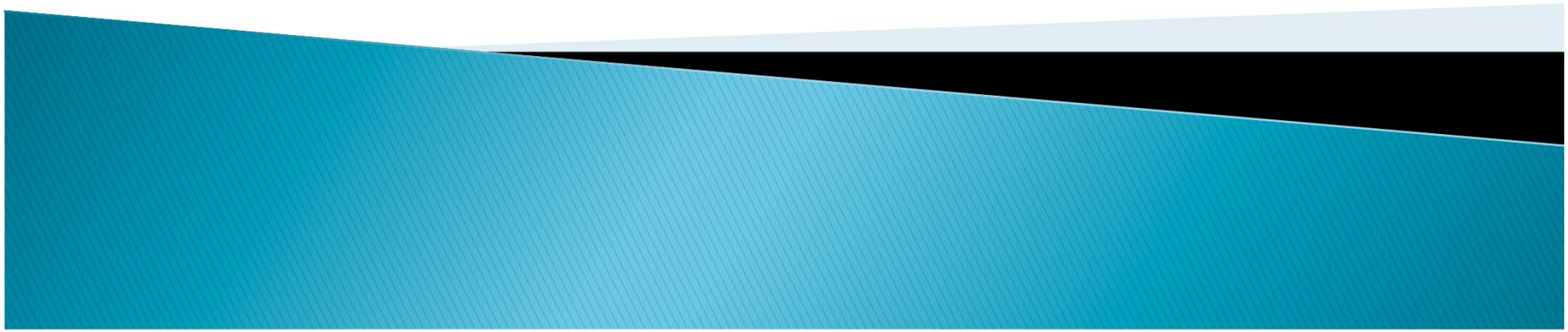
TOF System Performance: Calibrations & Time Resolutions

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
- 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

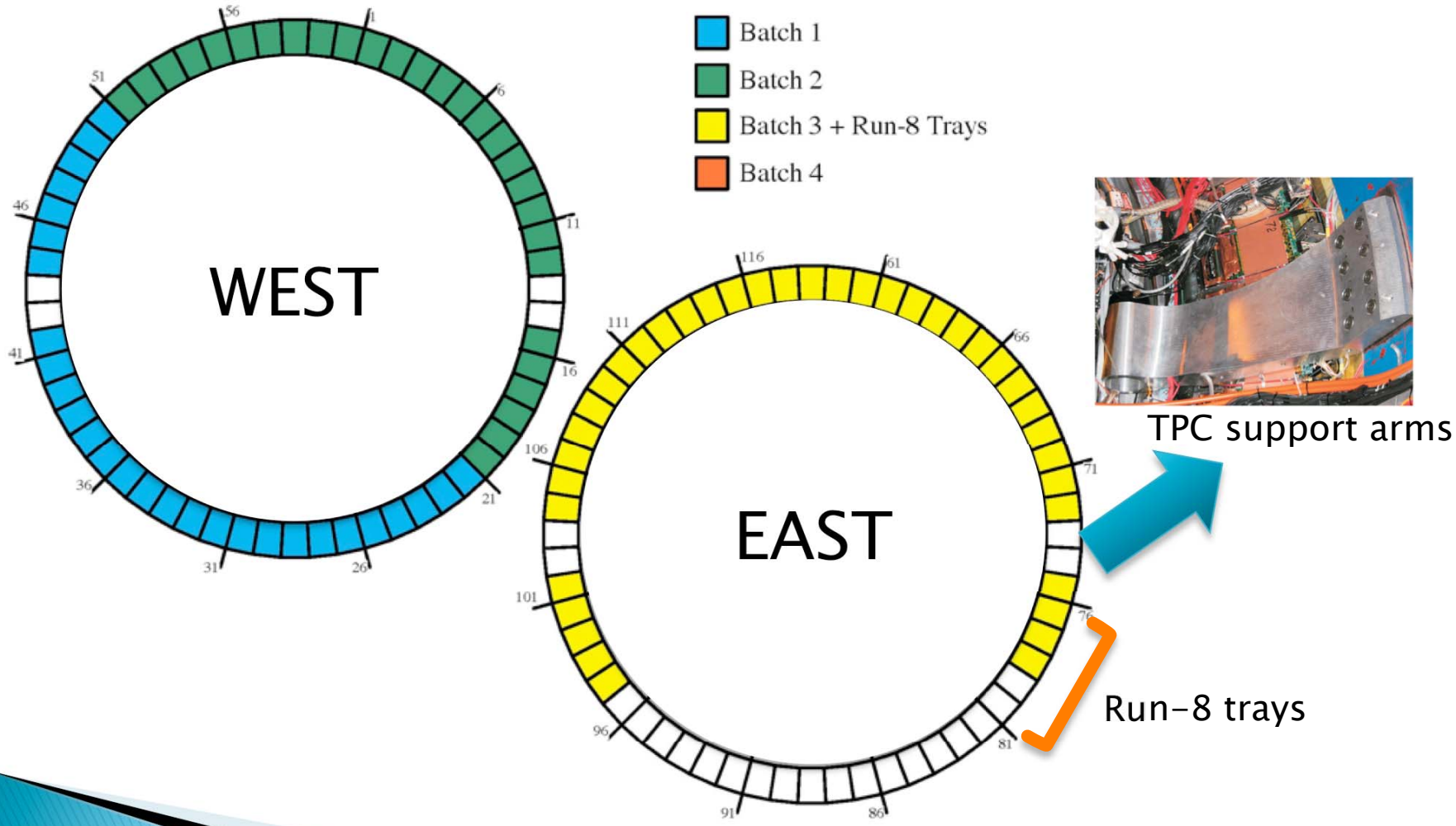
Significant increase in scale:

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

Run 9 experience:

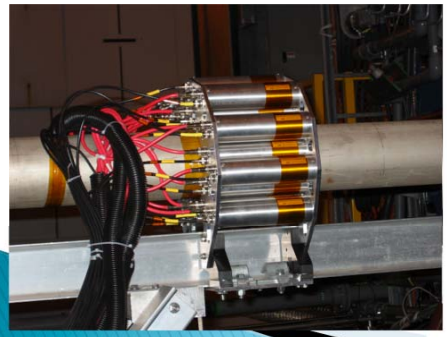
- stable running, TOF participated in nearly all runs;
- 9 dead channels out of 16,512;
- average noise rate per channel is less than 10 Hz.

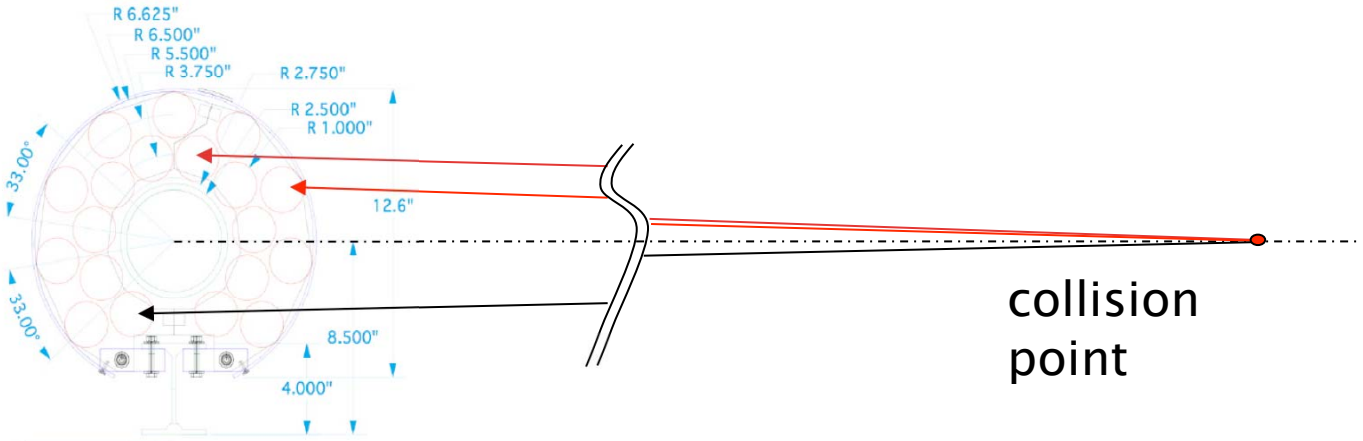
Run 9 TOF trays



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

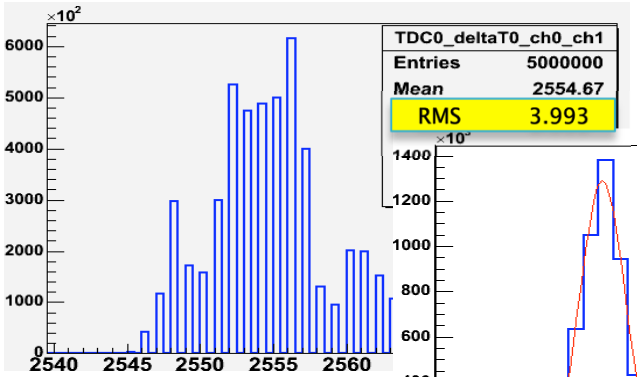
- Start-side calibration upVPD
  - signal slewing, T vs. Time-over-Threshold (TOT)
- Stop-side calibration Barrel TOF
  - TOF T0
  - signal slewing (T vs. TOT)
  - MRPC cell signal propagation (T vs. Z_{local})
  - tray alignment calibration

Integral Non-Linearity Calibration

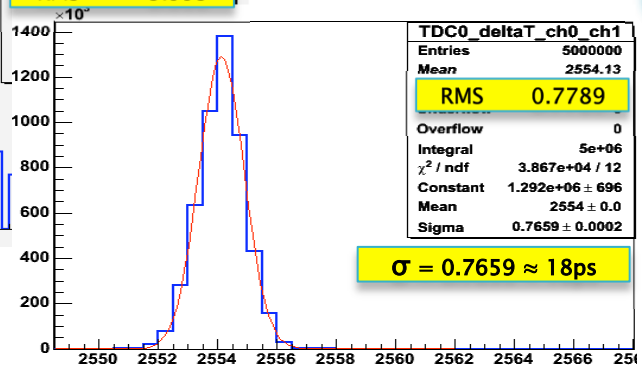
Jing Liu

HPTDC integral non-linearity (INL):

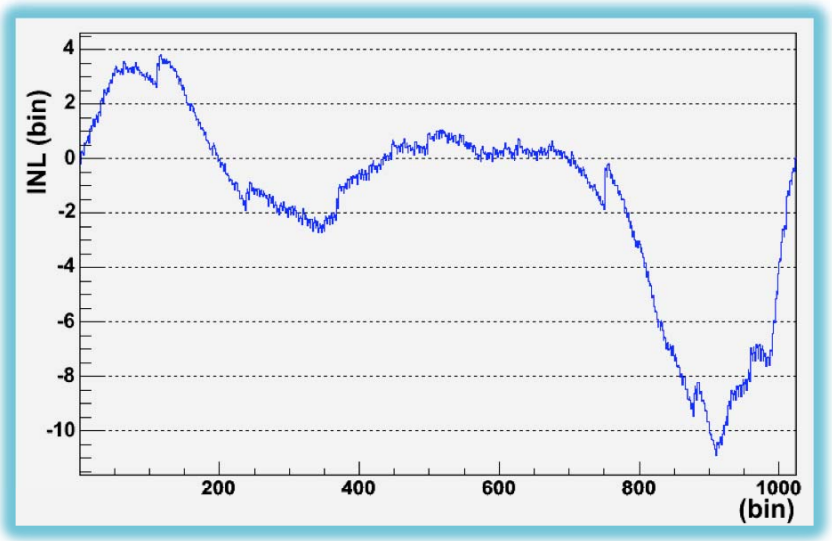
- periodicity 1024 bins (25ns)
- calibration data collected on test bench
- expect no change, but will monitor



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

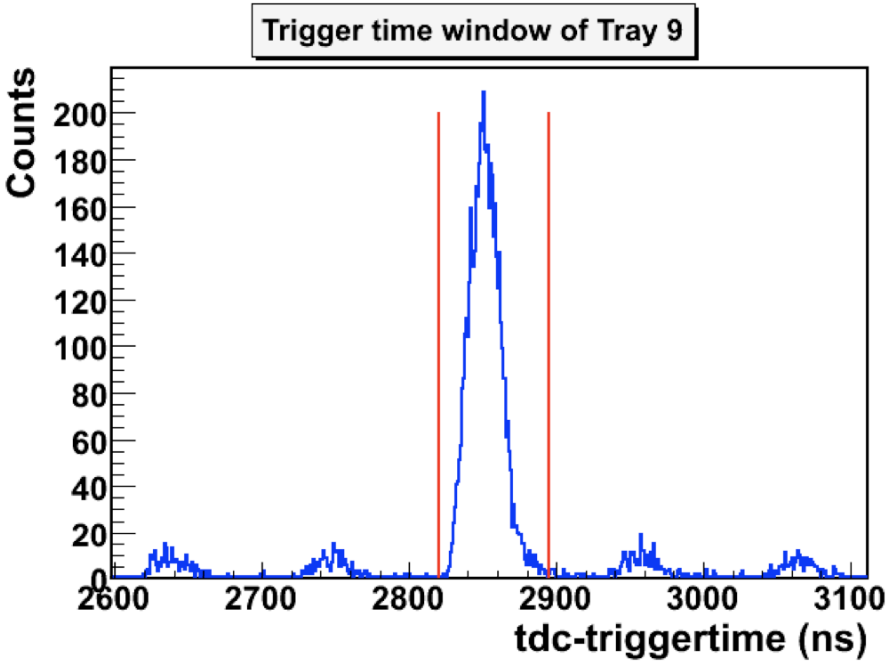
Trigger Matching Window

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

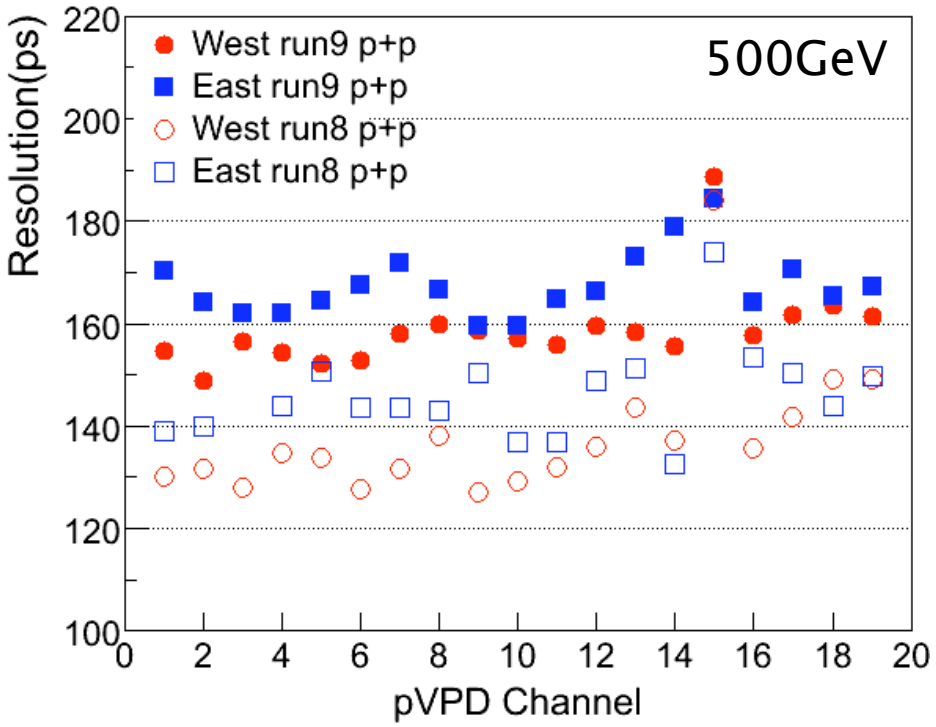


upVPD Calibration

Zebo Tang
Xiaoping Zhang

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

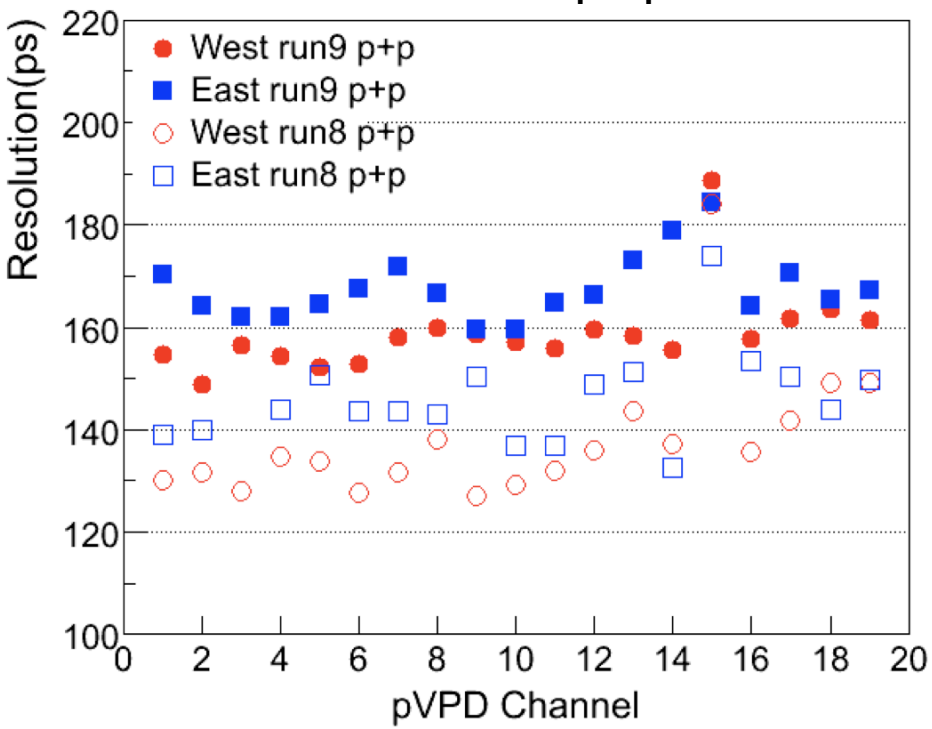
- iterative process
- separate East & West Calibration
- low multiplicity in upVPD is an issue
  - not all events will have a start-time
- calibration constants ready for database (500GeV)
  - 200GeV in progress
- applied in offfline production (StBTofCalibMaker)



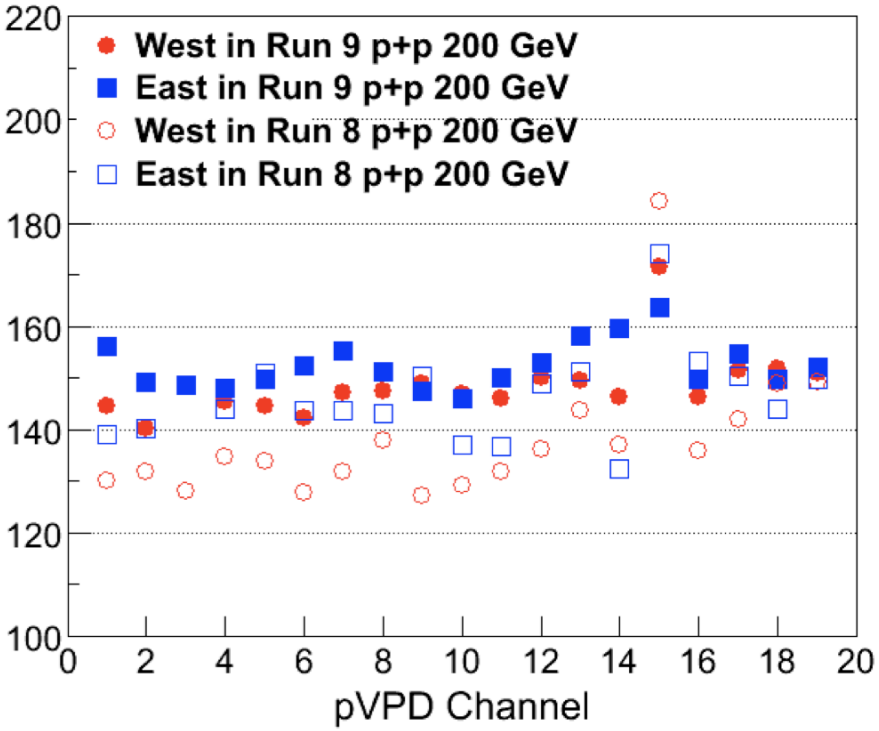
upVPD Calibration (cont'd)

Xiaoping Zhang

500GeV p+p



200GeV p+p



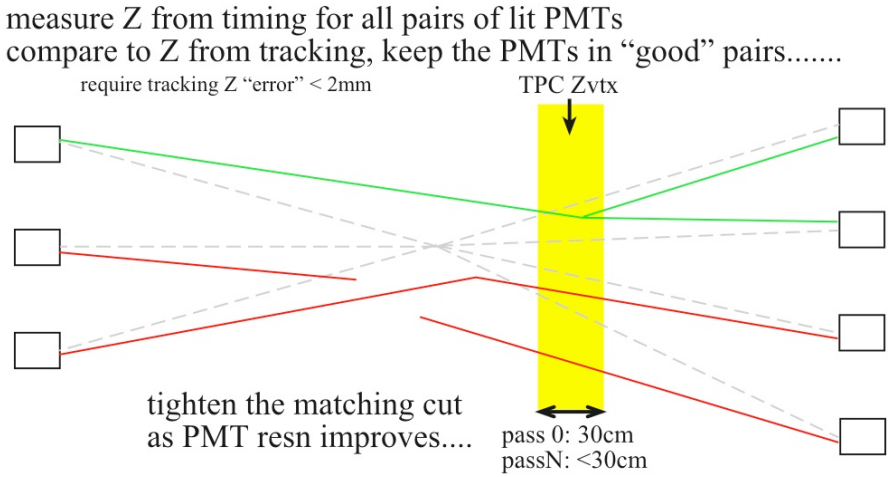
- 200GeV preliminary results based on recent calibration performed on subset of fast-offline data (days 132-152)
- calibration procedure is sensitive to out-of-time "*outlier*" hits

upVPD Calibration (cont'd)

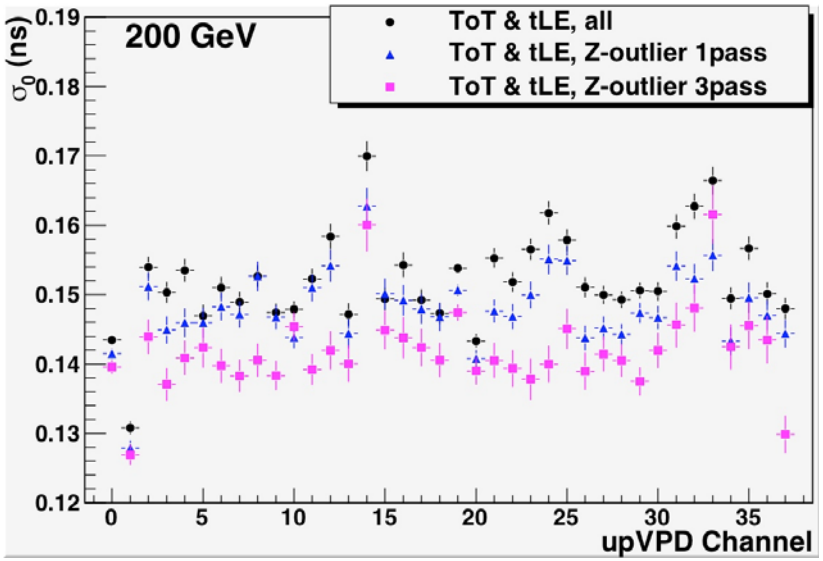
Bill Llope

Alternative approach in upVPD calibration

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



Promising first results:



Resolution per upVPD channel ~140ps

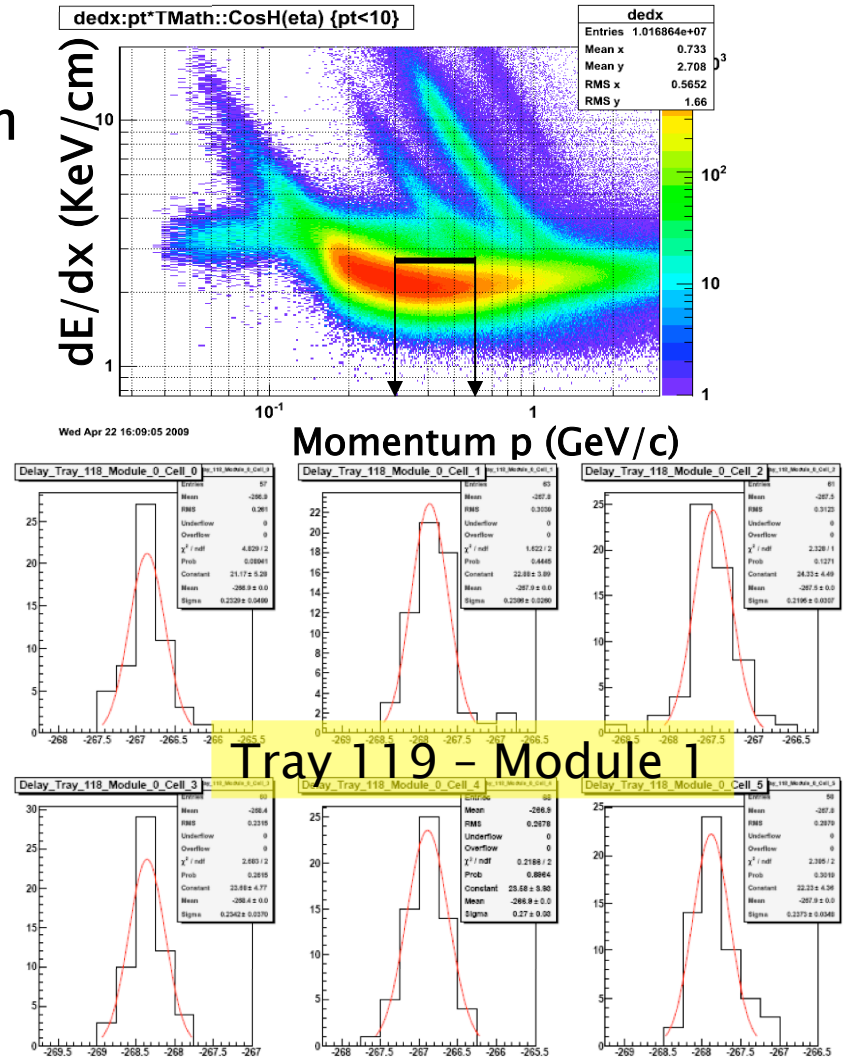
➔ TOF start resolution < 100ps (for 1.AND.1)

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)

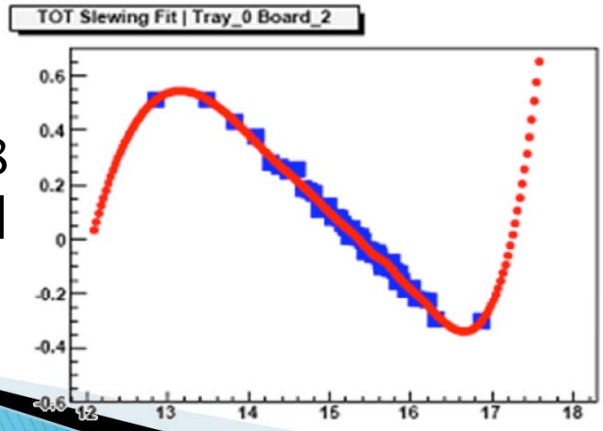


Barrel TOF Calibration (cont'd)

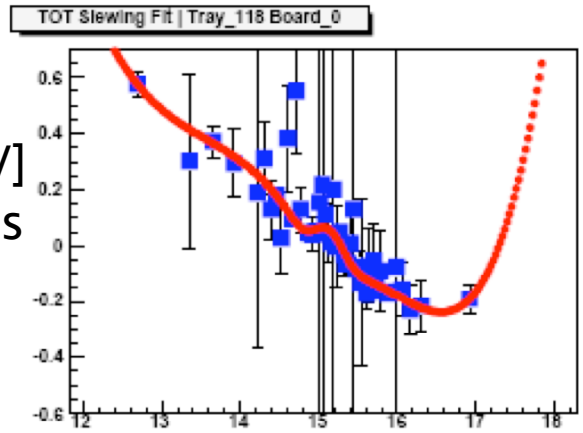
Slewing Correction

- 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]

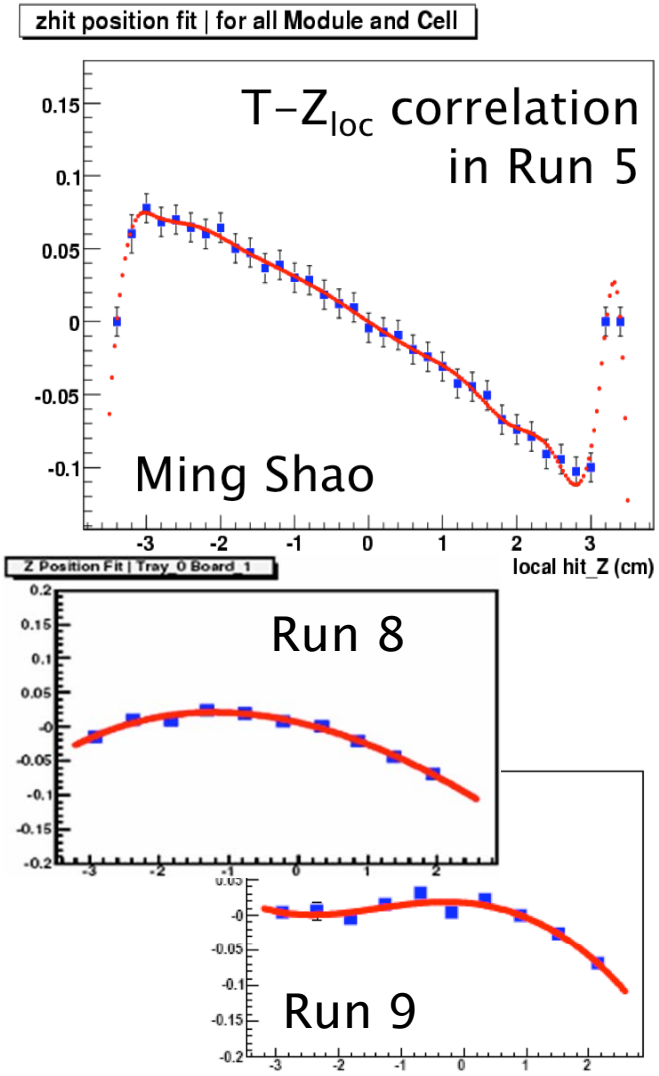


Run-9 [500GeV]
3M events

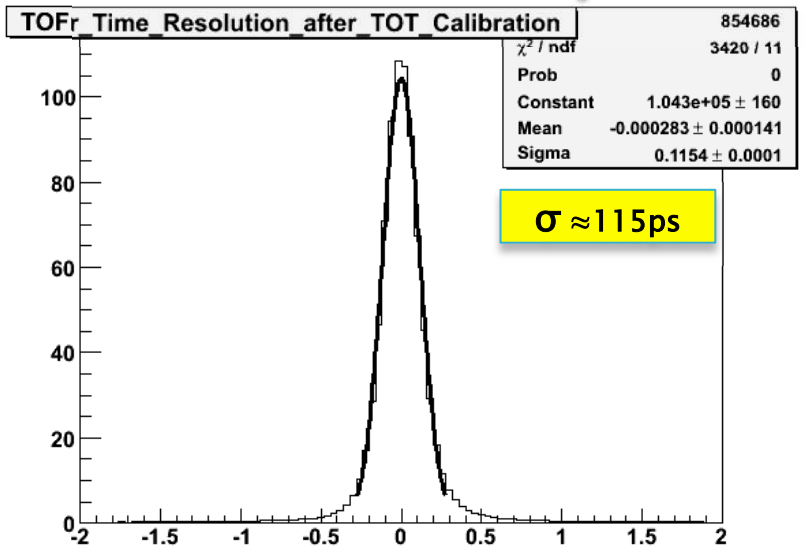


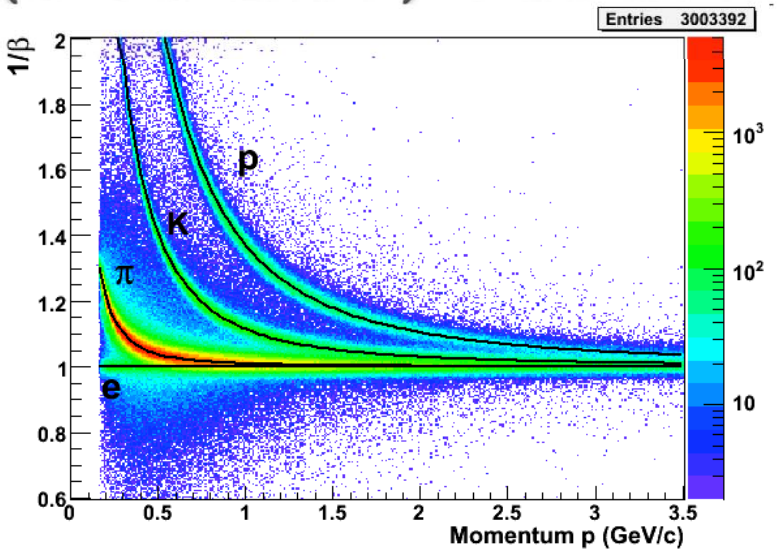
Barrel TOF Calibration (cont'd)

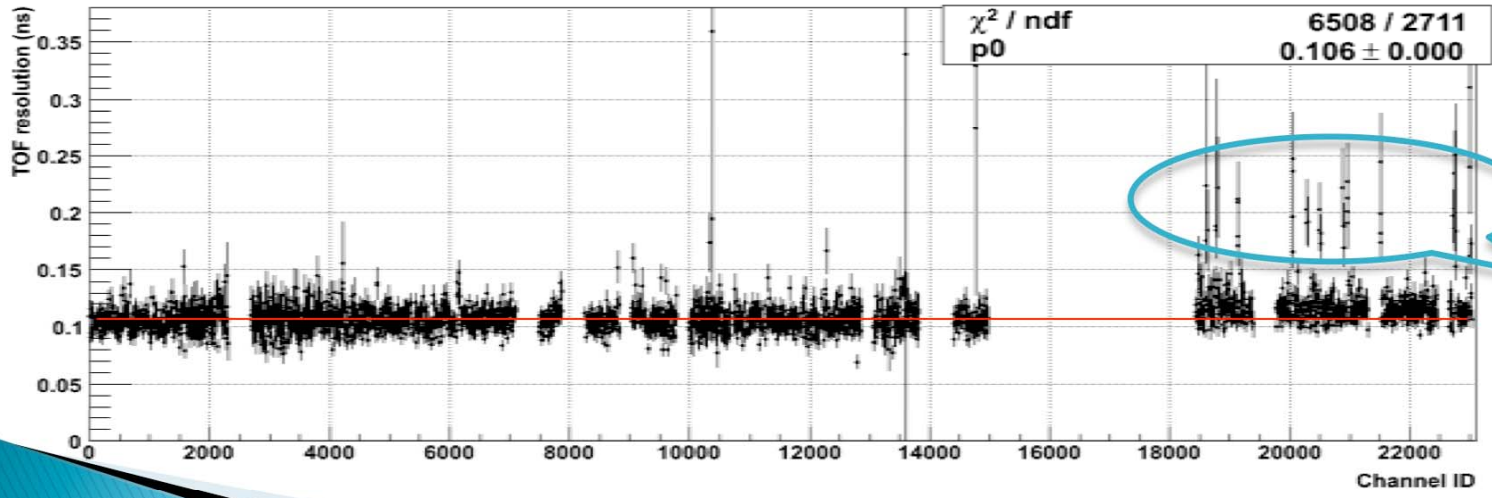
- Local Z-hit position correction
  - Expect a Z_{hit} dependence as signal propagation on the pick-up pads can be 40-50ps/cm
  - No strong dependence observed in Run 8 and 9; not yet understood.
- Corrections are available for Run 9 p+p
  - 500GeV: ready for database, applied by StBTofCalibMaker
  -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



Preliminary Run 9 (500GeV) results



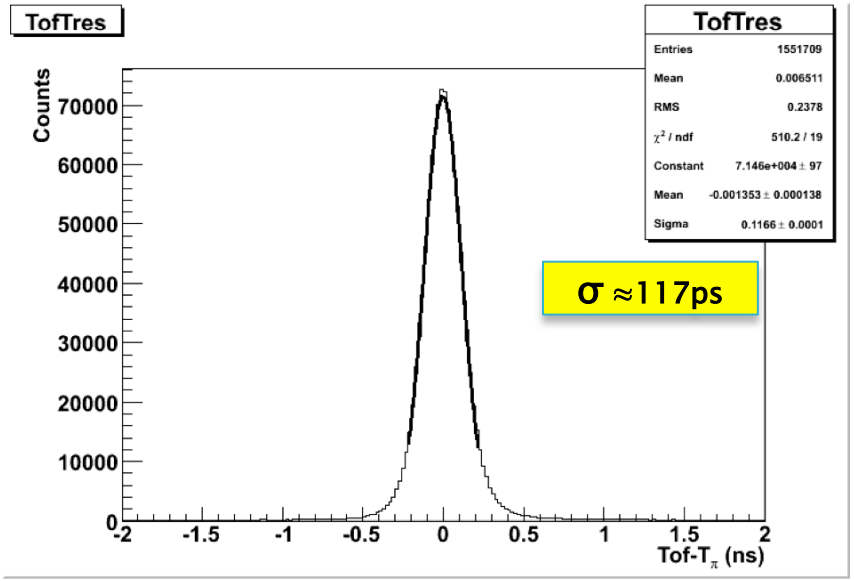


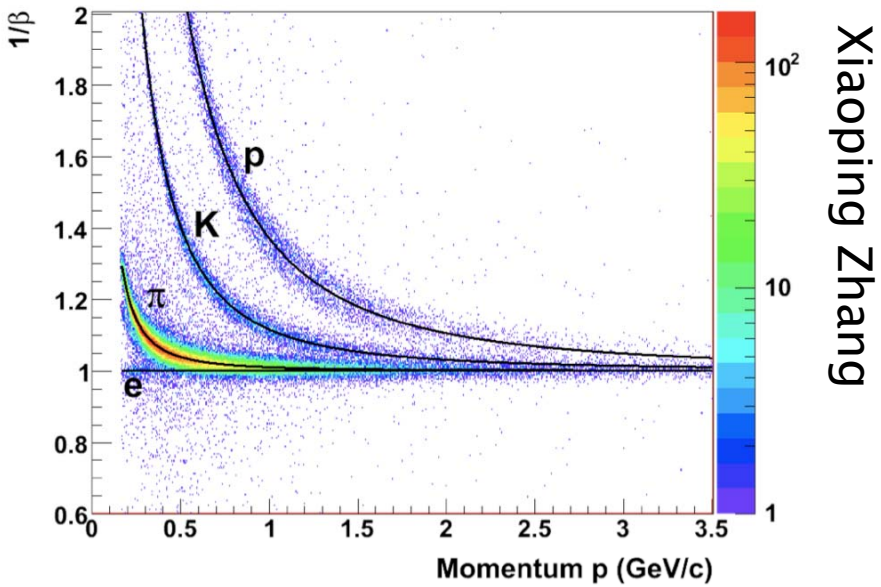


ToT fit failures

Zebo Tang

Preliminary Run 9 (200GeV) results





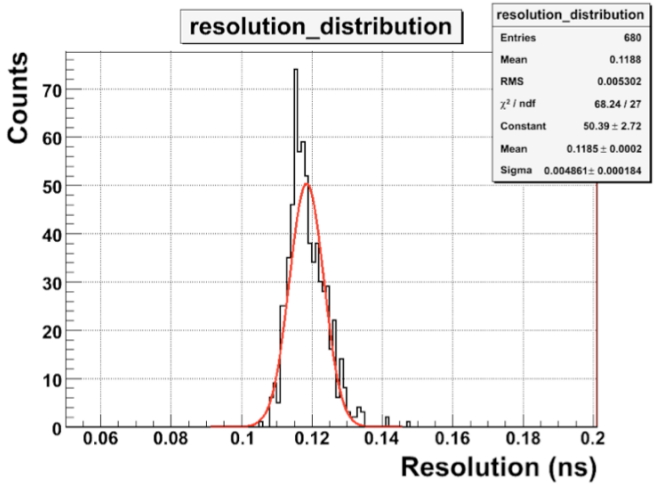
Xiaoping Zhang

- 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)

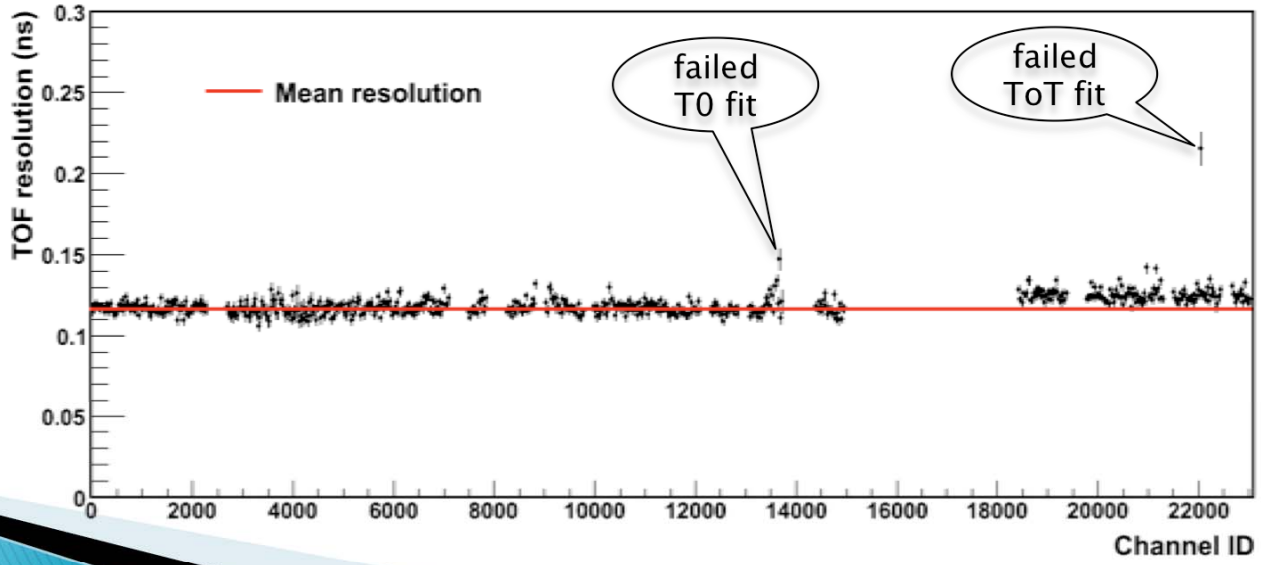
- time resolution distribution

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



- 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*

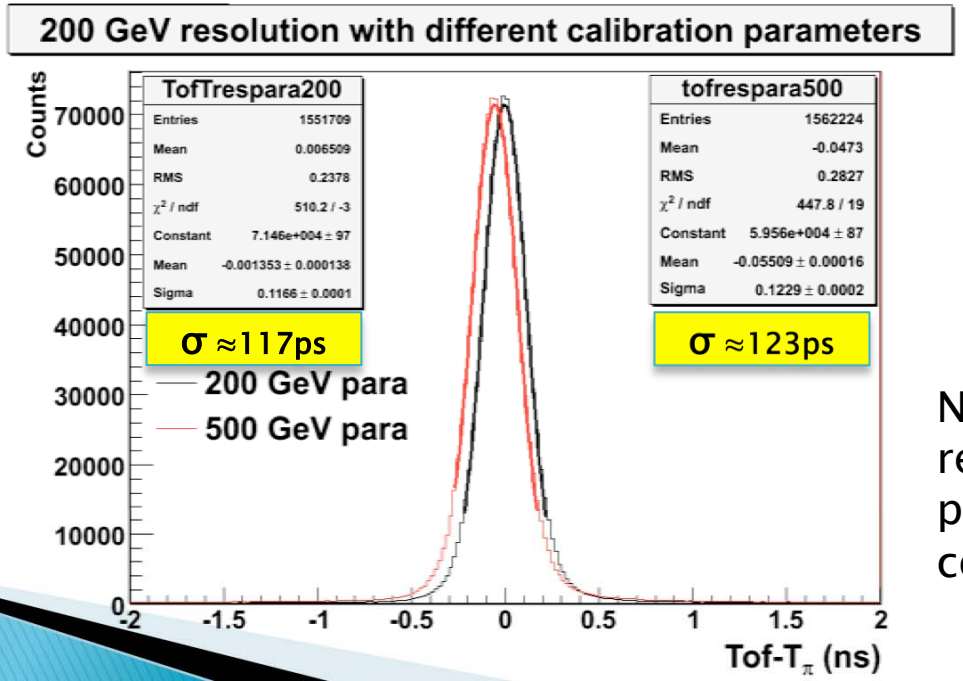
Calibration Requirements

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

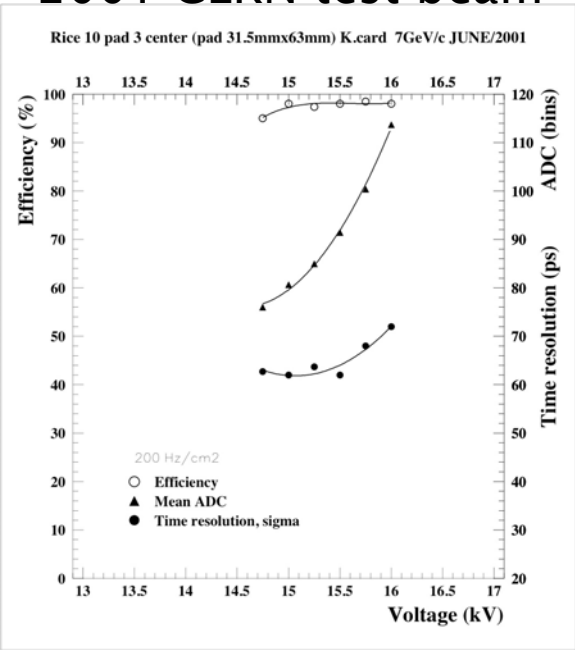


Note that subtle differences remain, making these parameter sets not completely compatible.

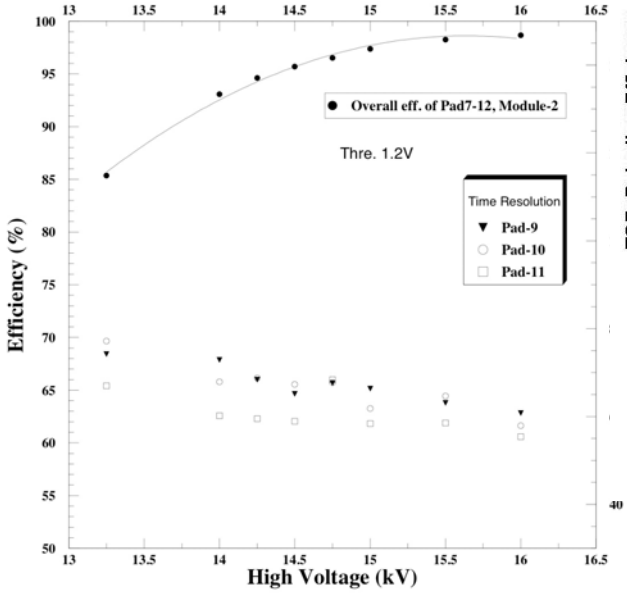
TOF Efficiency

- Efficiencies in Test Beams and STAR

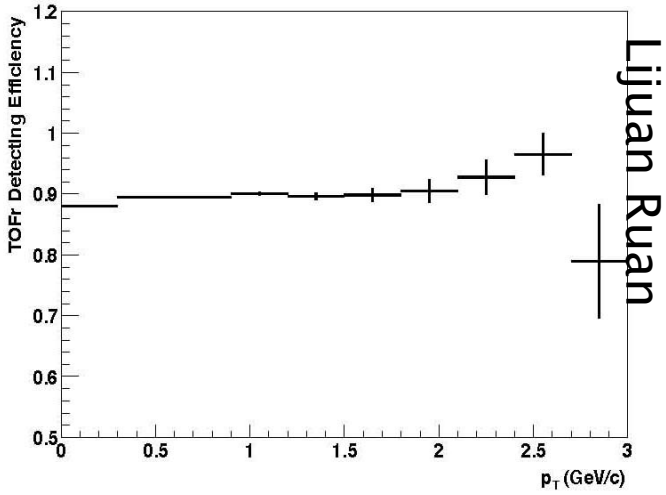
2001 CERN test beam



2003 AGS test beam

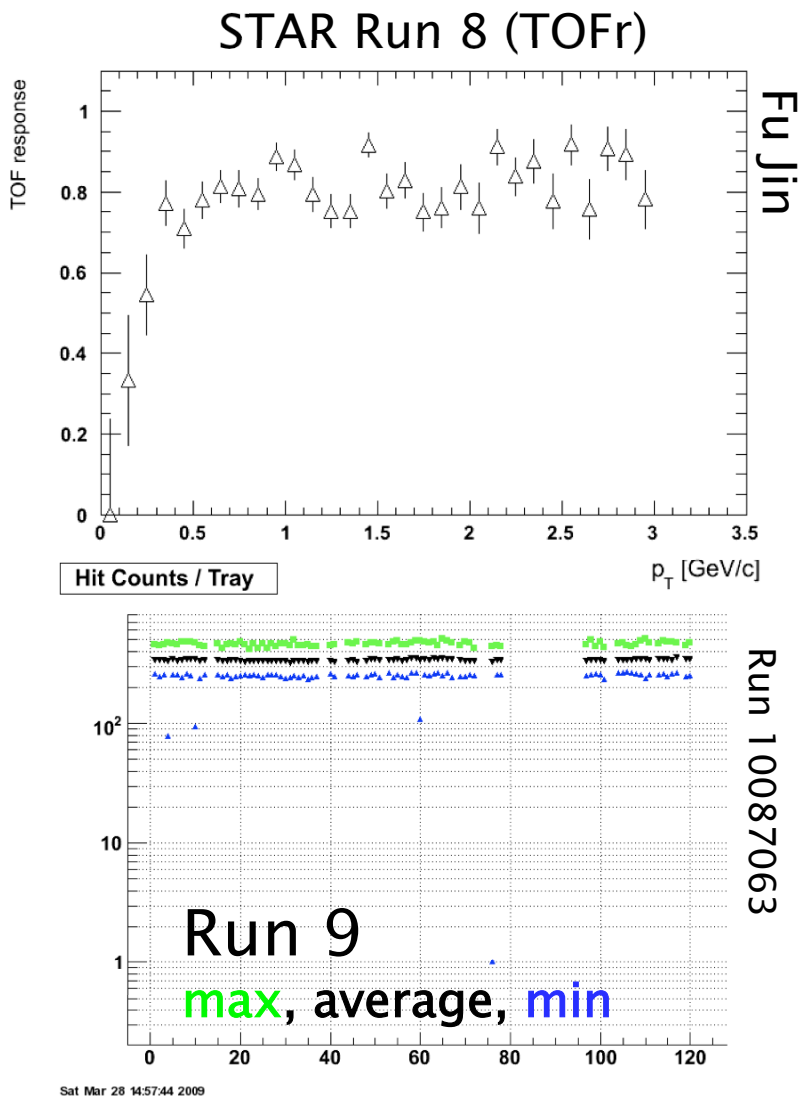


STAR Run 3 (TOFr)



TOF Efficiency (cont'd)

- Run 8
  - significant pile-up complicates analysis
    - ~12% remaining pile-up
- Run 9
  - pile-up issue diffucult to handle in Fast-offline data
  - detailed analysis pending STAR production, incl. EMC and final TPC calibration (~Sept'09)
  - from test beam data we know that good time resolutions mean high efficiencies
  - observed hit patterns in Run9 are constant



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.