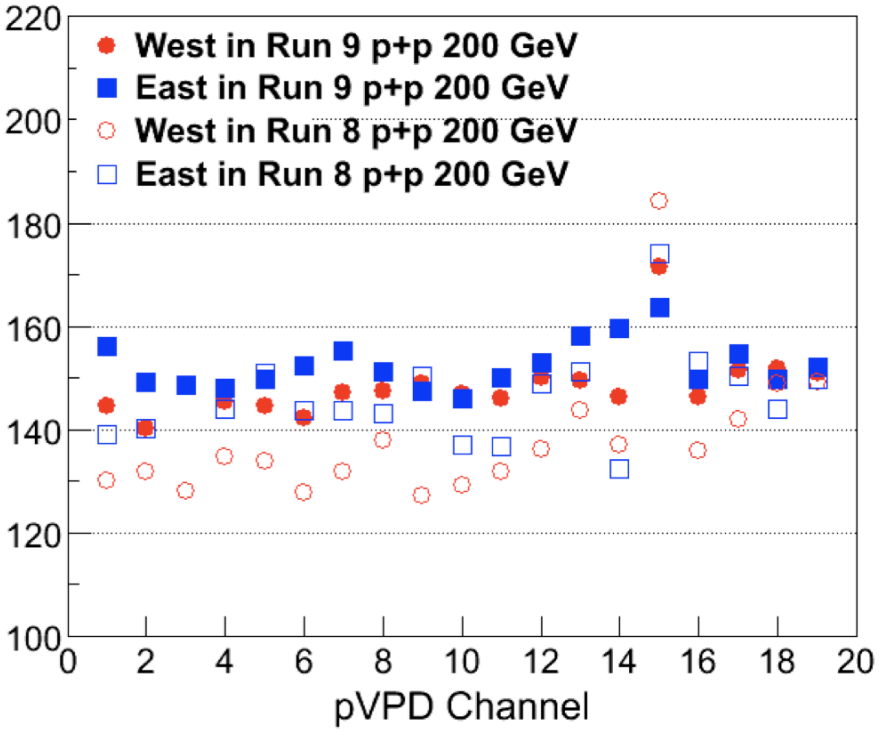
# upVPD Calibration (cont'd)

Xiaoping Zhang

500GeV p+p




200GeV p+p



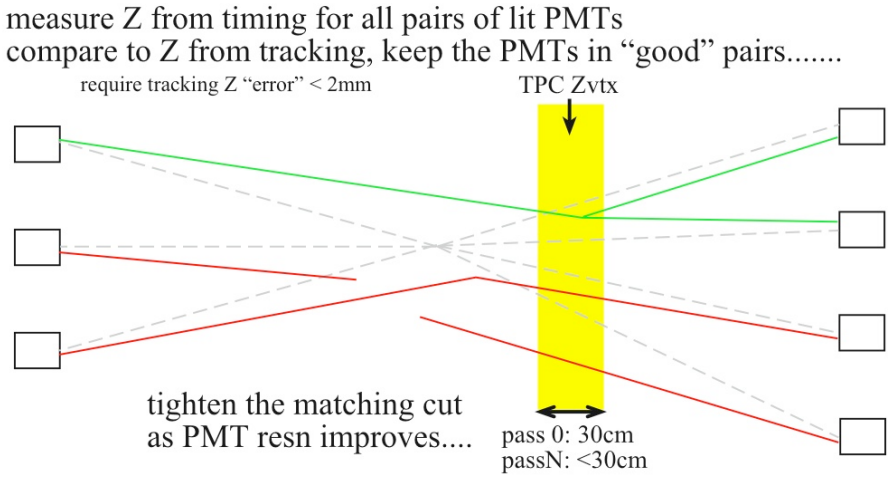

- 200GeV preliminary results based on recent calibration performed on subset of fast-offline data (days 132-152)
- calibration procedure is sensitive to out-of-time "*outlier*" hits

# upVPD Calibration (cont'd)

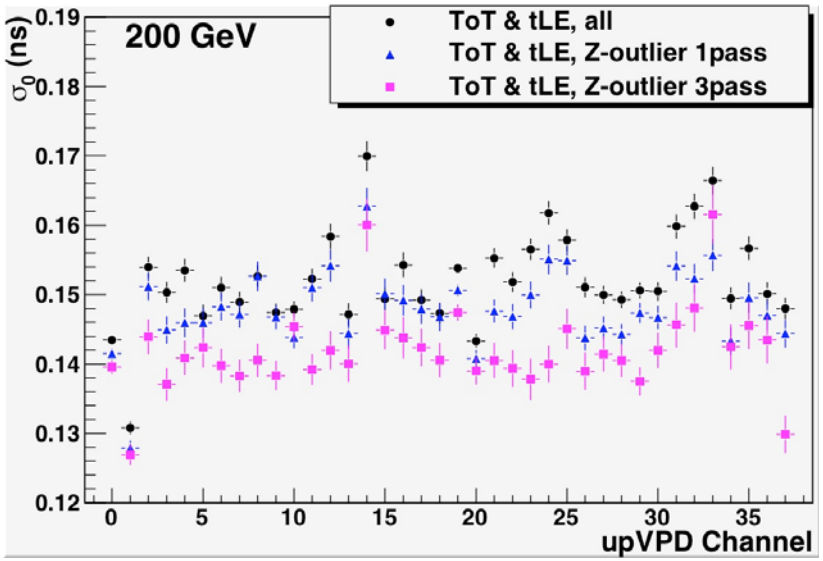
Bill Llope

Alternative approach in upVPD calibration

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




Promising first results:




Resolution per upVPD channel ~140ps

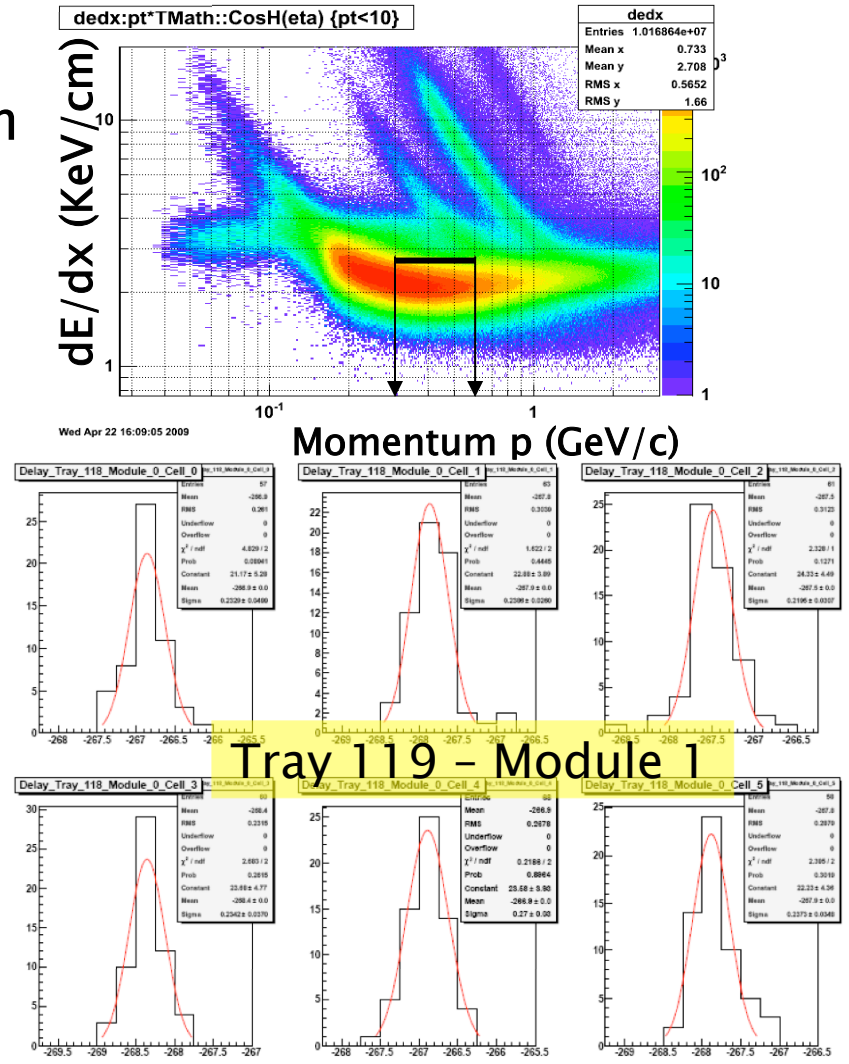
➔ TOF start resolution < 100ps (for 1.AND.1)

down to ~23ps (19.AND.19)

# 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.
  - determined channel by channel, *i.e.* per MRPC cell
  - parameters done for 500GeV
    - Ready for database
    - 200GeV in progress
  - applied in offline production (StBTofCalibMaker)

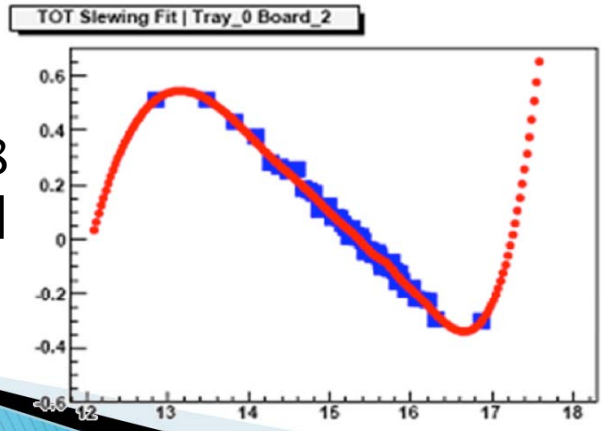


# Barrel TOF Calibration (cont'd)

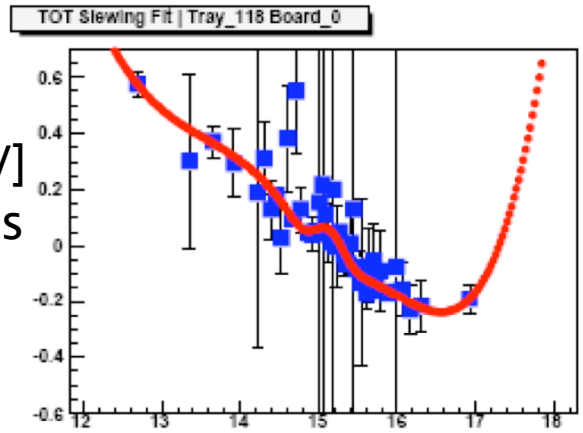
Slewing Correction

- 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]

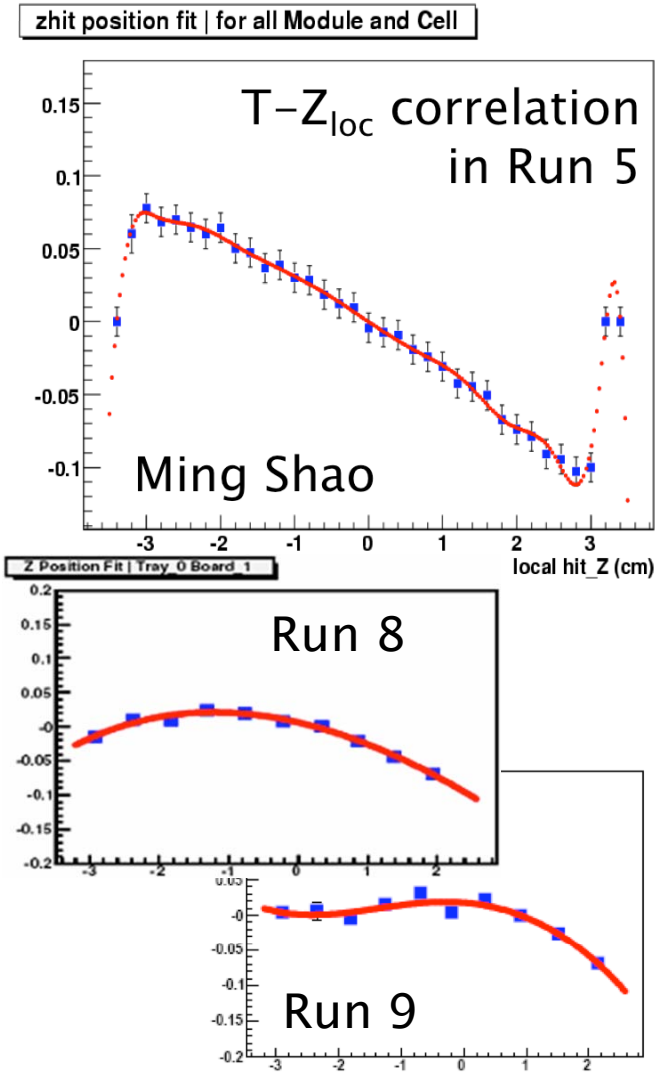



Run-9 [500GeV]
3M events

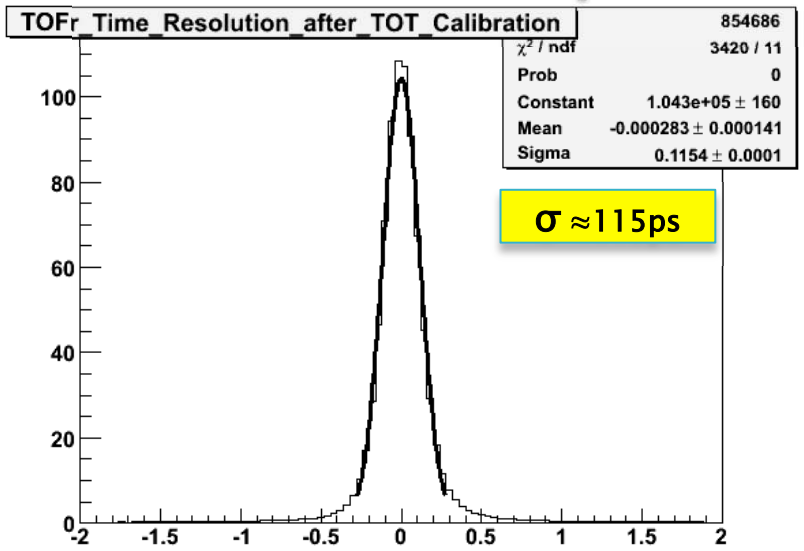


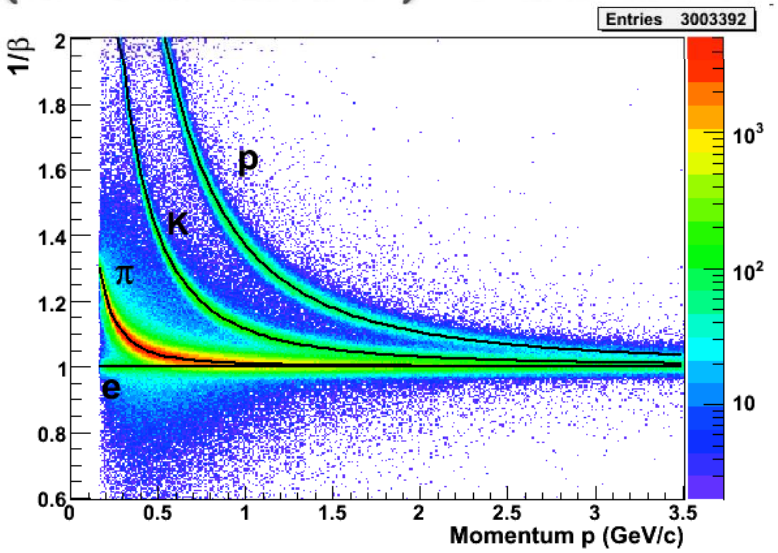
# Barrel TOF Calibration (cont'd)

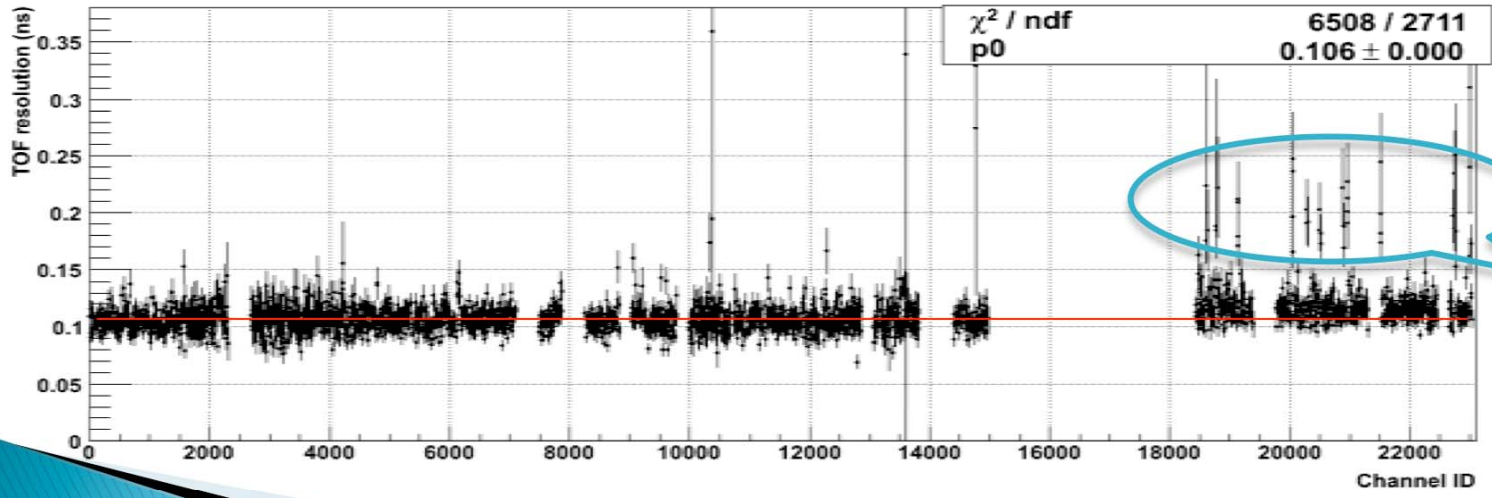
- Local Z-hit position correction
  - Expect a $Z_{hit}$ dependence as signal propagation on the pick-up pads can be 40-50ps/cm
  - No strong dependence observed in Run 8 and 9; not yet understood.
- Corrections are available for Run 9 p+p
  - 500GeV: ready for database, applied by StBTofCalibMaker
  - 200GeV: verification in progress
- Once a large statistical sample is available determine the tray alignment calibration



# Preliminary Run 9 (500GeV) results



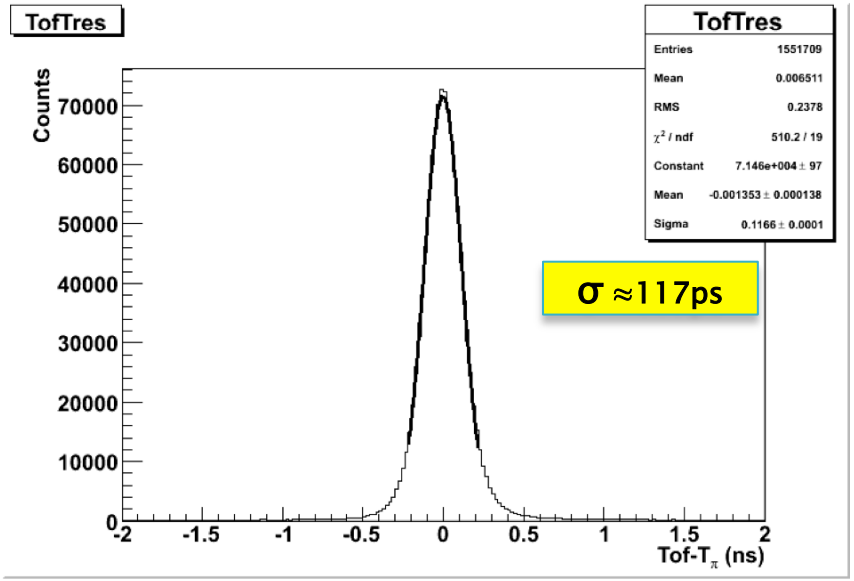



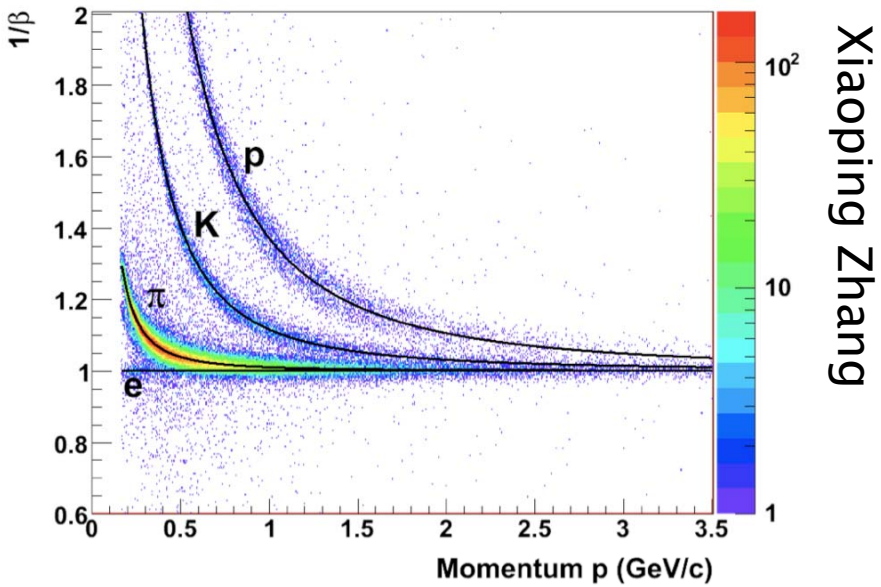




ToT fit failures

Zebo Tang

# Preliminary Run 9 (200GeV) results



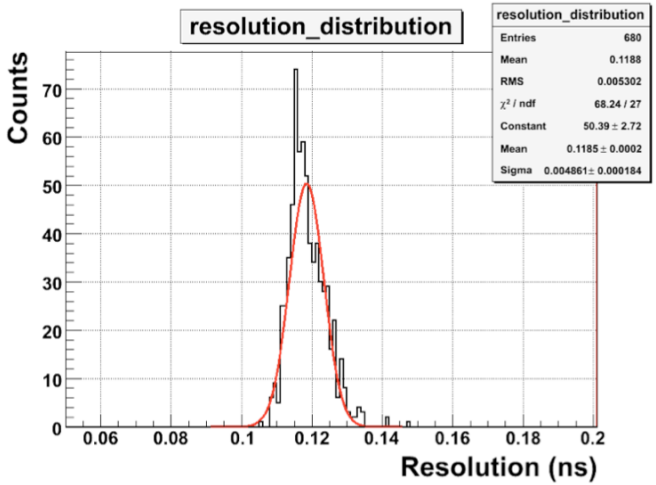

Xiaoping Zhang

- Preliminary 200GeV data based on subset of Fast-Offline data
  - discriminator threshold similar to previous run periods
- Near-future detailed studies on discriminator thresholds and magnetic field polarities
  - significant 200GeV data sets available
- Pending STAR production with final TPC calibrations (Sept.'09)

# Preliminary Run 9 Results (cont'd)

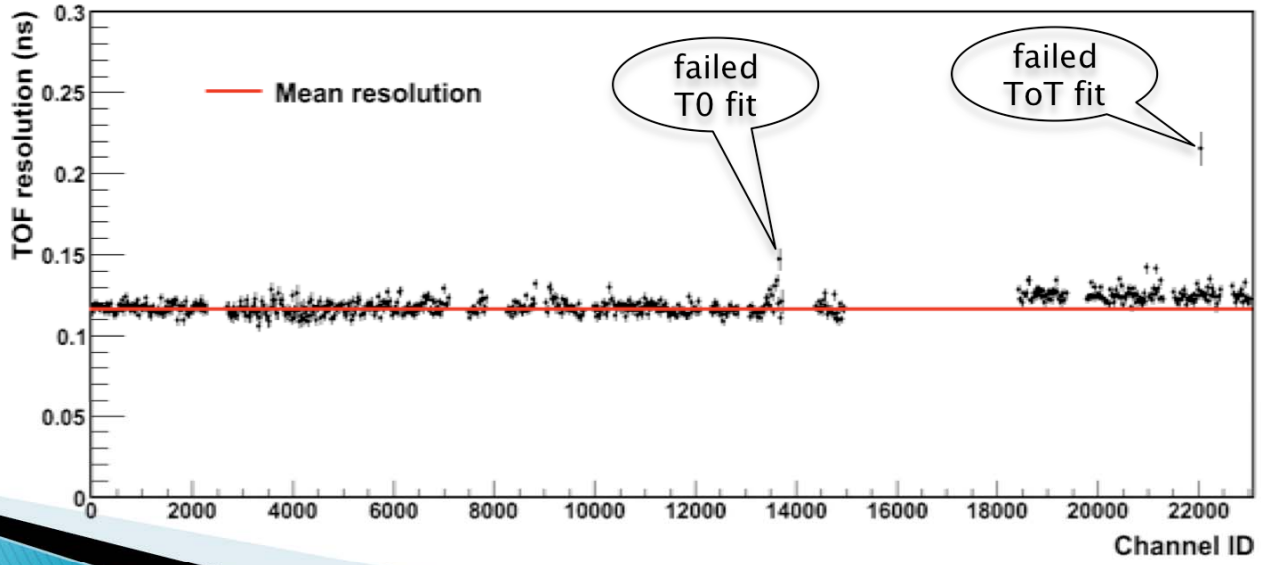
- time resolution distribution

$$\sigma(\sigma_{TOF}) = 5\text{ns}$$




- Note: channels grouped by TDIG board

- time resolution per channel (board) for 200GeV p+p




Xiaoping Zhang

# 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 | 200GeV d+Au (ToT) | | NA | NA | NA |
| | 200GeV p+p (ToT) | | 83 | 112 | 75 |
| Run IX | *500GeV p+p (preliminary)* | | *85* | *115* | *78* |
| | *200GeV p+p (preliminary)* | | *90* | *117* | *74* |

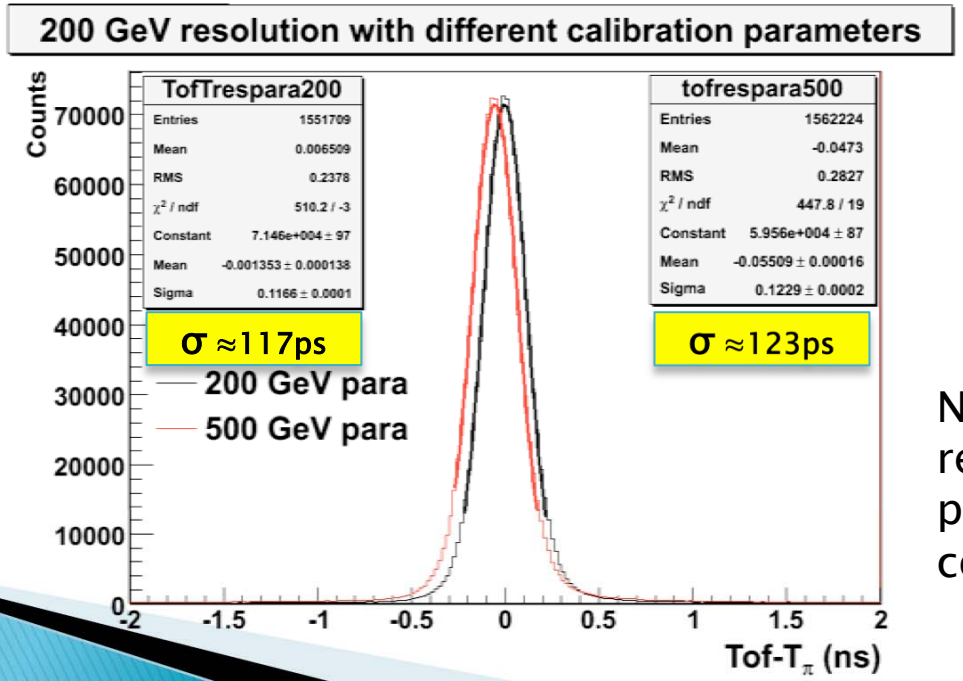
# Calibration Requirements

| Collisions [MinBias] | $\left\langle \frac{dN_{ch}^{raw}}{d\eta} \right\rangle$ taken from [1] | ×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 | 0.15M |
| Au+Au (0-10%) | 515 | 206 | 8.9e-3 | 1.2M | 0.2M | 0.05M | 0.06M |

[1] STAR Collab. Phys.Rev.C79 034909 (2009)

# Cross-verification of Calibration

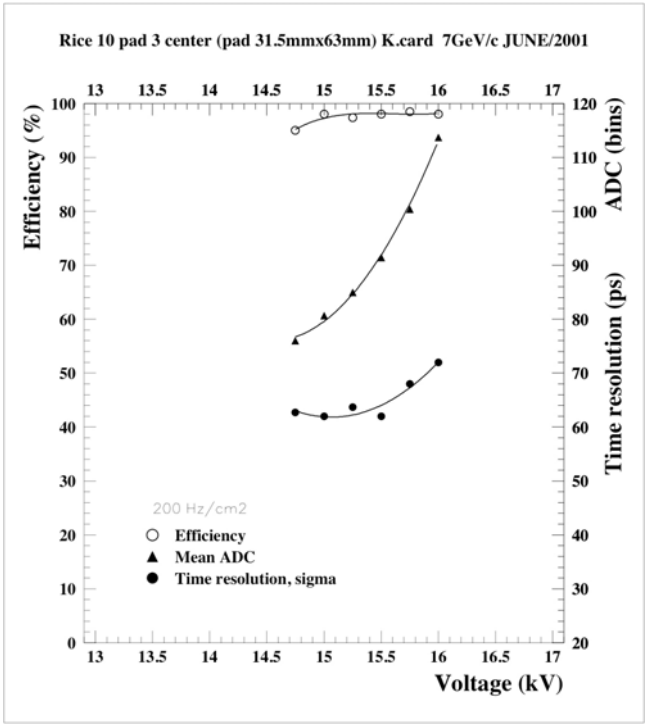
- Significant statistics requirements effect turn-around time for prompt TOF PID
  - application of “online” PID
- Cross-verification of p+p calibration parameters
  - apply 500GeV calibration on 200GeV data sample



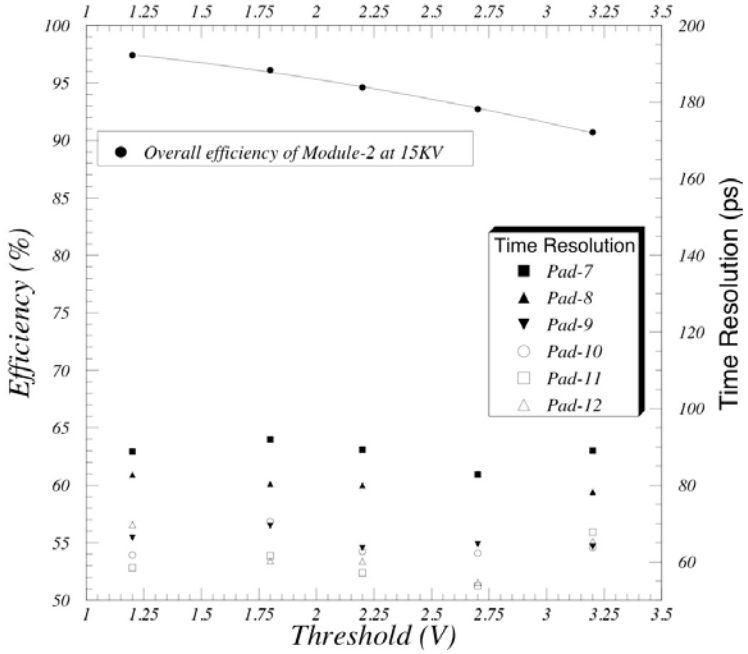

Note that subtle differences remain, making these parameter sets not completely compatible.

# MRPC TOF Efficiency

2001 CERN test beam




2003 AGS test beam




- Run 9: efficiency analysis pending STAR production incl. EMC and final TPC calibration
  - ~Sept'09

# 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 requirement (100±15ps for Au+Au)
  - expect further improvements by increasing statistics
  - expect a significant improvement of start-side resolution in full energy Au+Au (see Llope's presentation) ranging from 44ps in very peripheral down to 23ps in mid-central to central collisions.
  - Expect associated overall TOF time resolutions between 88-96ps.