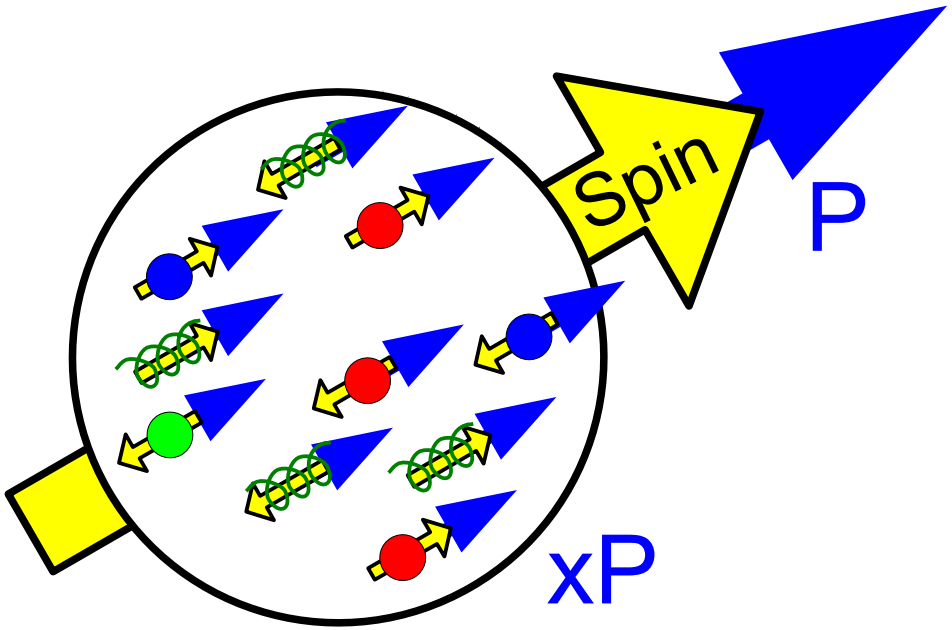
Prospects of the Forward W Measurement in Polarized pp Collisions at the RHIC-PHENIX Experiment

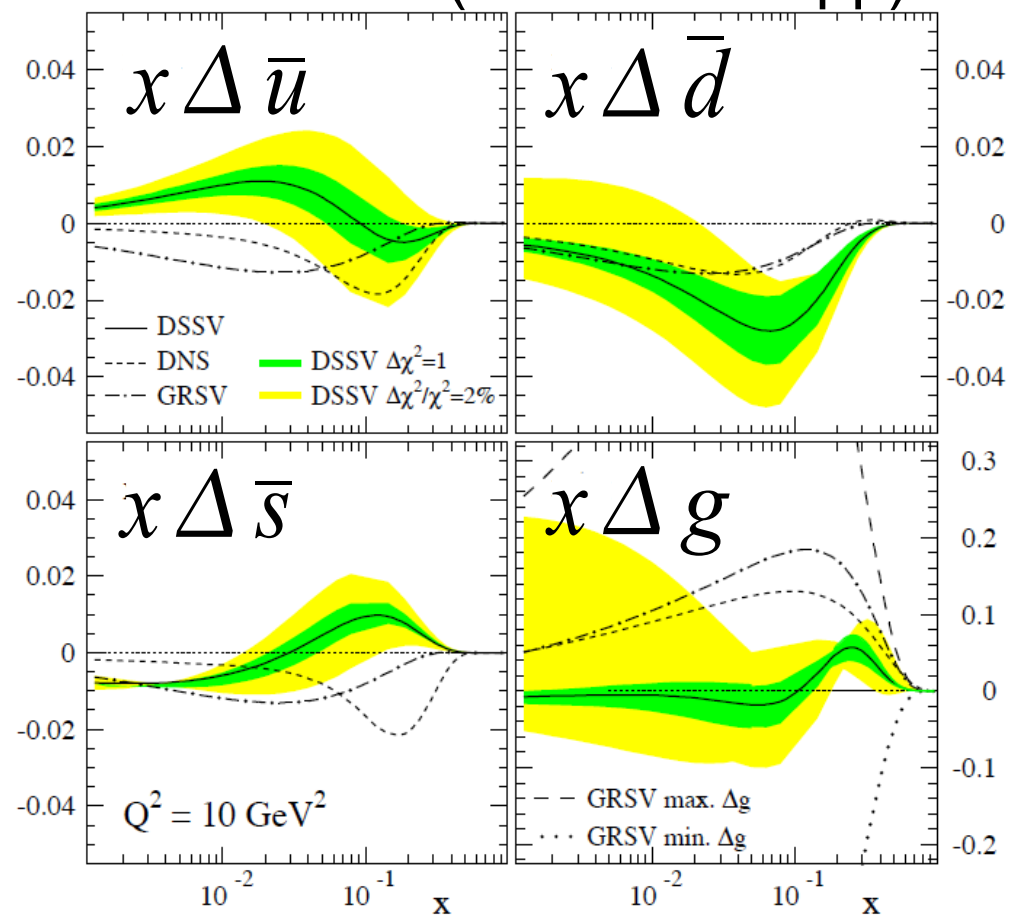
25 July 2010
The Physics of W and Z Bosons
RIKEN
Fukao, Yoshinori

Proton Spin Structure



Spin of parton is parallel or anti-parallel to proton?

DSSV2008 (DIS+SIDIS+pp)



$$\frac{1}{2}=\frac{1}{2}\Delta\Sigma+\Delta G+L$$

ΔQ_v : Well known

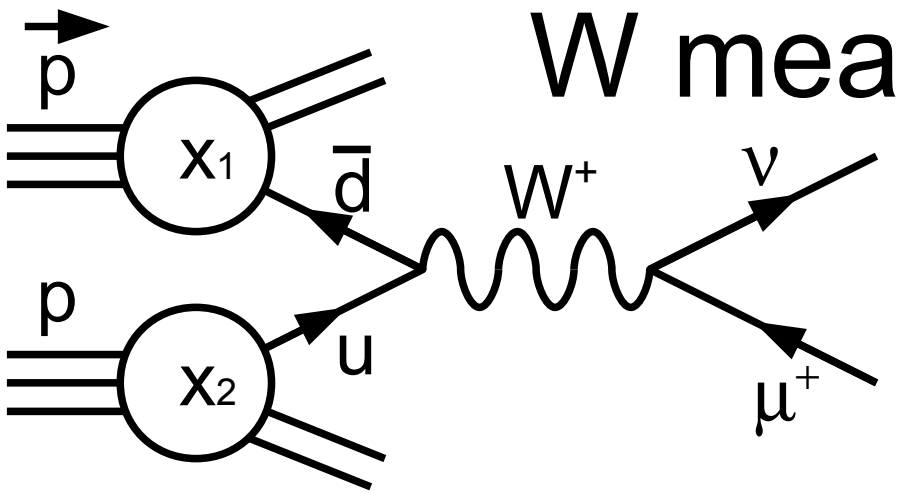
ΔG : Being revealed

$\Delta\bar{Q}$: **Less well-known**

L : Unknown

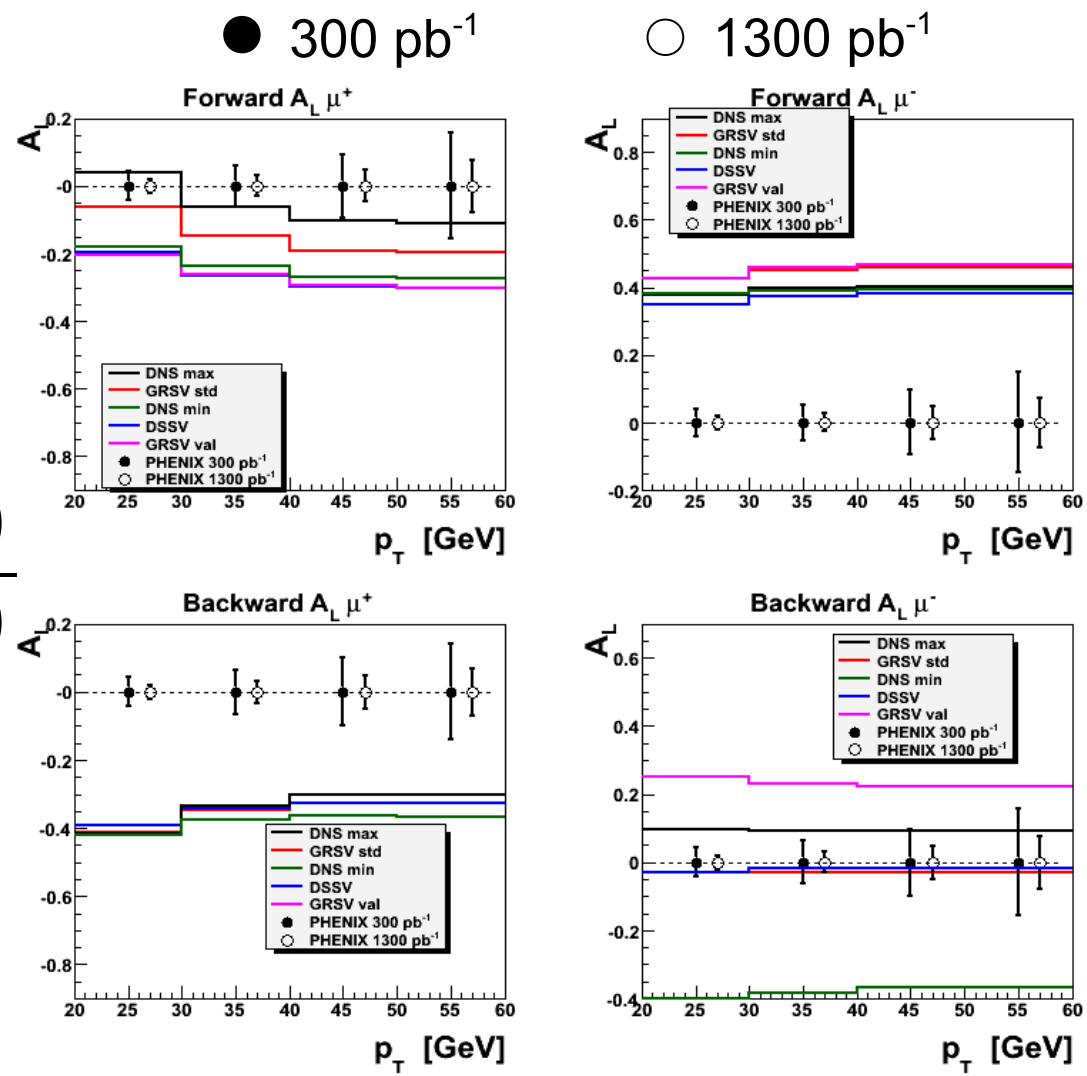
This talk focuses on sea quark, in particular about $\bar{u}$ $\bar{d}$ flavor separation by W measurement.

Sea Quark Polarization by W measurement



$$A_L^{W^+} = \frac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-}$$

$$\sim \frac{\Delta u(x_1)\bar{d}(x_2) - \Delta \bar{d}(x_1) u(x_2)}{u(x_1)\bar{d}(x_2) + \bar{d}(x_1) u(x_2)}$$

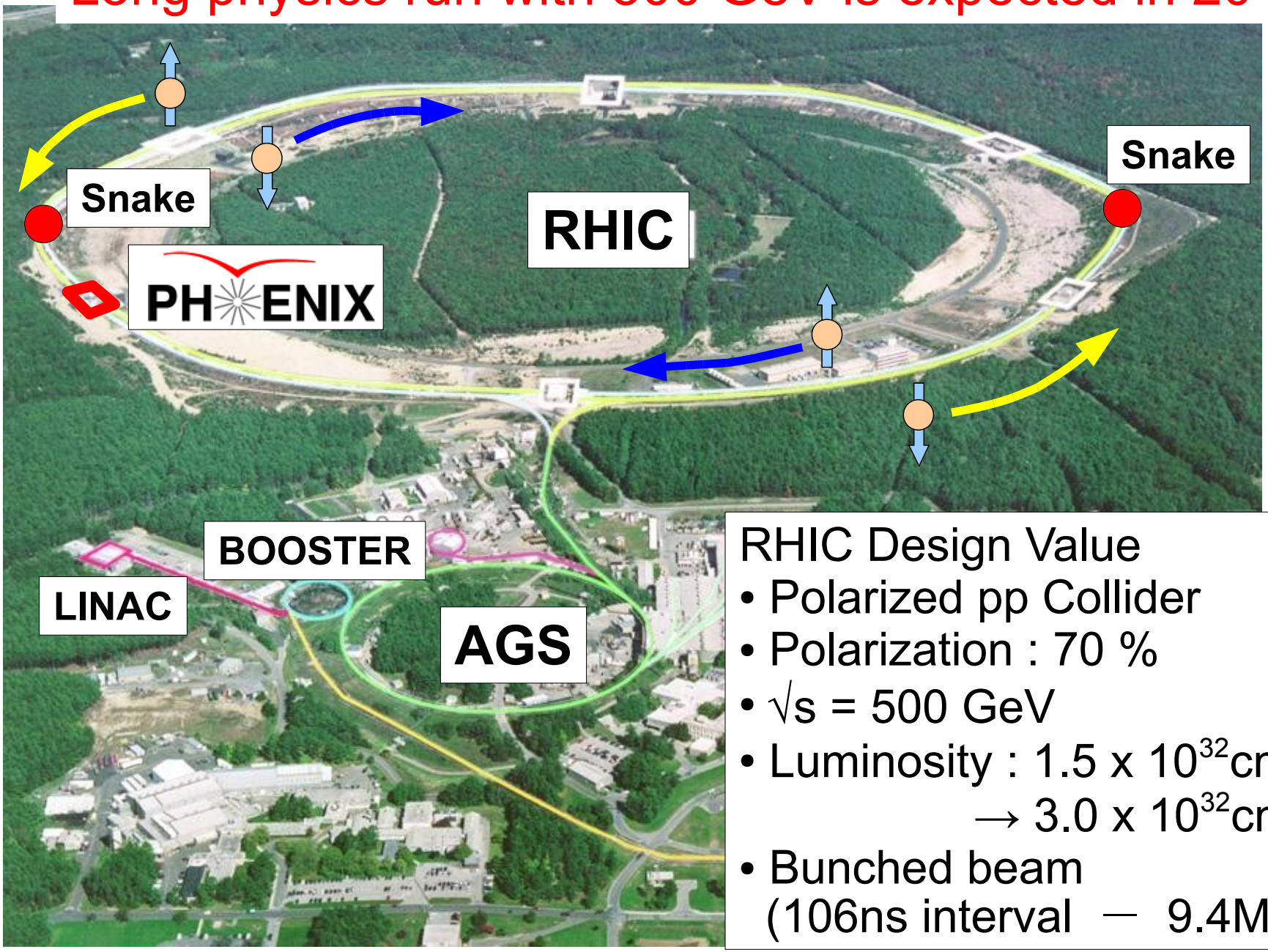


Feature of pp->W at RHIC

- $u+\bar{d} \rightarrow W^+$, $\bar{u}+d \rightarrow W^-$
- q : helicity–, $\bar{q}$: helicity+
- No uncertainty from fragmentation function.
- But, low statistics

RHIC

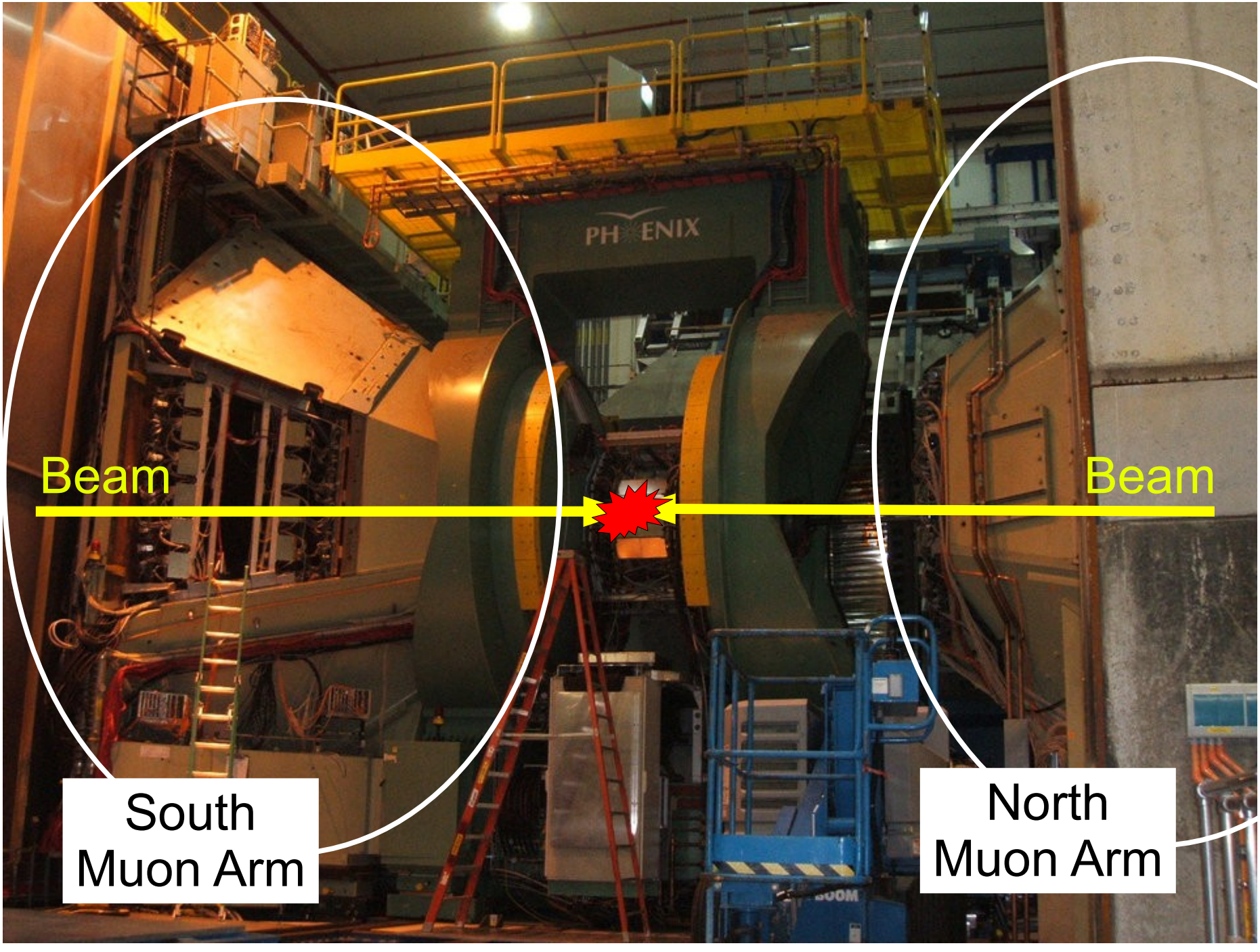
Long physics run with 500 GeV is expected in 2011



RHIC Design Value

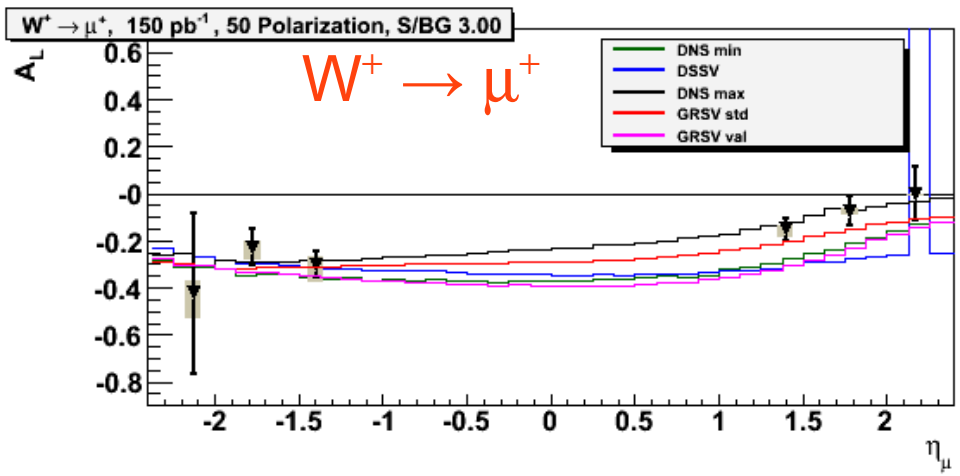
- Polarized pp Collider
- Polarization : 70 %
- $\sqrt{s}$ = 500 GeV
- Luminosity : 1.5 x $10^{32}cm^{-2}s^{-1}$
  $\rightarrow$ 3.0 x $10^{32}cm^{-2}s^{-1}$
- Bunched beam
  (106ns interval — 9.4MHz)

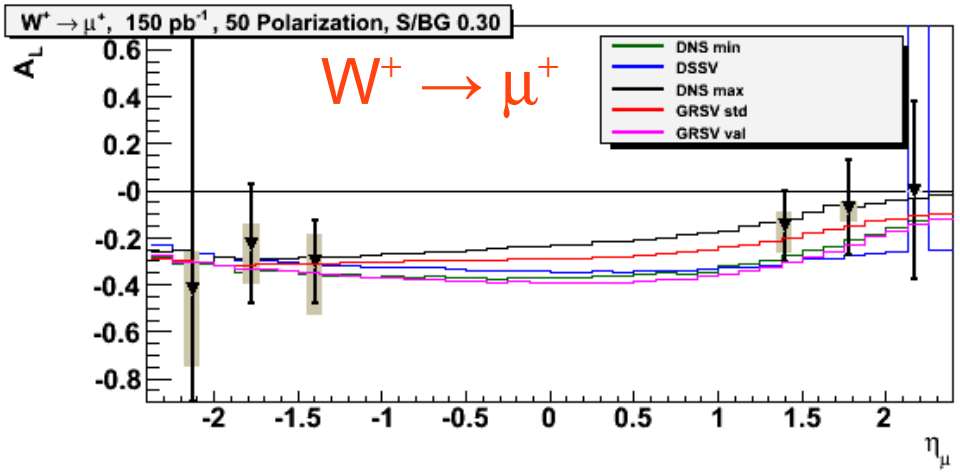
PHENIX detector (Muon Arm)

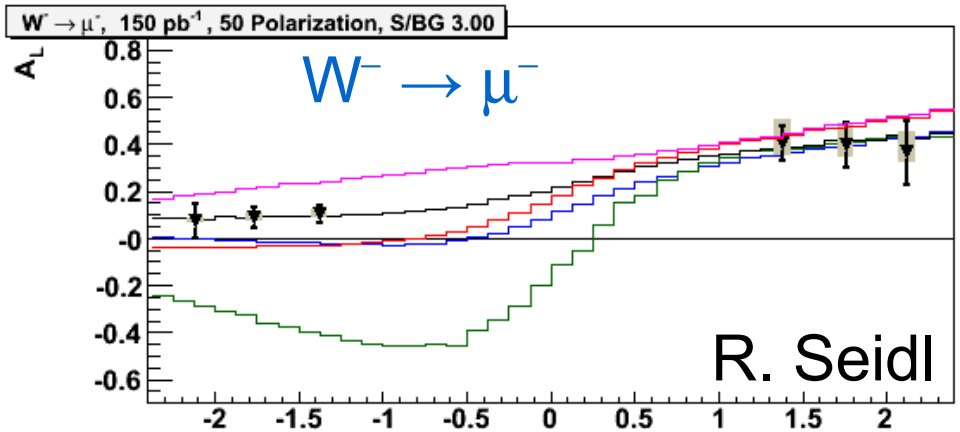


Expectation of A_L in $W \rightarrow \mu$
–– Short Term Goal ––

Run 2011+2012 Projection (150 pb^{-1}, 50% pol.)

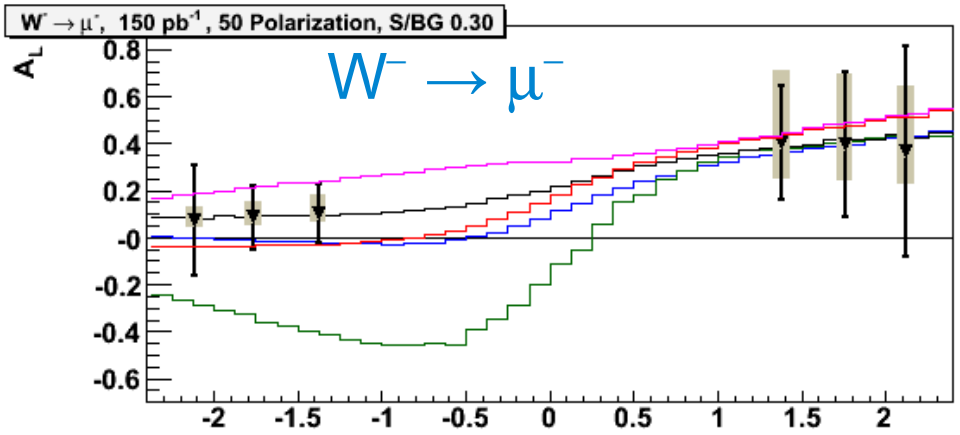






η_μ (muon pseudorapidity)

S/B = 3.0 (optimistic)



η_μ (muon pseudorapidity)

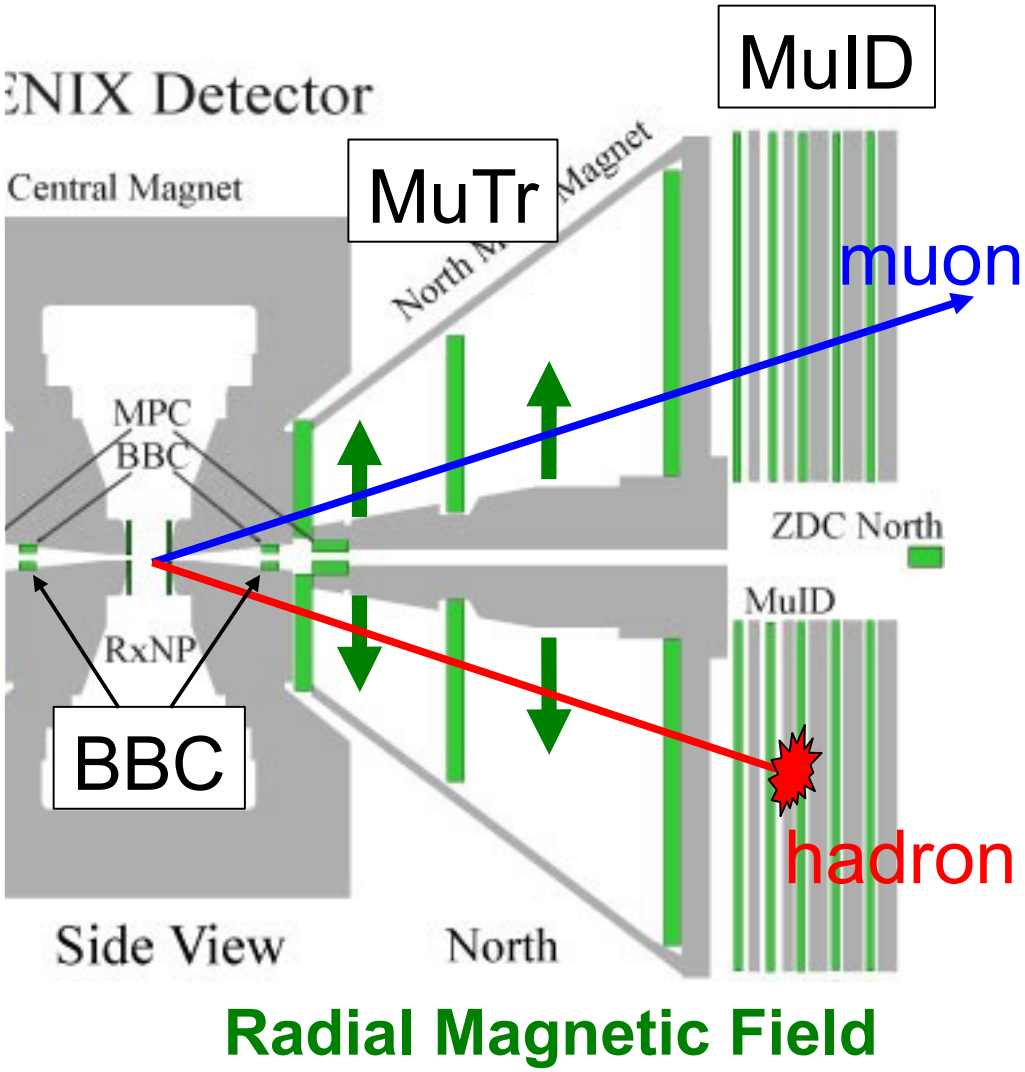
S/B = 0.3 (conservative)

Current Muon Arm

Beam-Beam Counter (BBC)
- Minimum Bias Trigger
- Look at ~30 mb
- Decide trigger timing.

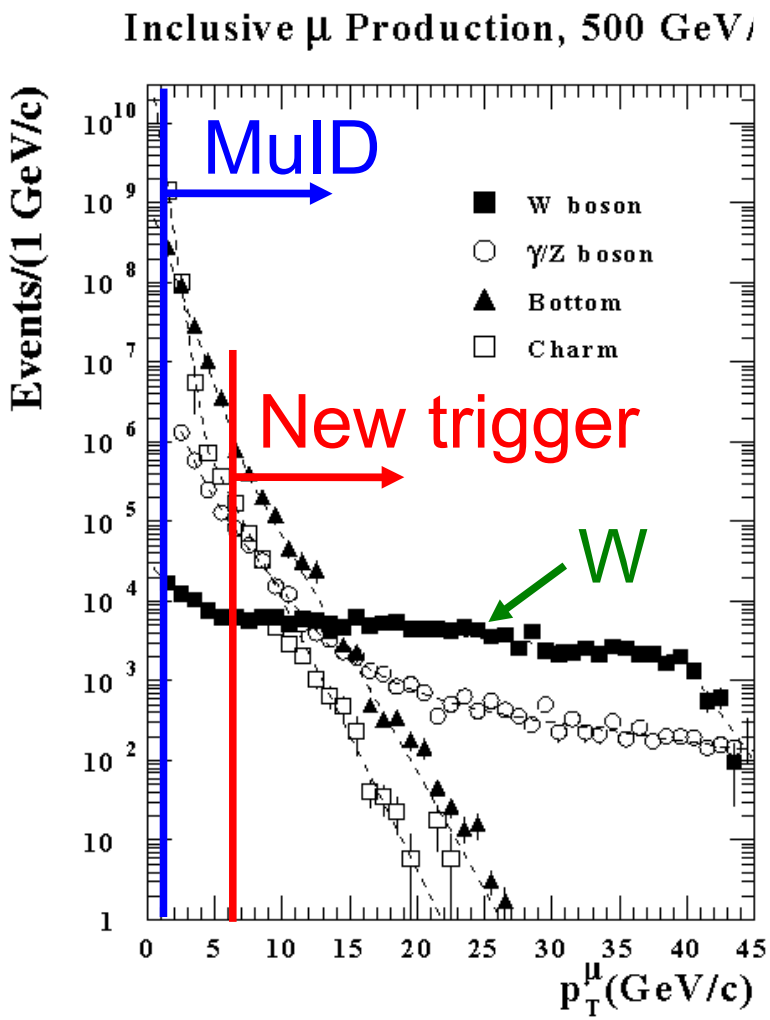
Muon Tracking Chamber (MuTr)
- 3 stations of Cathode Strip Chambers
- 3 gaps + 3 gaps + 2 gaps
- Each gap has non-stereo plane, stereo-plane, and anode plane

Muon Identifier (MuID)
- 5 layers of Iarocci tubes in x and y directions
- 80 cm of steel plate absorber (total)
- **Provides trigger p_{muon} > 1.5 GeV/c**



Trigger threshold by MuID is too low to collect W events.
(Rejection Power ~ 100)

Requirement of New W Trigger



Existing MuID trigger (RP~100)

Momentum threshold is too low

↓

New Momentum Sensitive Trigger

Fast online tracking and select straight track

Expected luminosity at the next 2011 run is $1.5 \times 10^{32} cm^{-2} s^{-1}$

~9 MHz pp collision rate

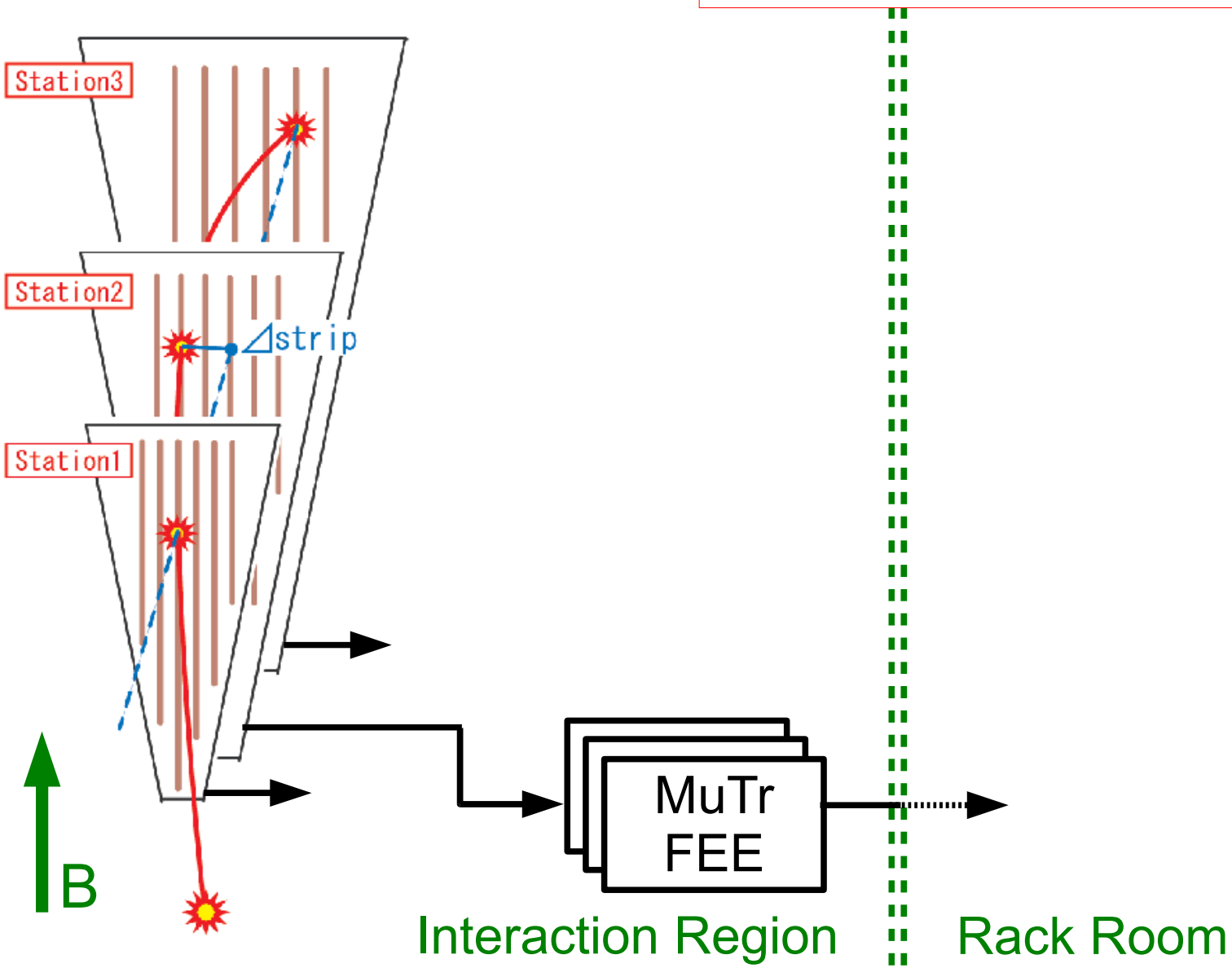
DAQ band width

~2 kHz

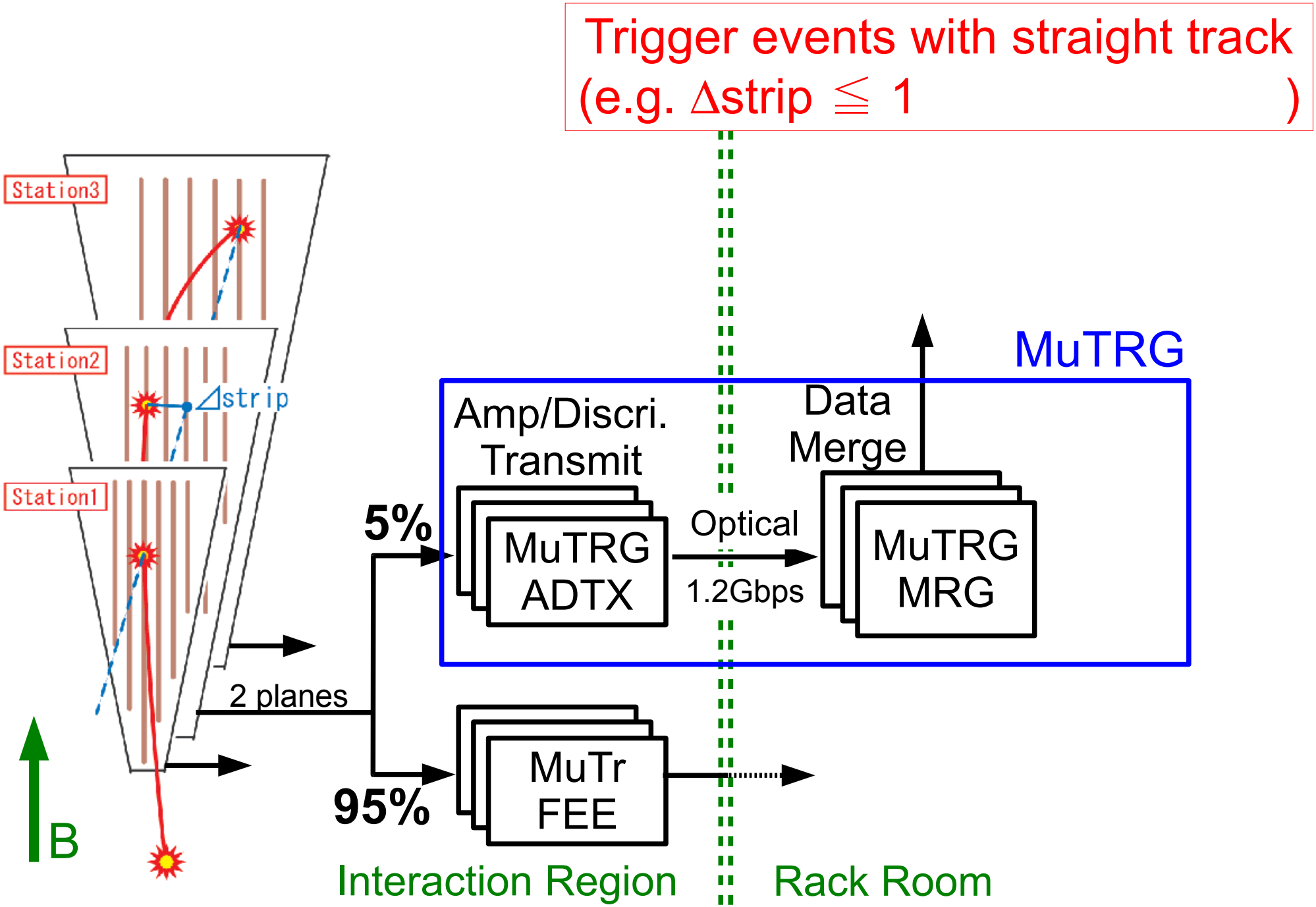
Need **Rejection Power ~ 4500**

W Trigger System

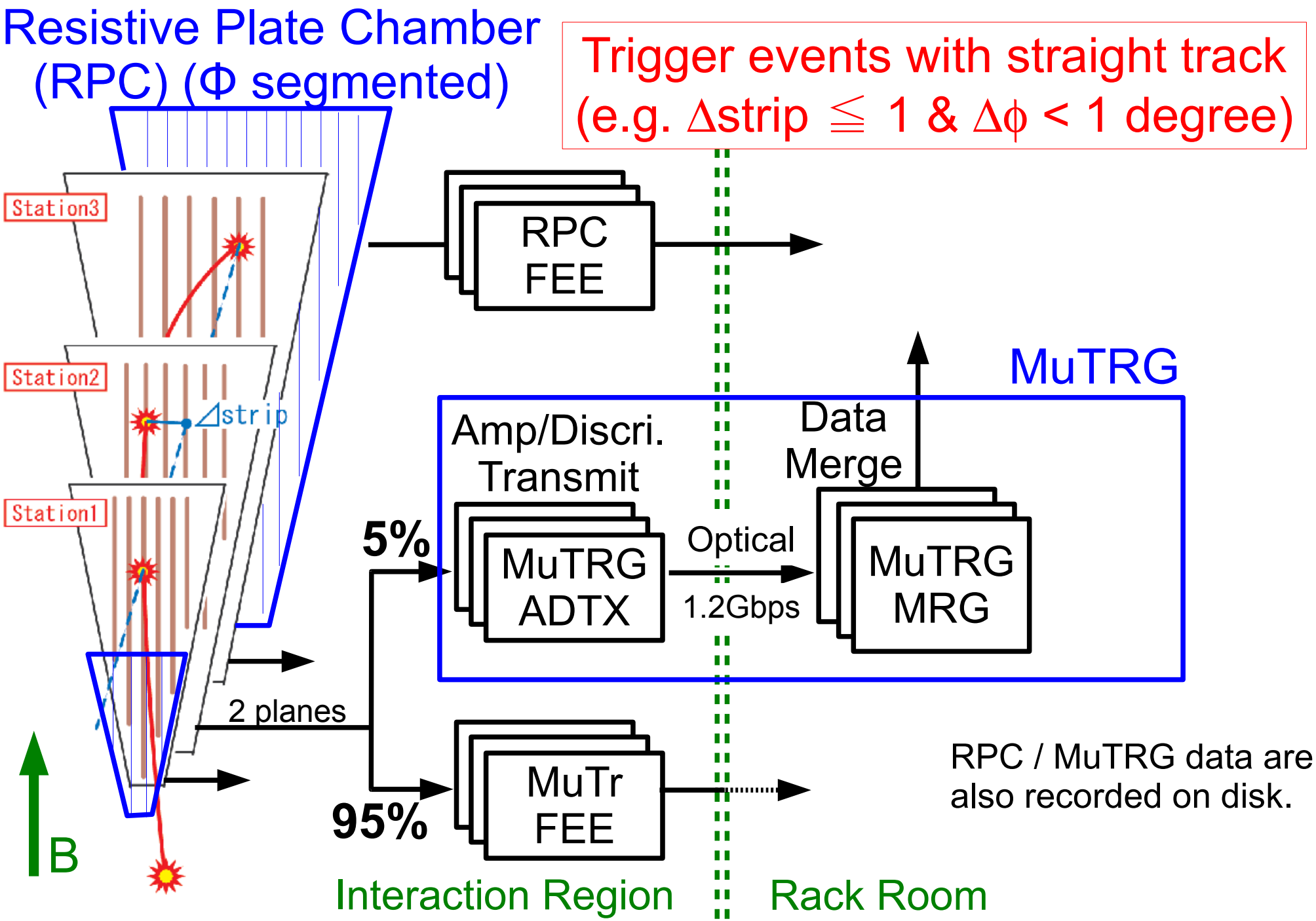
Trigger events with straight track



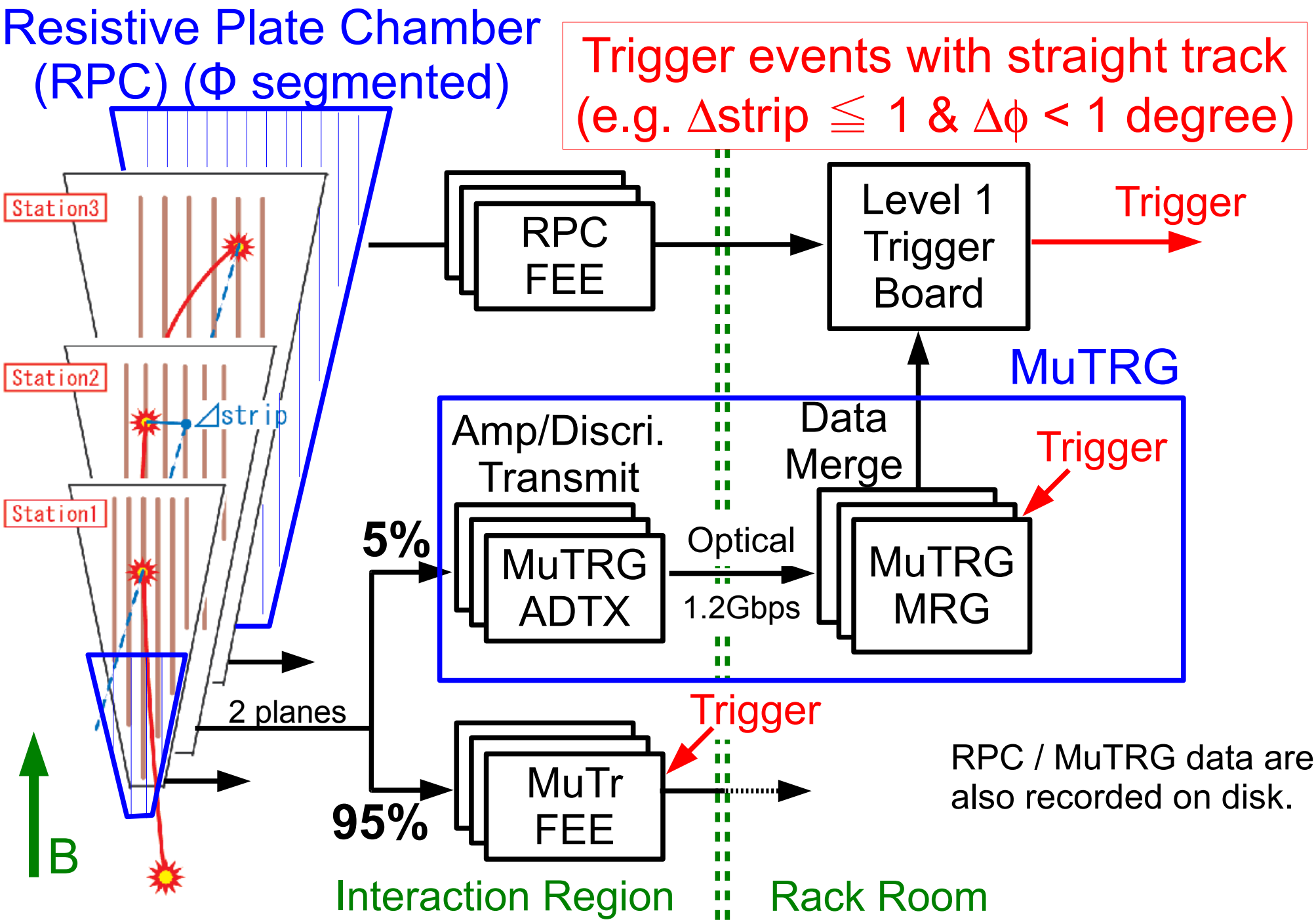
W Trigger System



W Trigger System

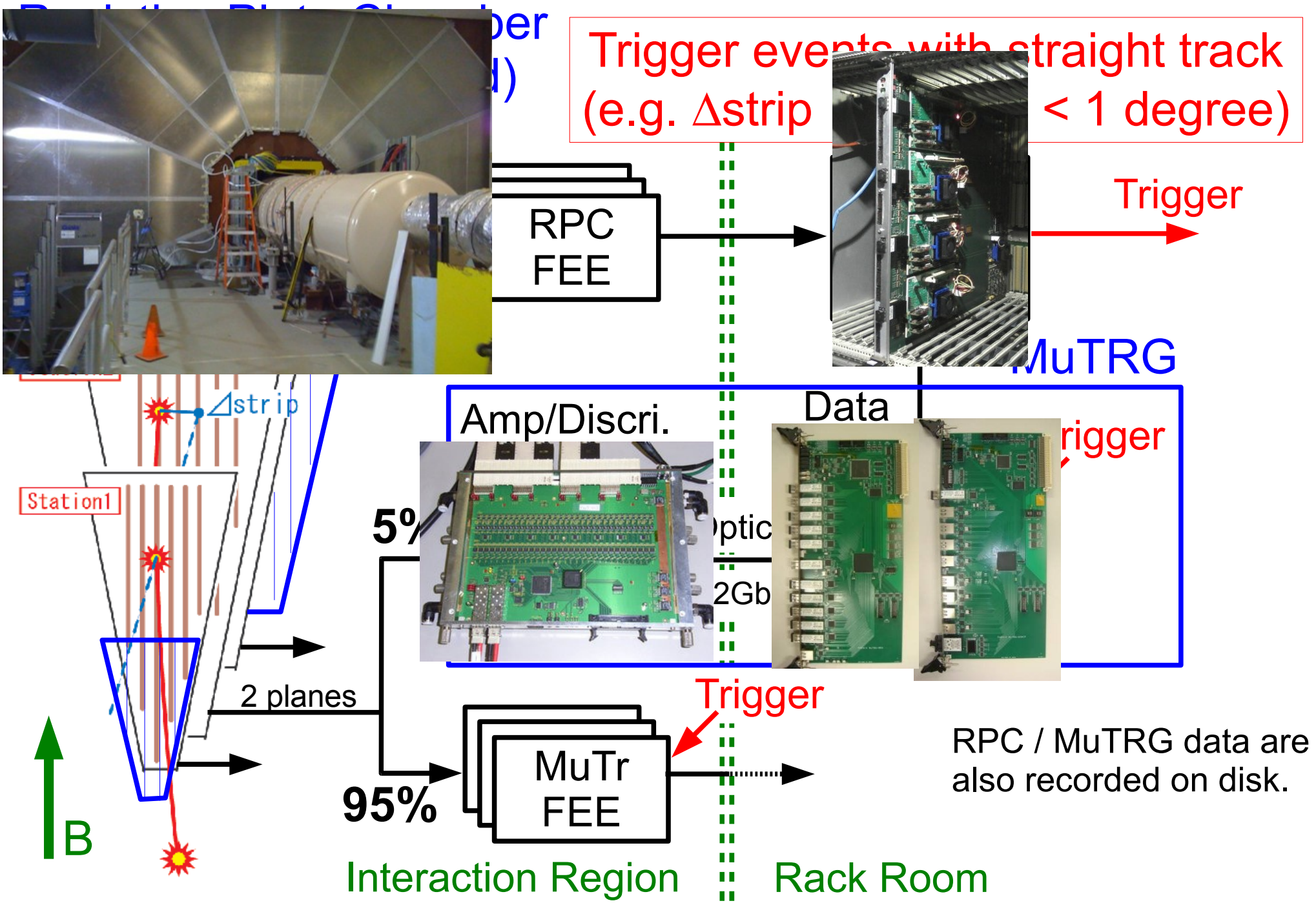


W Trigger System



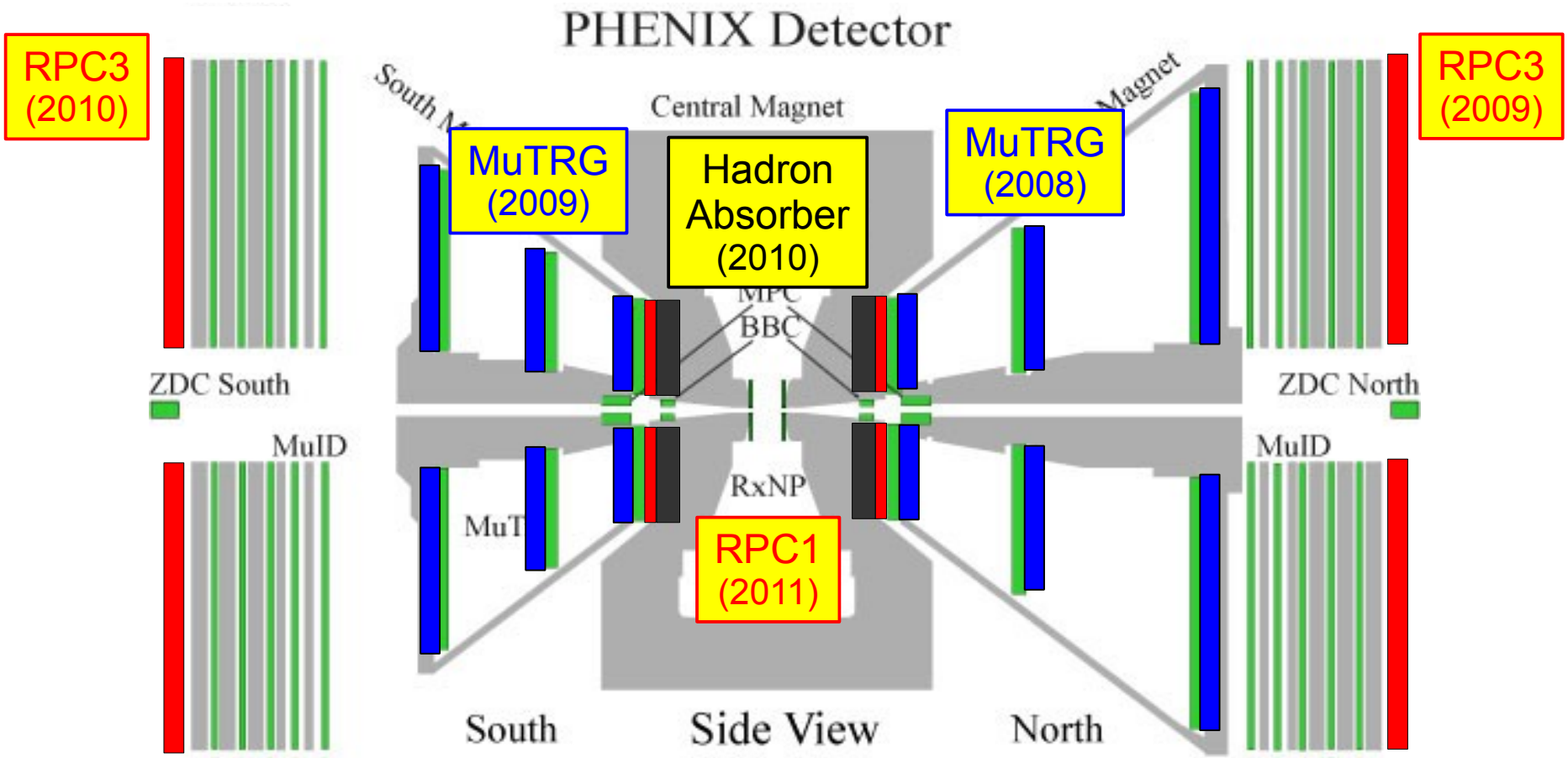
RPC / MuTRG data are also recorded on disk.

W Trigger System



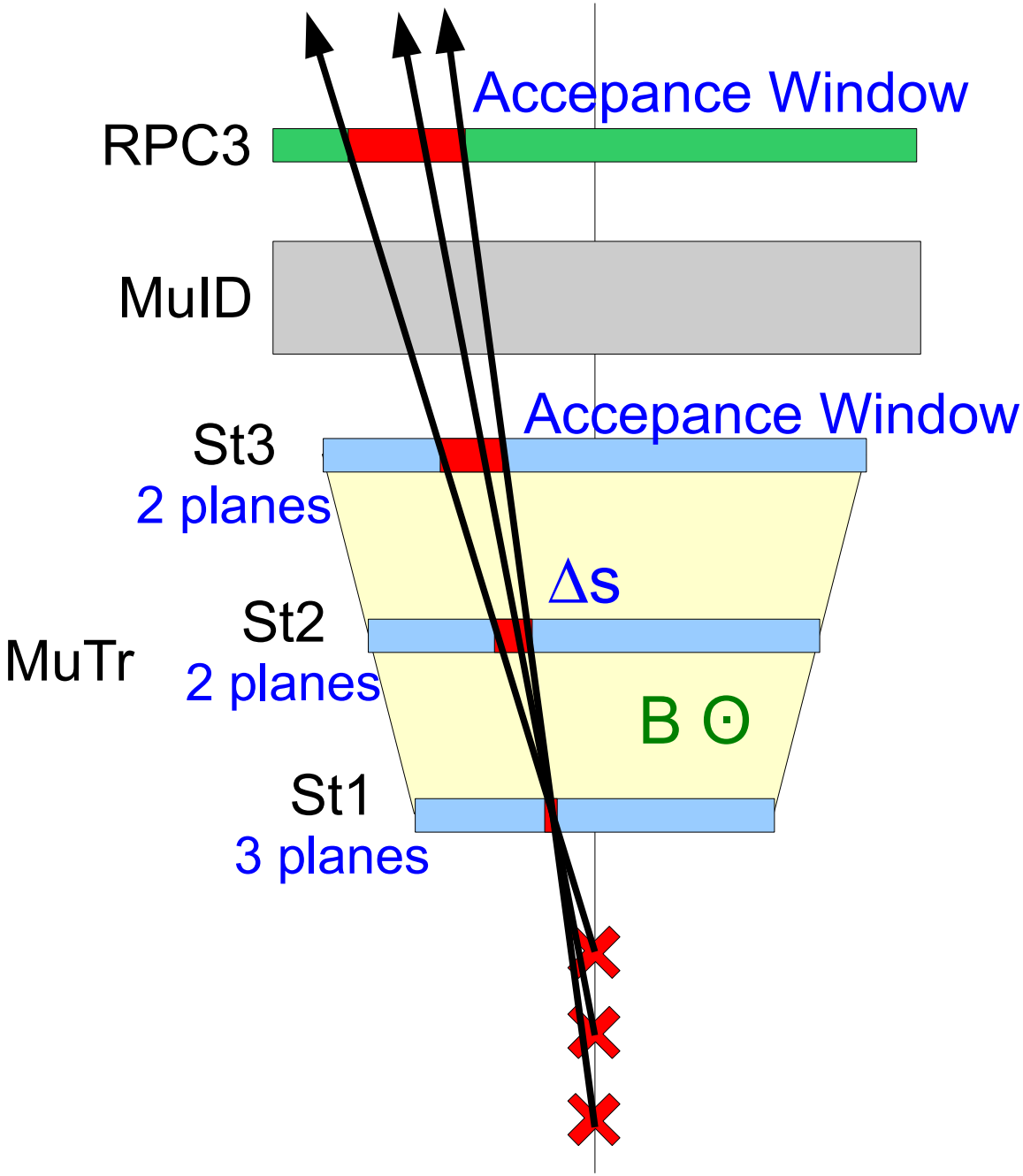
RPC / MuTRG data are also recorded on disk.

Installation of New W Trigger



- MuTRG and RPC3 : Ready for Run 2011.
- RPC1 : Additional trigger rejection, acceptance improvement and tighter timing cut
- Hadron Absorber : Powerful background rejection (partially interfere with RPC1)

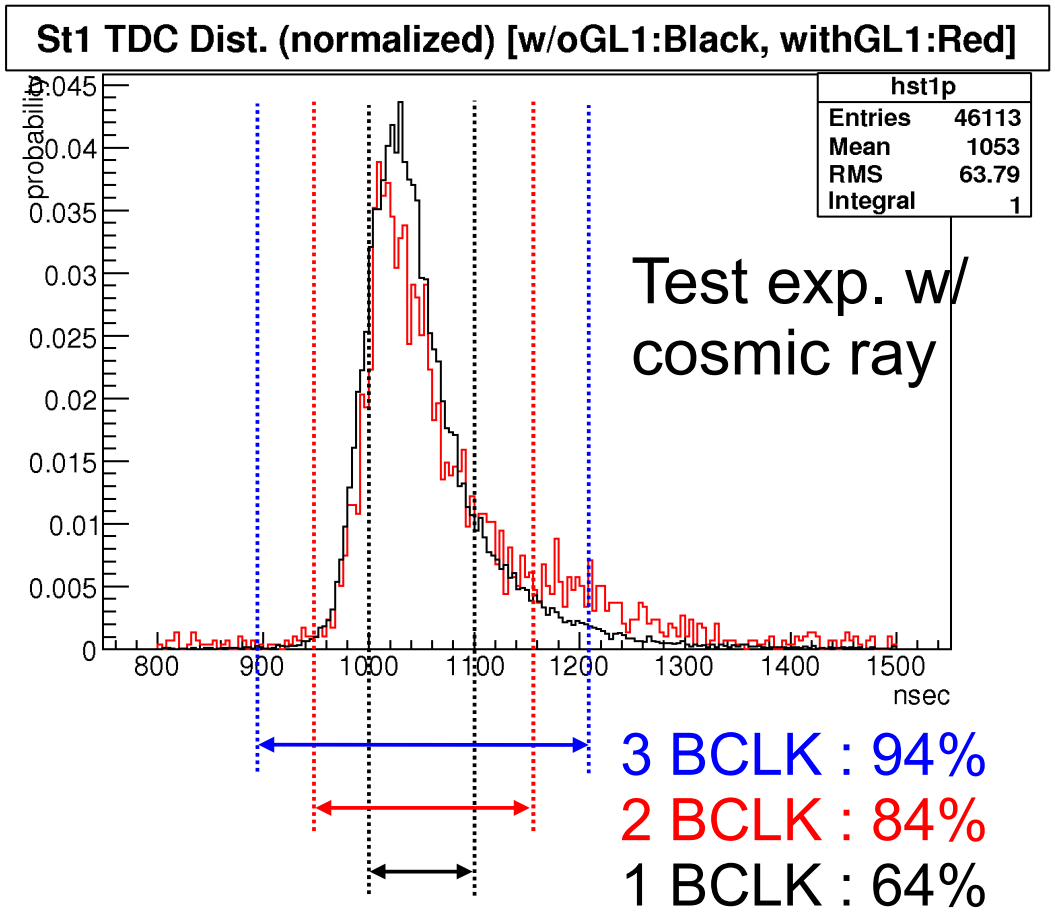
Trigger Algorithm (Run 2011)



Fire events with straight tracks

Optimization Parameter
- OR / AND of planes for each MuTr station.
- Saggita Δs for St2, corresponding to momentum threshold.
- Acceptance Window for St3 and RPC3
- Threshold for MuTRG and RPC
- Timing Cut
- Clustering (succesive hits are merged)

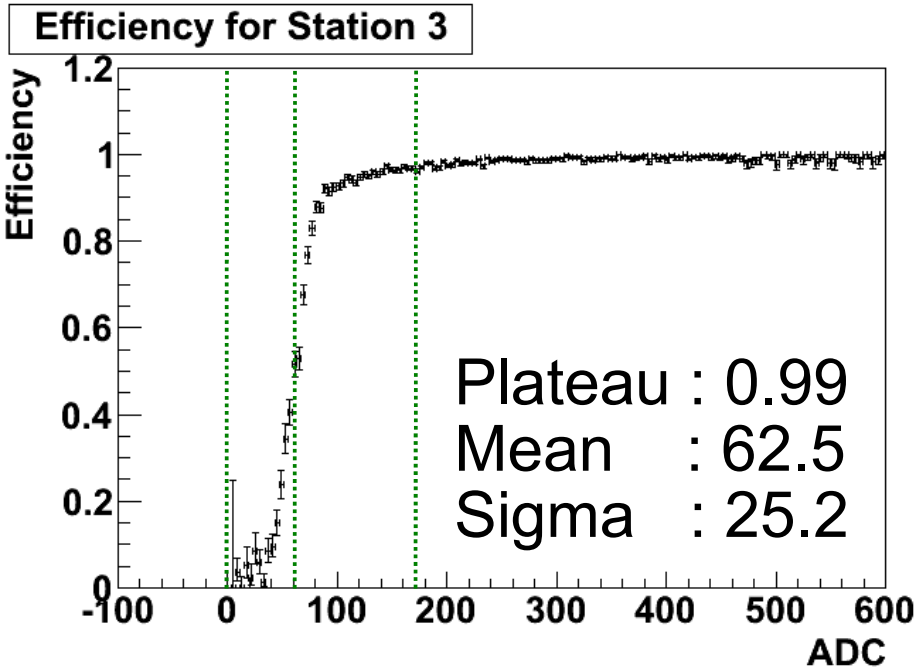
MuTRG Timing Resolution

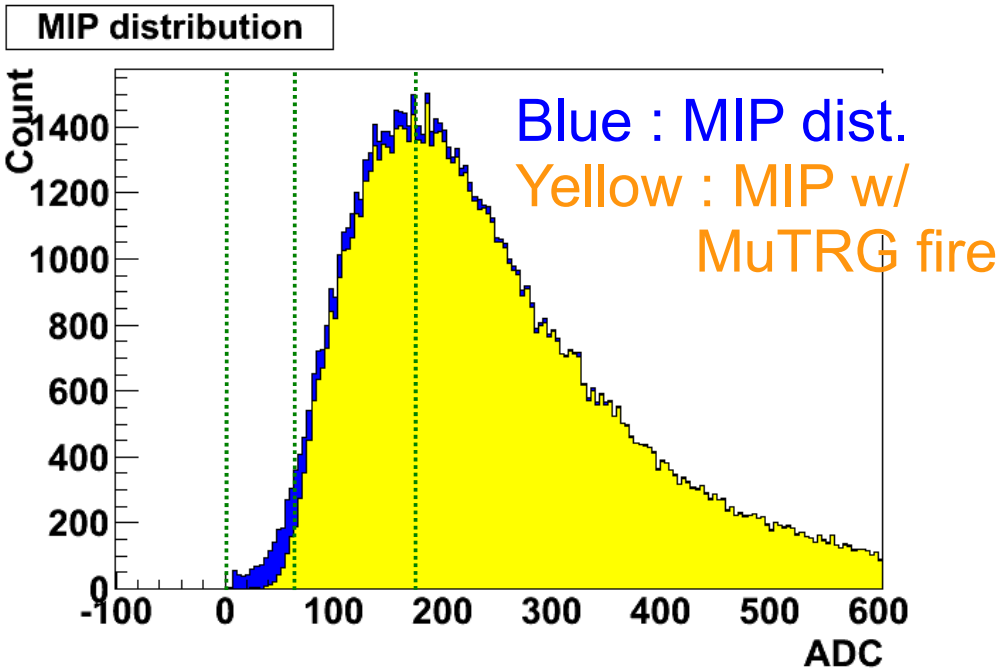


(1 BCLK gate ~ 106 nsec)

- Timing resolution is consistent between cosmic ray data and beam data.
- Efficiency is 94% with 3 BCLK gate. Achieve 99% by taking OR of 2 planes.
- RPC information is necessary to determine trigger timing

Cathode Plane Efficiency of MuTRG





Measured in Run 2009

Threshold : 40mV

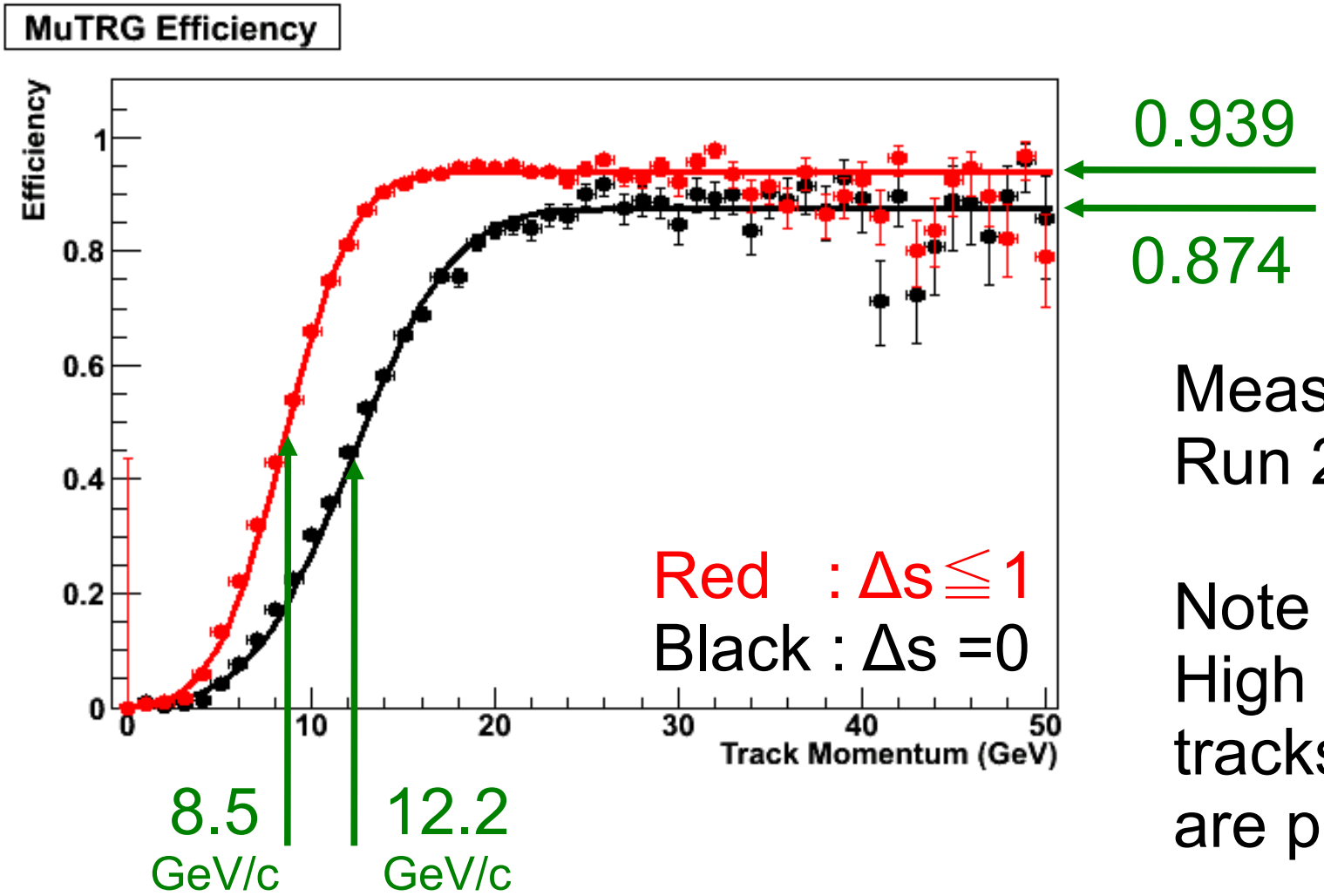
Timing Gate : 3 BCLK
OR of 2 planes
→ Efficiency at
Plateau ~ 99%

Most Probable Value
of MIP ~ 175 ch

Turn on Point ~ 60 ch

Efficiency for MIP is
96% (Yellow / Blue)

MuTRG Efficiency for Track



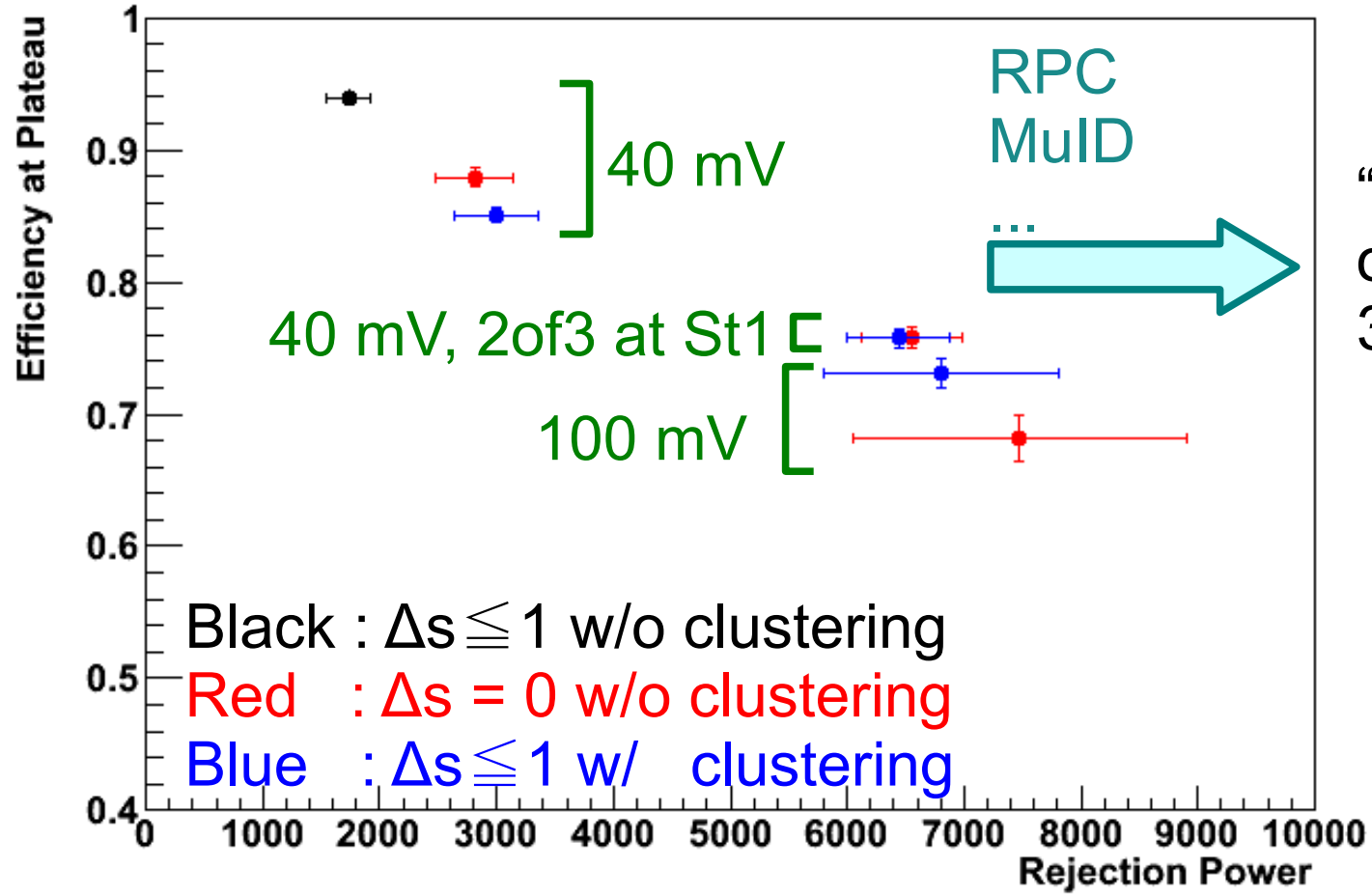
Measured in Run 2009

Note :
High momentum tracks in the plot are probably fake.

- Sufficient efficiency can be achieved in MuTRG
- Turn on point is enough low with Δs=0.
  (12.2 GeV/c in p, ~6 GeV/c in pT)

Rejection Power with MuTRG only
(MuID & BBC & MuTRG)

MuTRG performance at 3 MHz (almost max luminosity at 2009 run)



"2of3" is requirement of 2-plane hits out of 3 planes.

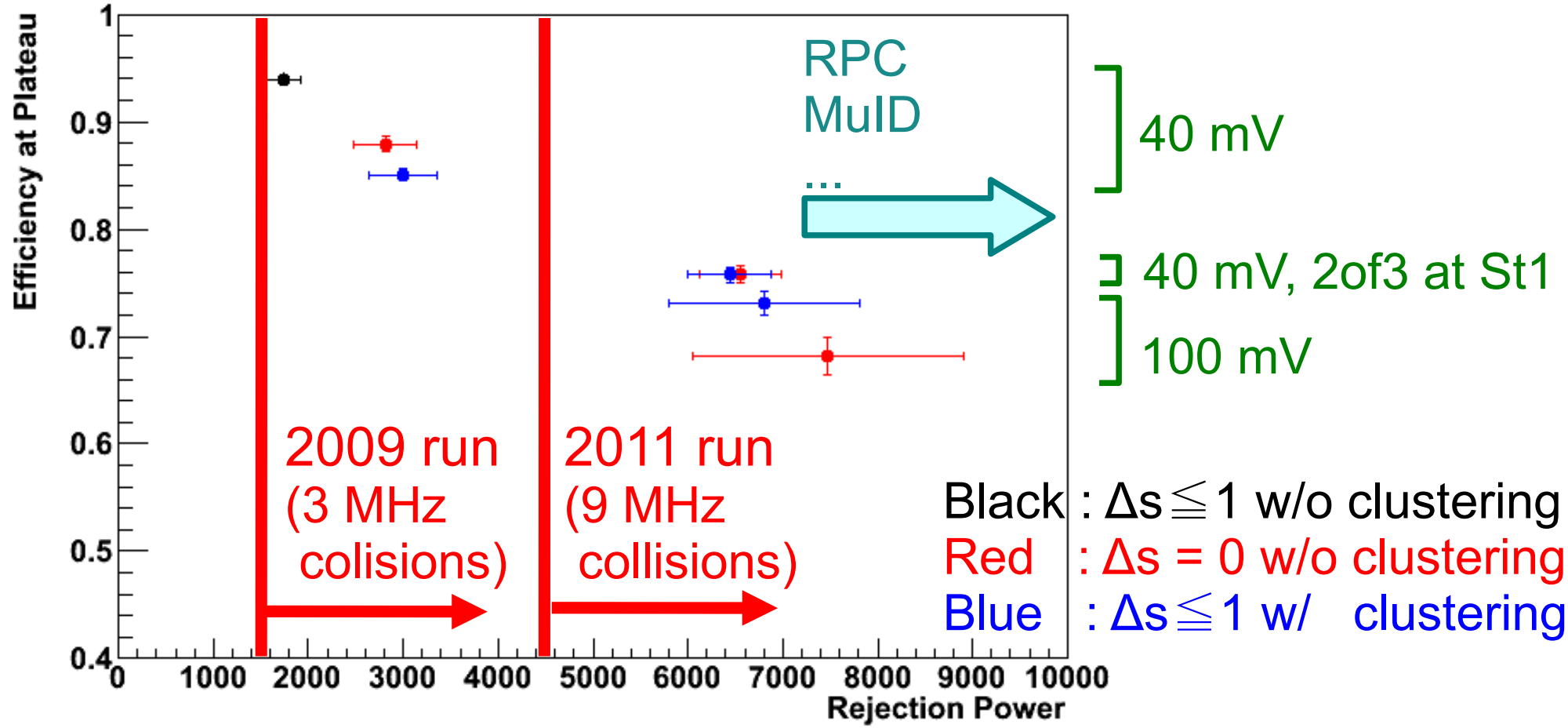
Rejection Power of BBC is taken as 2.

RP of MuID ~ 100

- Larger rejection power can be obtained by applying tight cut.
- More improvement is expected by RPC and other items.

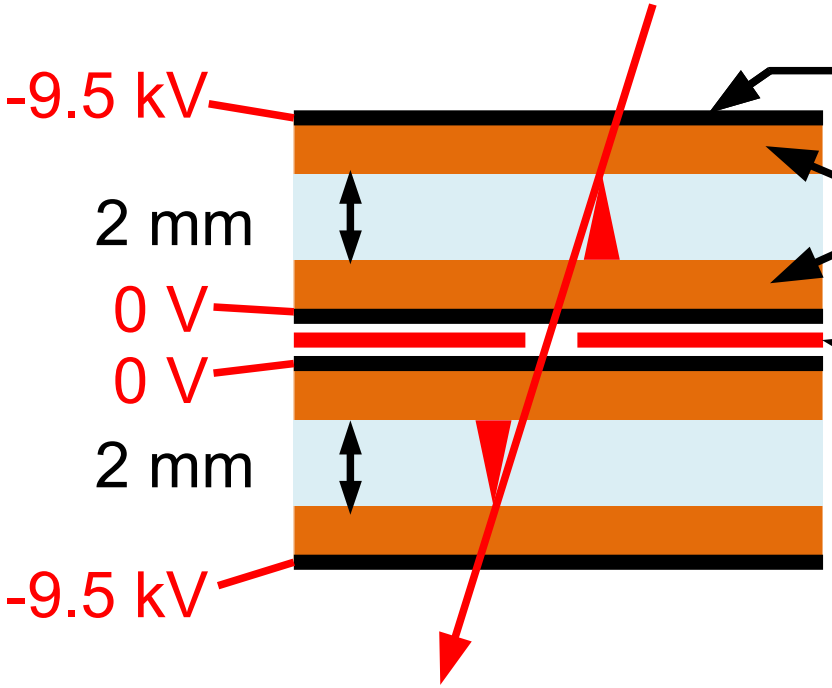
Rejection Power with MuTRG only
(MuID & BBC & MuTRG)

MuTRG performance at 3 MHz (almost max luminosity at 2009 run)



- Larger rejection power can be obtained by applying tight cut.
- More improvement is expected by RPC and other items.

Resistive Plate Chamber (RPC)



Graphite : Resistivity 100 – 500 kΩ/cm^2

Bakelite : Resistivity 10^{10} – 10^{11} Ω cm

Signal Strip

Time resolution 1-2 nsec

Efficiency 96% for MIP

Noise Rate 0.5 – 5 Hz/cm^2

Mixed Gas :

95% $C_2H_2F_4$ (base gas)

4.5% i-C_4H_{10} (photon quencher)

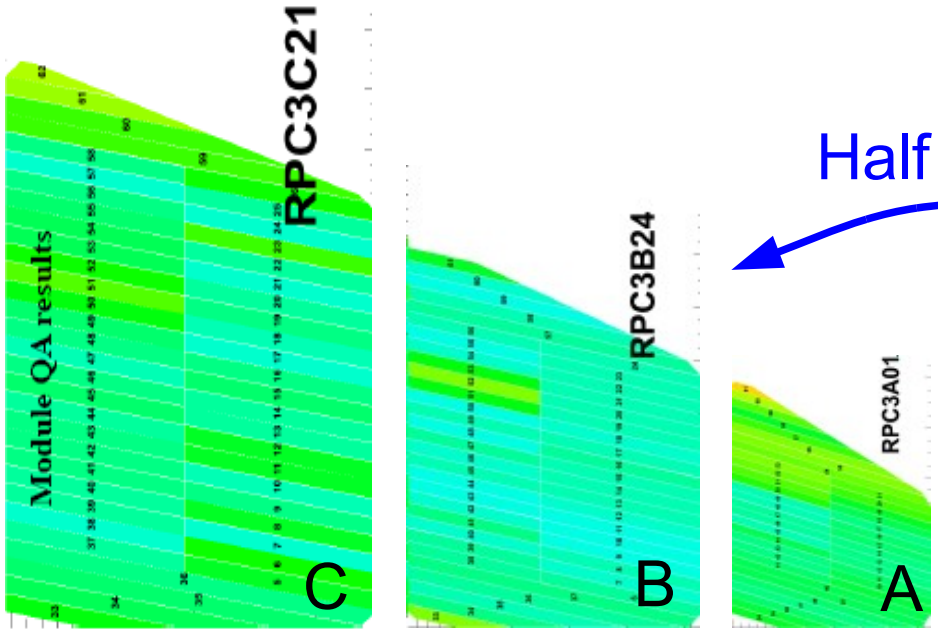
0.5% SF_6 (electron quencher)

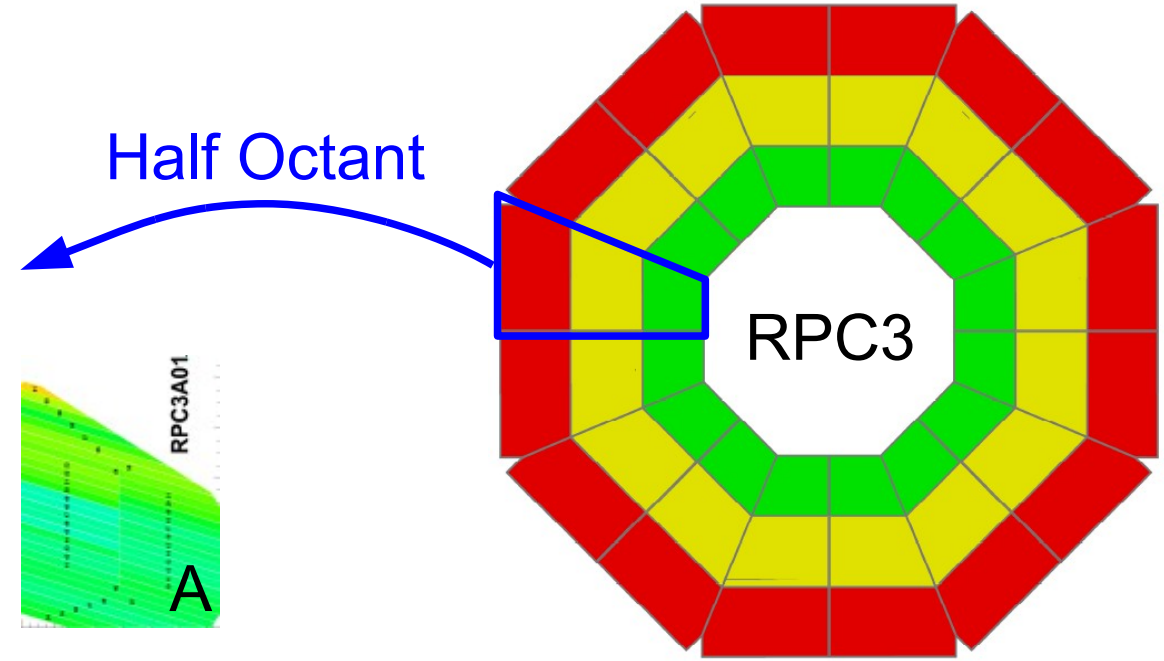
20 – 40 % relative humiidity

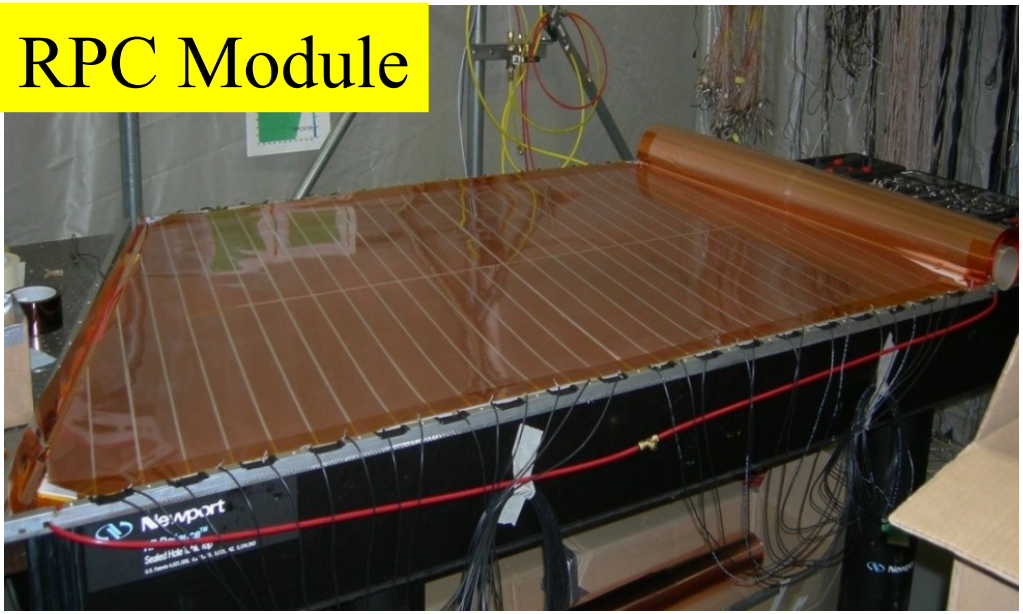
Requirement for W trigger

Time resolution	≤ 3 ns
Average cluster size	≤ 2 strips
Efficiency	> 95%
Rate capability	0.5 kHz/cm^2
Number of streamers	< 10 %

RPC3 Assembly

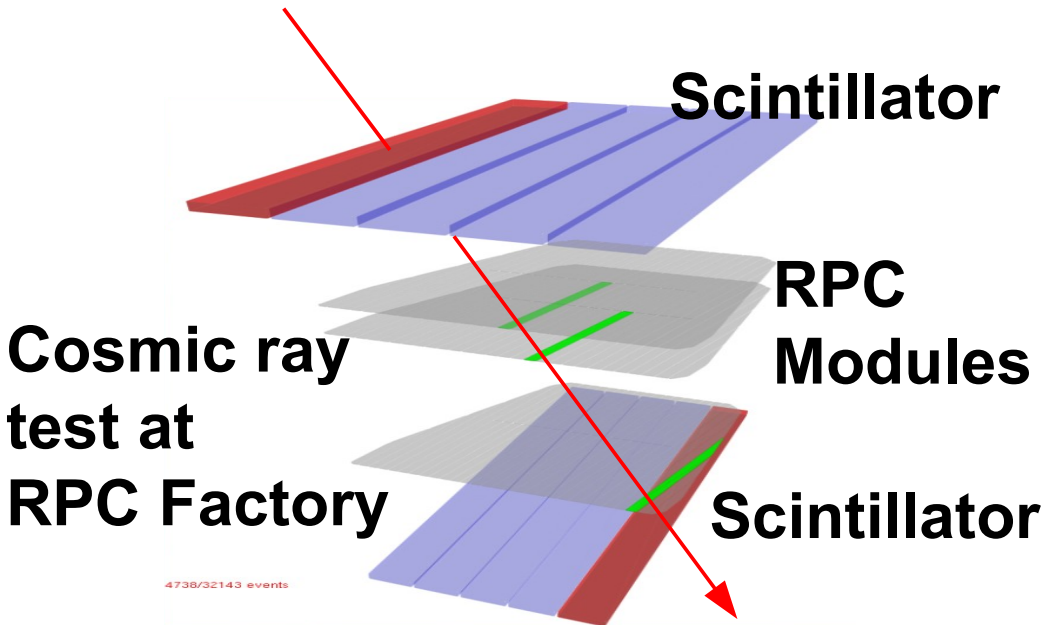


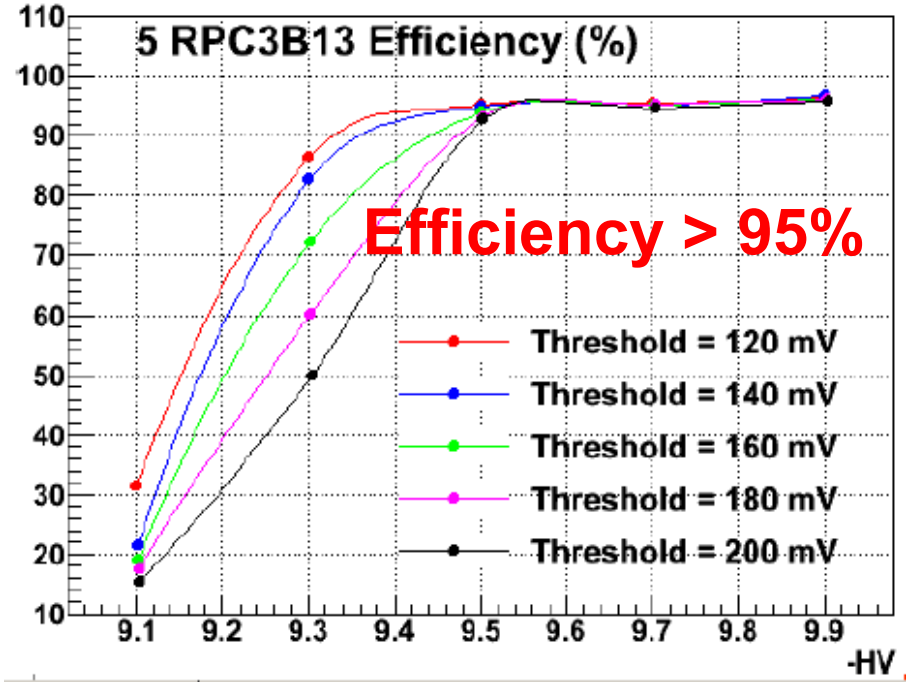


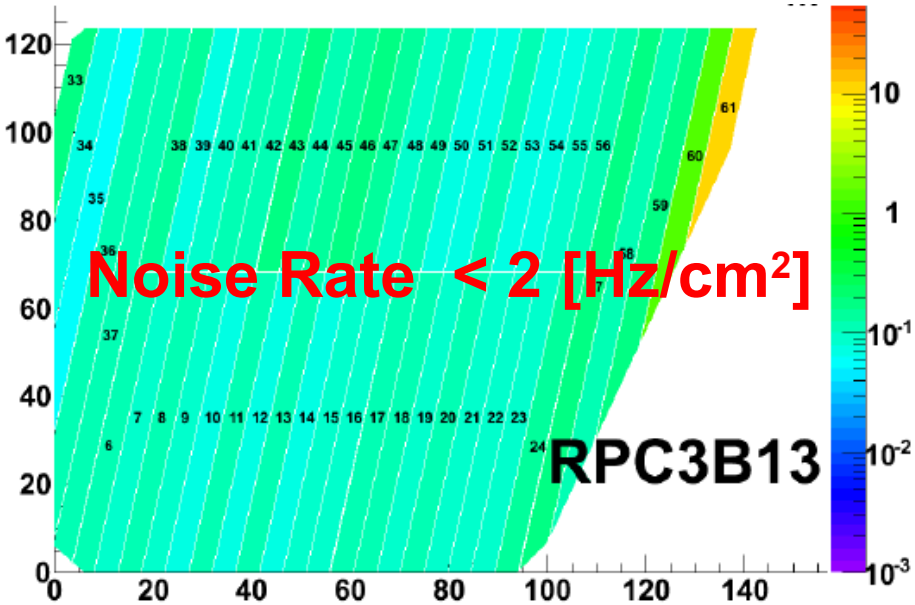


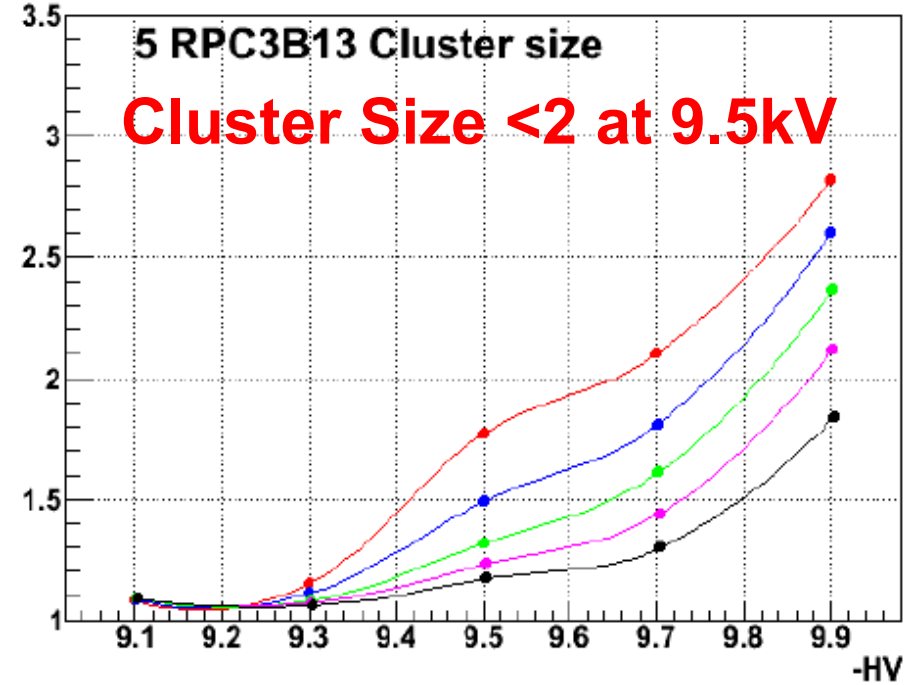
> RPC3 consists of 16 half octants
> 1 half octant consists of 3 modules
> Rough segmentation in R direction
> Fine segmentation in ϕ direction

RPC Module Eff. & Noise Rate



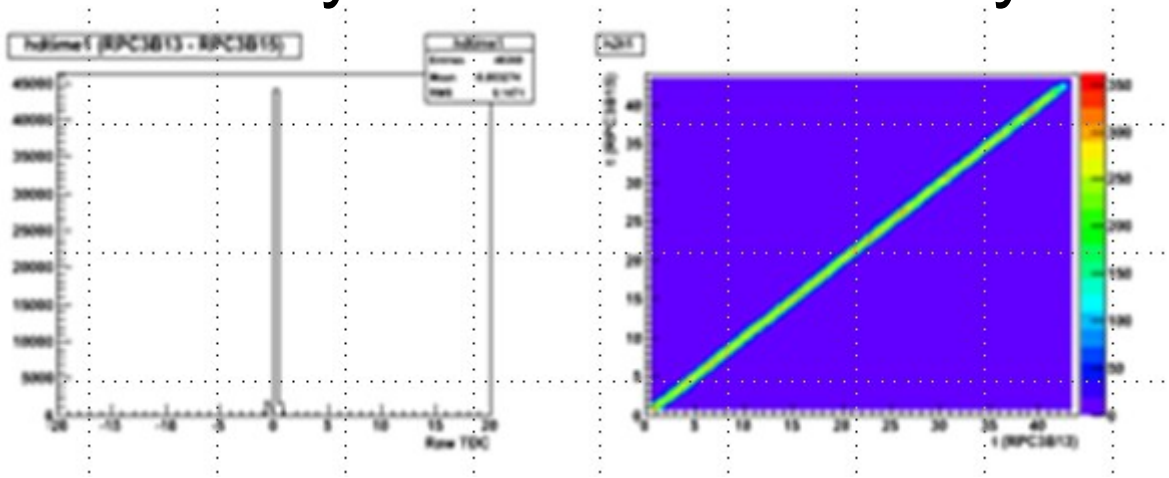






RPC Timing

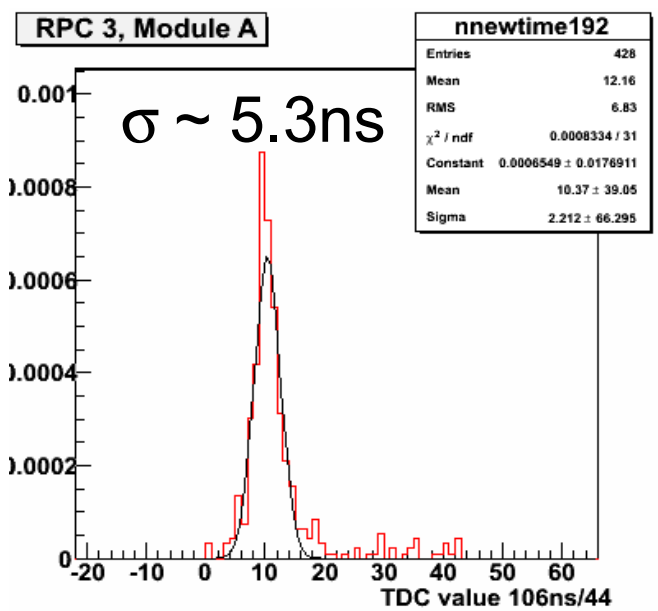
Cosmic ray test at RPC Factory

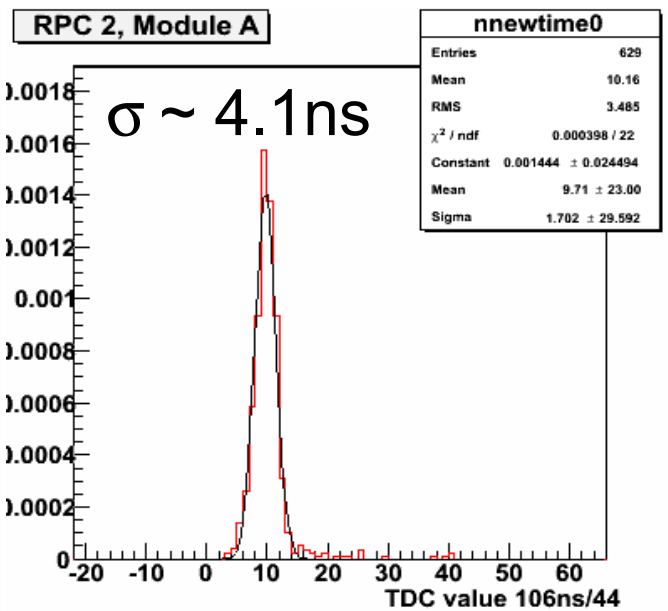


Timing difference between two RPC modules

Timing resolution ~ 2 ns

Prototype commissioning with Run 2009 beam





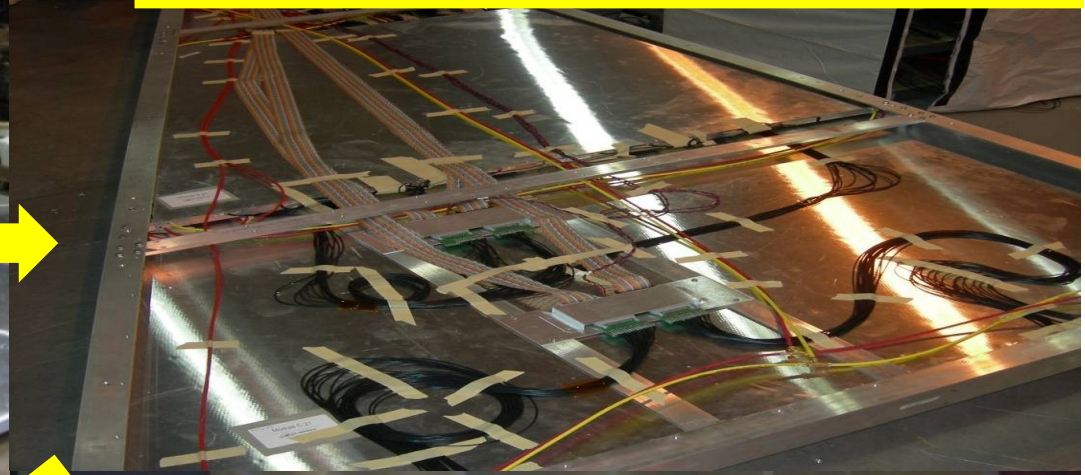
From two prototype half octants

Timing resolution ~ 5 ns (uncorrected by collision vertex of ±30cm : ~2 ns)

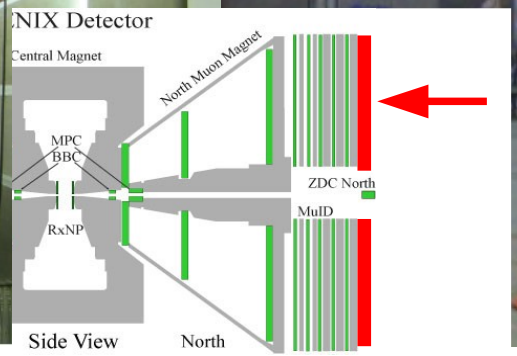
RPC3 North Installation

RPC3 Frame at UIUC

Half Octant assembly at Factory

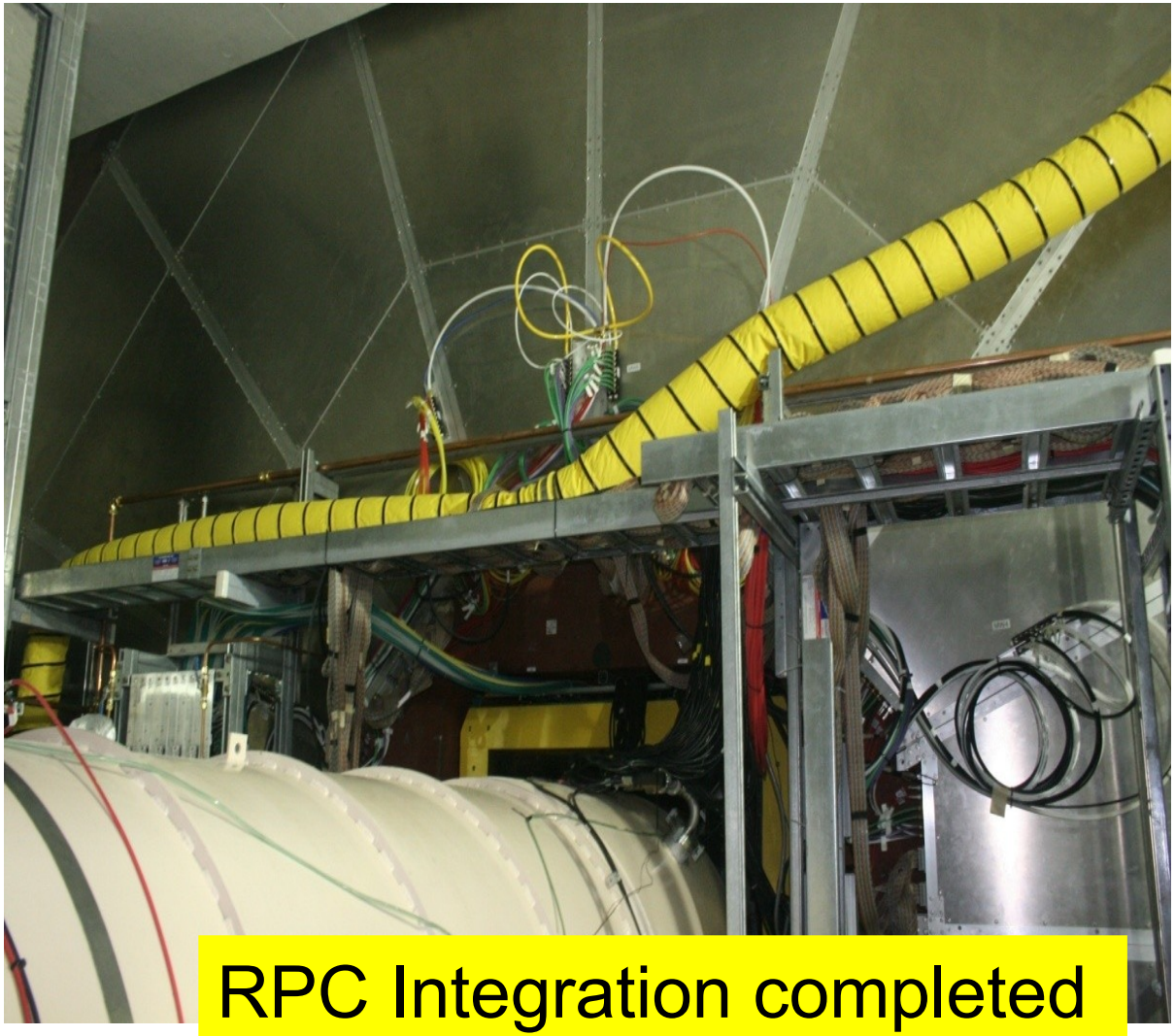


RPC3 North installation at PHENIX

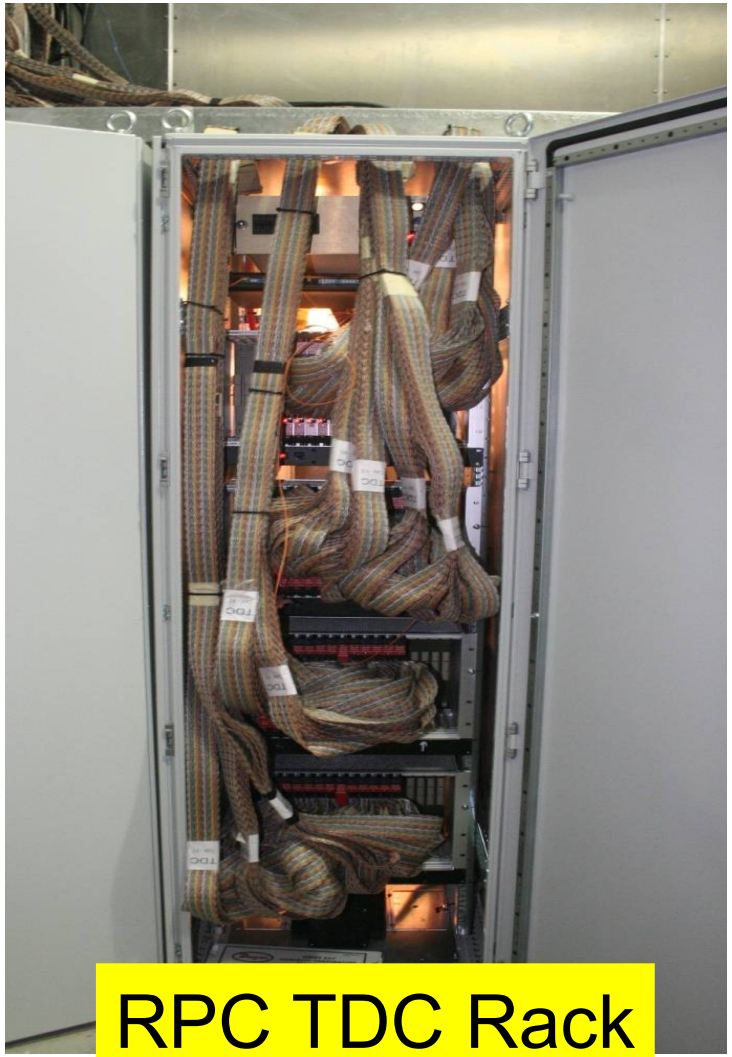


Installation completed

RPC3 North Integration Completed



RPC Integration completed

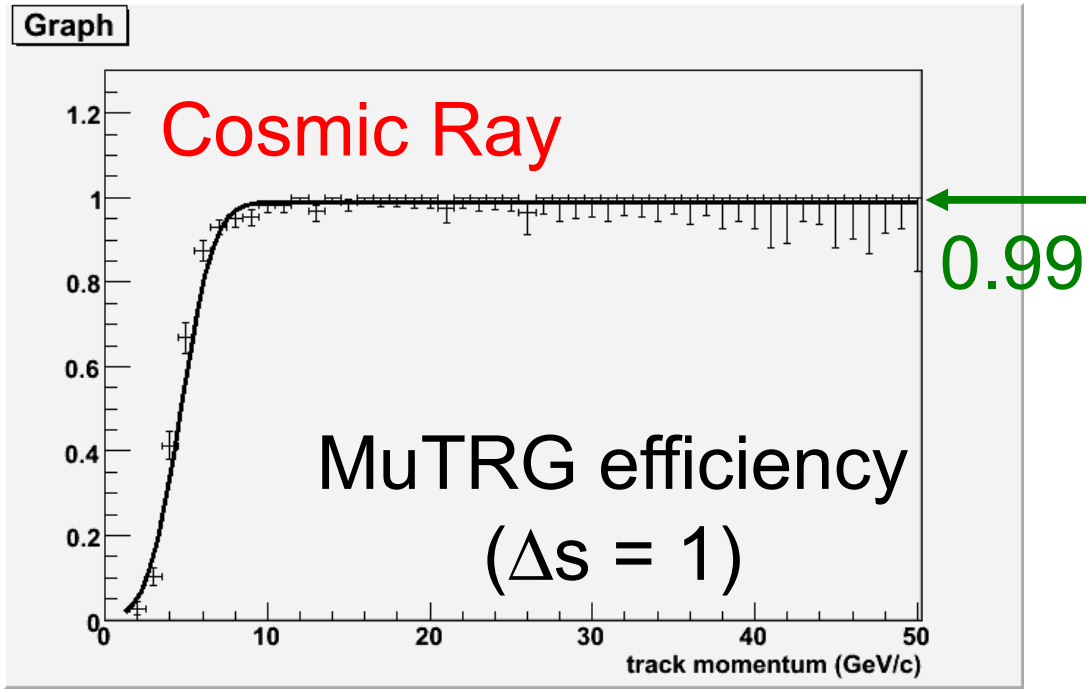


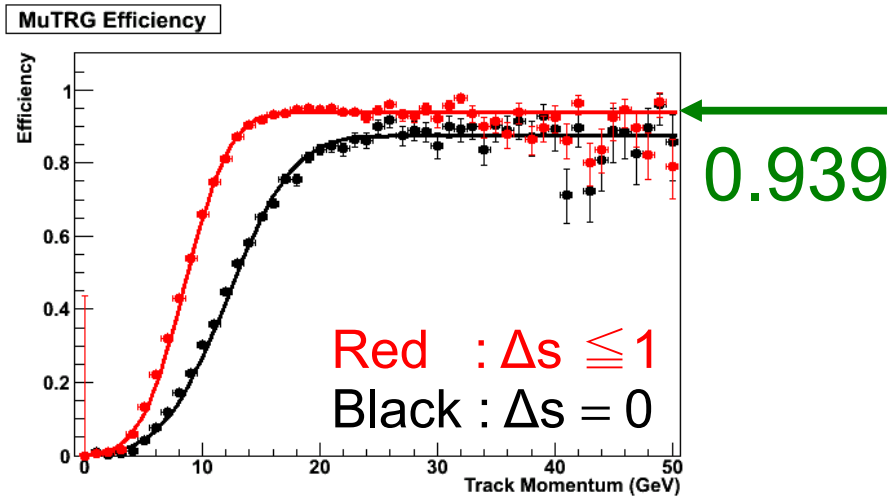
RPC TDC Rack

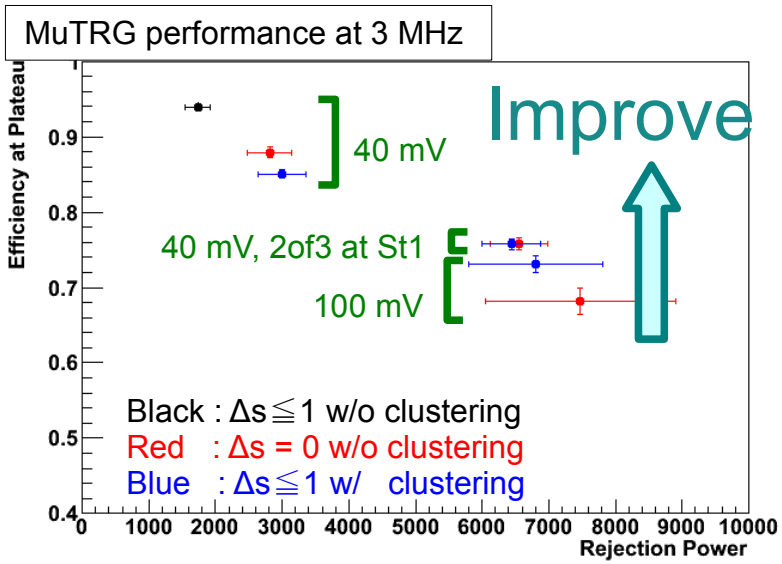
RPC3 North is commissioned in Run 2010
RPC3 South assembly will complete soon.

Cosmic Ray Test after Run 2010

> Commissioning of MuTRG and RPC3 North
Noise, Detection efficiency, Time resolution etc.
> Clean high momentum muon tracks are expected

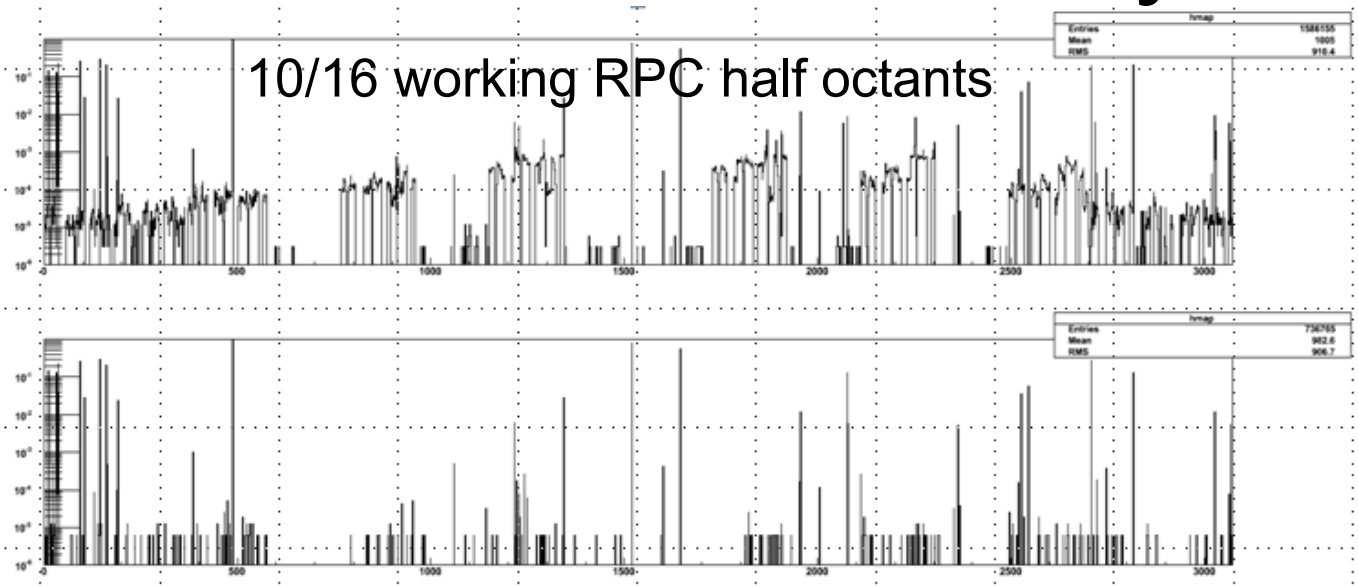






MuTRG measured good efficiency for track.
This implies that beam data include much fake tracks.

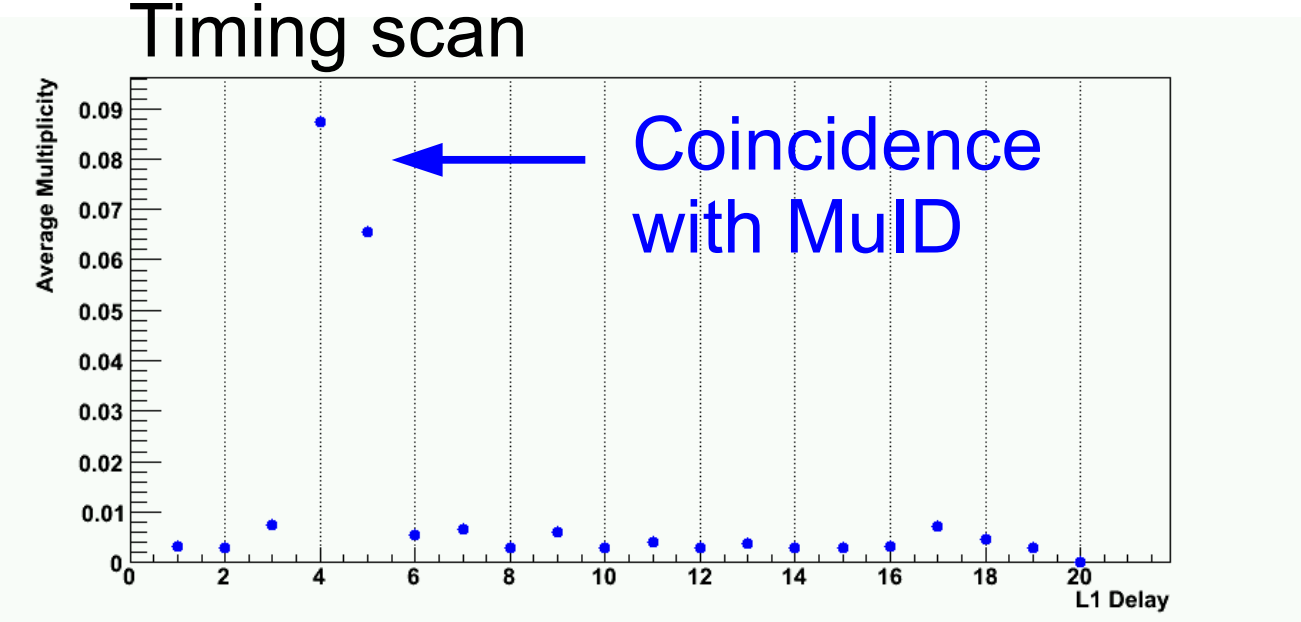
RPC Hit map and Time-in with Cosmic Ray



Timed in

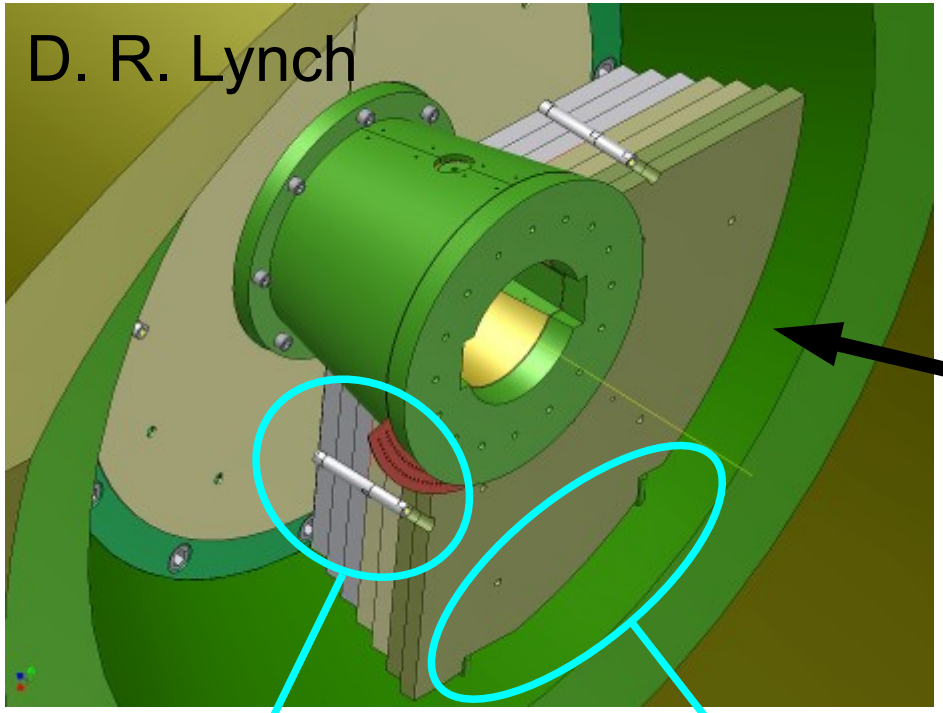
Timed out

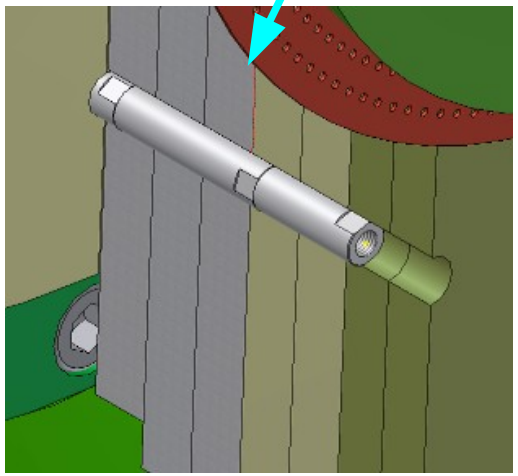
Timing scan

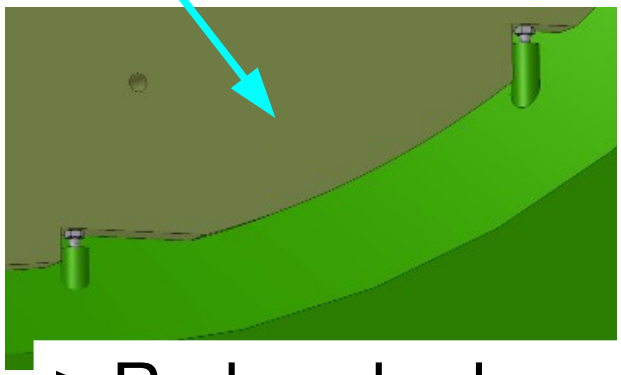


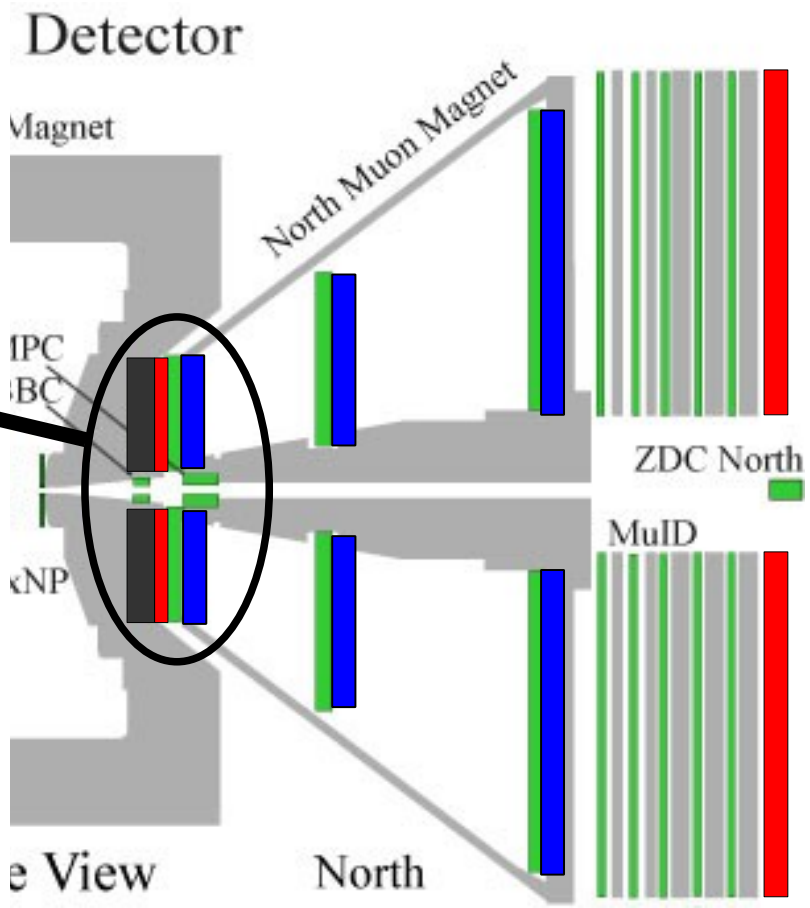
Further data analysis, including evaluation of full chain performance of MuTRG+RPC, is ongoing.

Hadron Absorber Installation





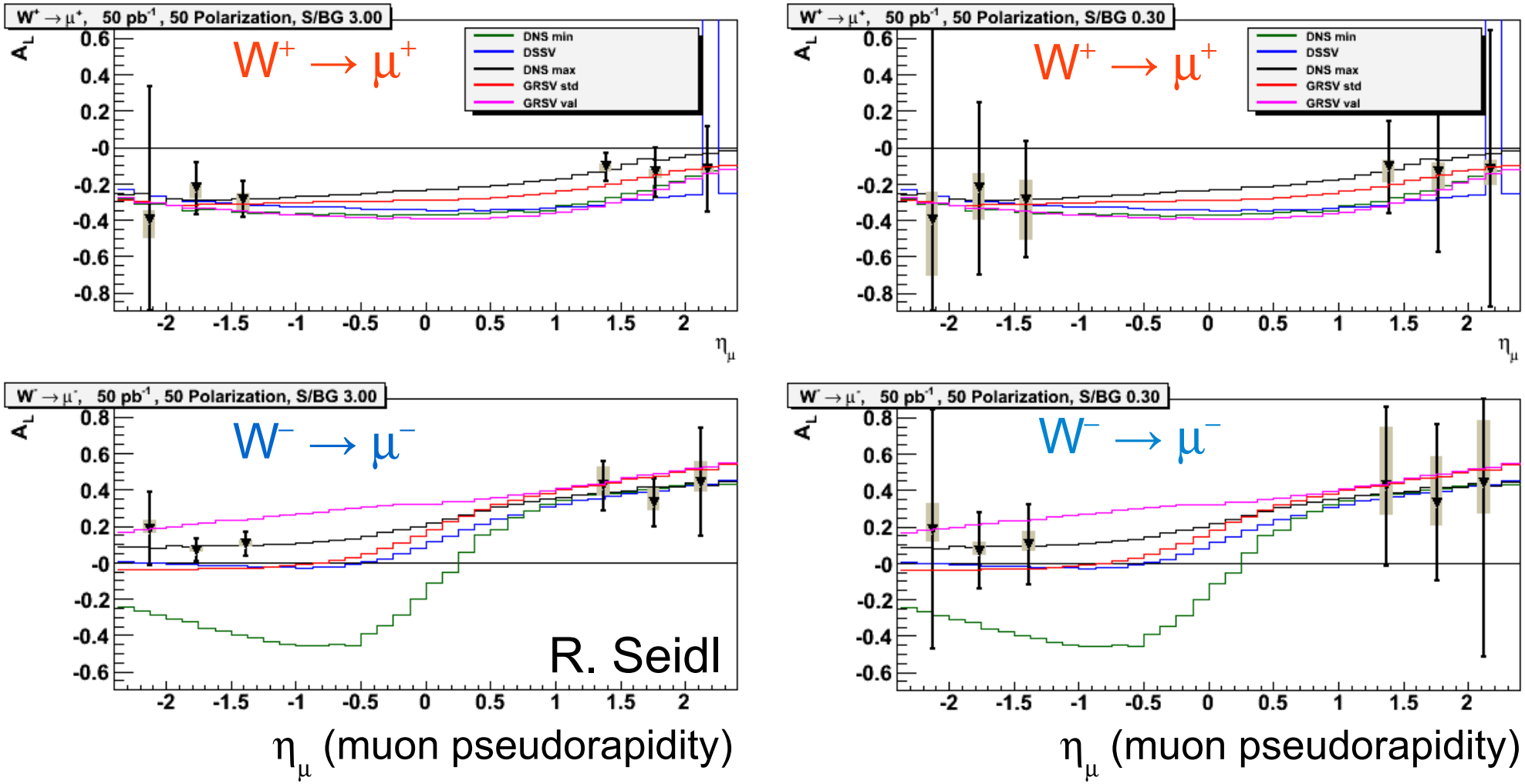




> Reduce hadrons whose decay to muon produces fake high momentum track.
> 35 cm-thick SS310
> In manufacture, to be installed coming August

Offline Analysis / Simulation

Run 2011 Projection (50 pb^{-1}, 50% pol.)



η_μ (muon pseudorapidity)

S/B = 3.0 (optimistic)

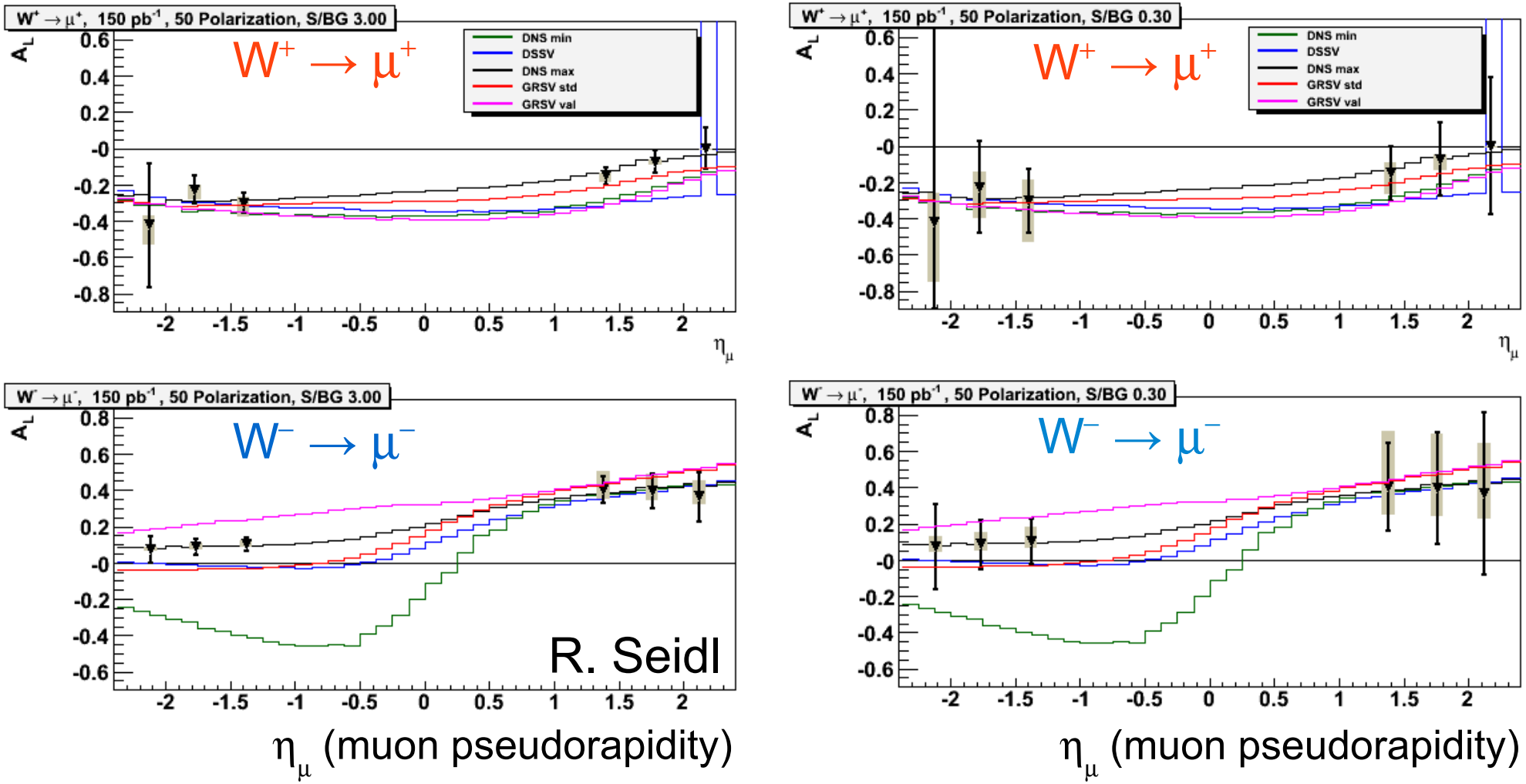
η_μ (muon pseudorapidity)

S/B = 0.3 (conservative)

> Offline background evaluation using Run 2009 data and simulation study to optimize event selection is ongoing.

Offline Analysis / Simulation

Run 2011+2012 Projection (150 pb^{-1}, 50% pol.)



η_μ (muon pseudorapidity)

S/B = 3.0 (optimistic)

η_μ (muon pseudorapidity)

S/B = 0.3 (conservative)

> New Foward VTX detector will be installed and improve S/B.

Summary

RHIC-PHENIX experiment aim to measure A_L in $W \rightarrow \mu$ process and impose significant constraint on anti-quark PDF in 500 GeV polarized pp program

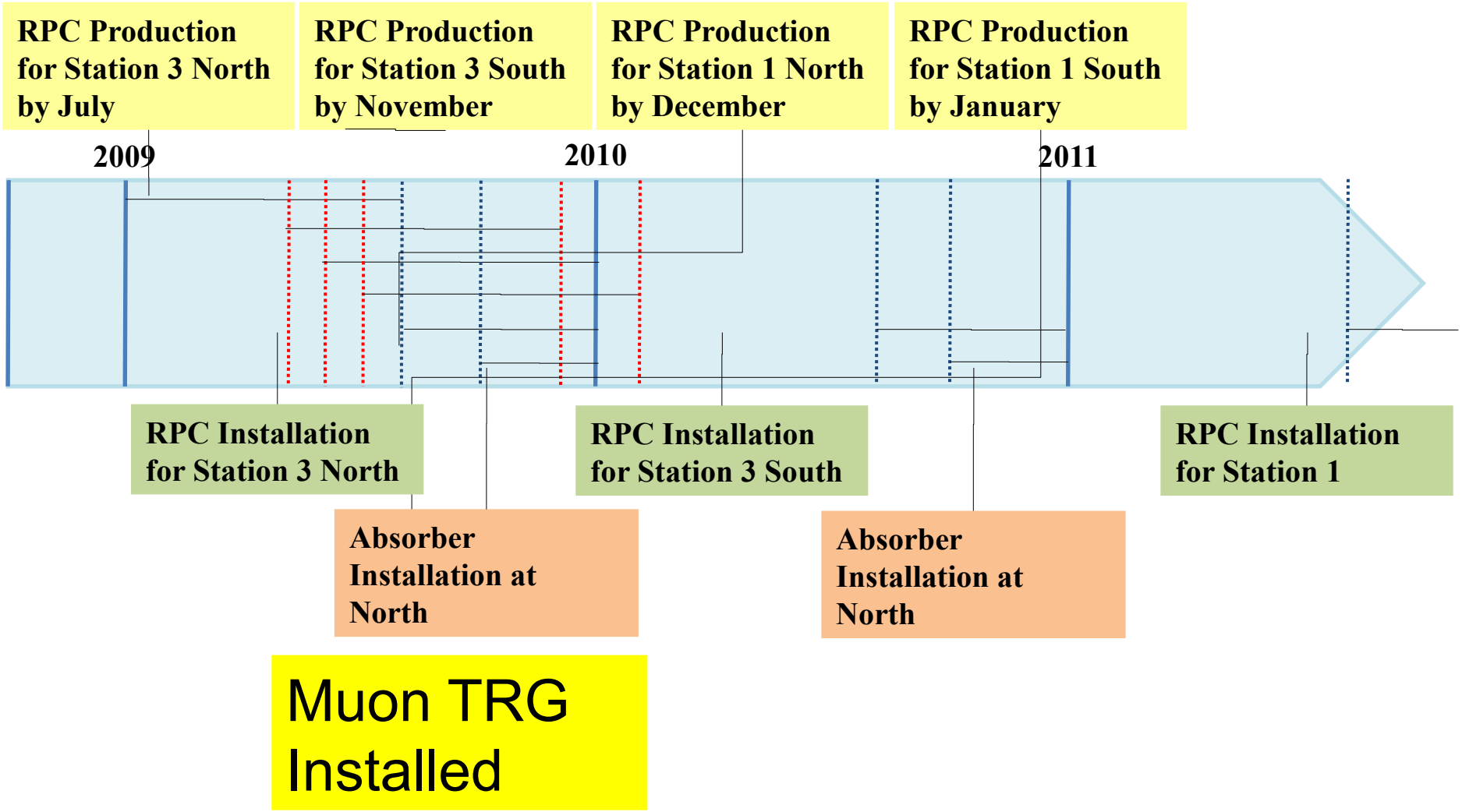
W trigger development
- MuTRG installation completed
- RPC3 North installation completed
- RPC3 South production is ongoing and will be installed in 2010 shutdown period
- RPC1 will be installed in 2011.
- Final performance evaluation of MuTRG+RPC is ongoing.

New hadron absorber is in manufacture and will be installed in 2010 shutdown period.

Offline analysis and simulation for W signal extraction are in progress towards 2011 physics run.

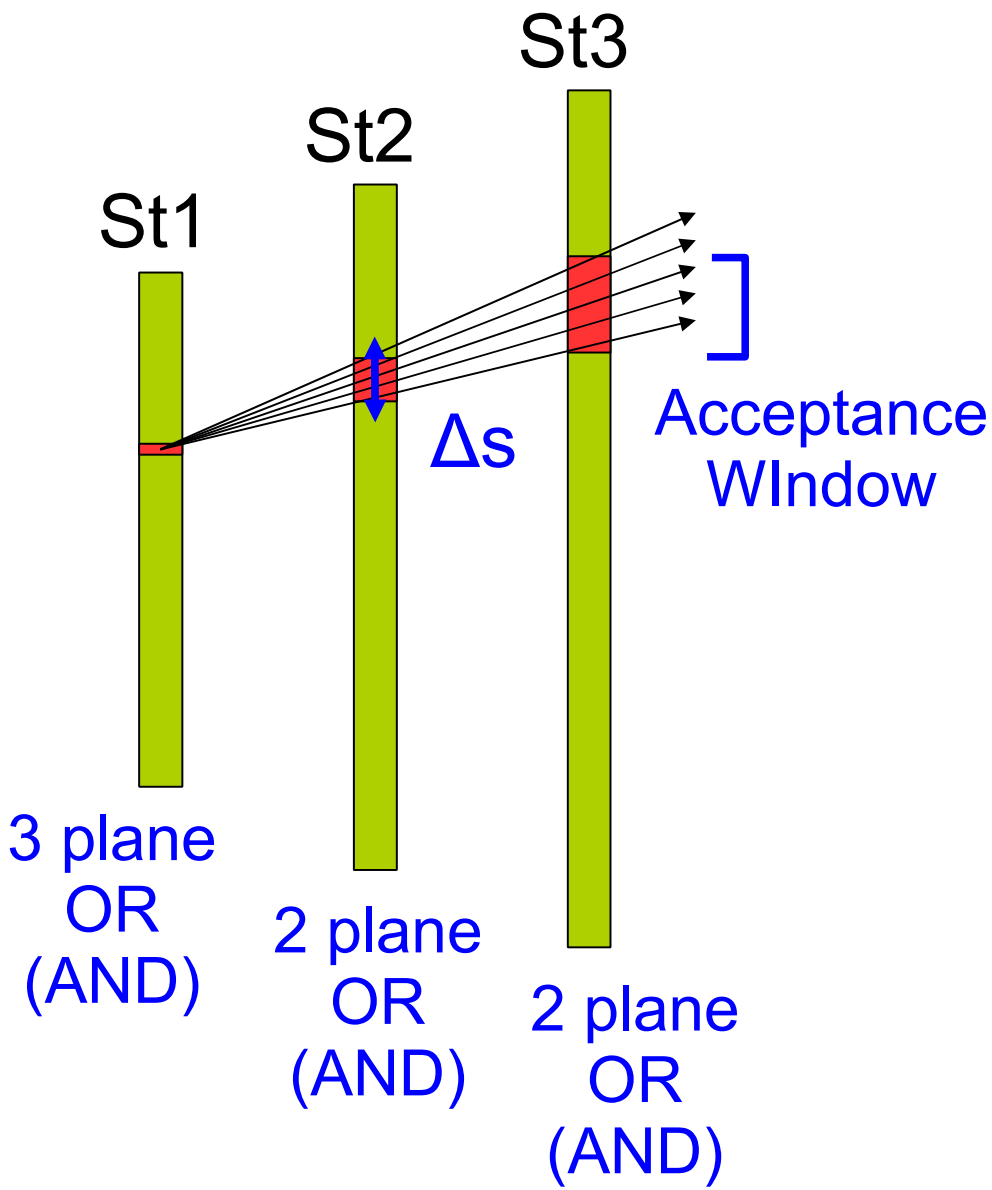
Back Up

Schedule



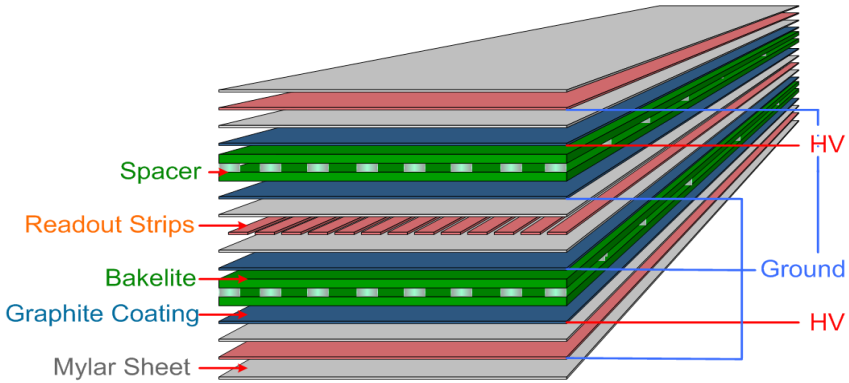
Muon TRG Installed

Trigger Algorithm (MuTRG)



Fire events with straight tracks

Optimization Parameter
- OR / AND of planes for each station.
- Acceptance Window for Station 3
- Saggita Δs for Station 2
- Threshold for charge on single strip
- Timing Gate
- Clustering (succesive hits are merged)



RPC Module
Cross section