CMS Muon Drift Tubes Trigger Performance on Bunched Test Beam

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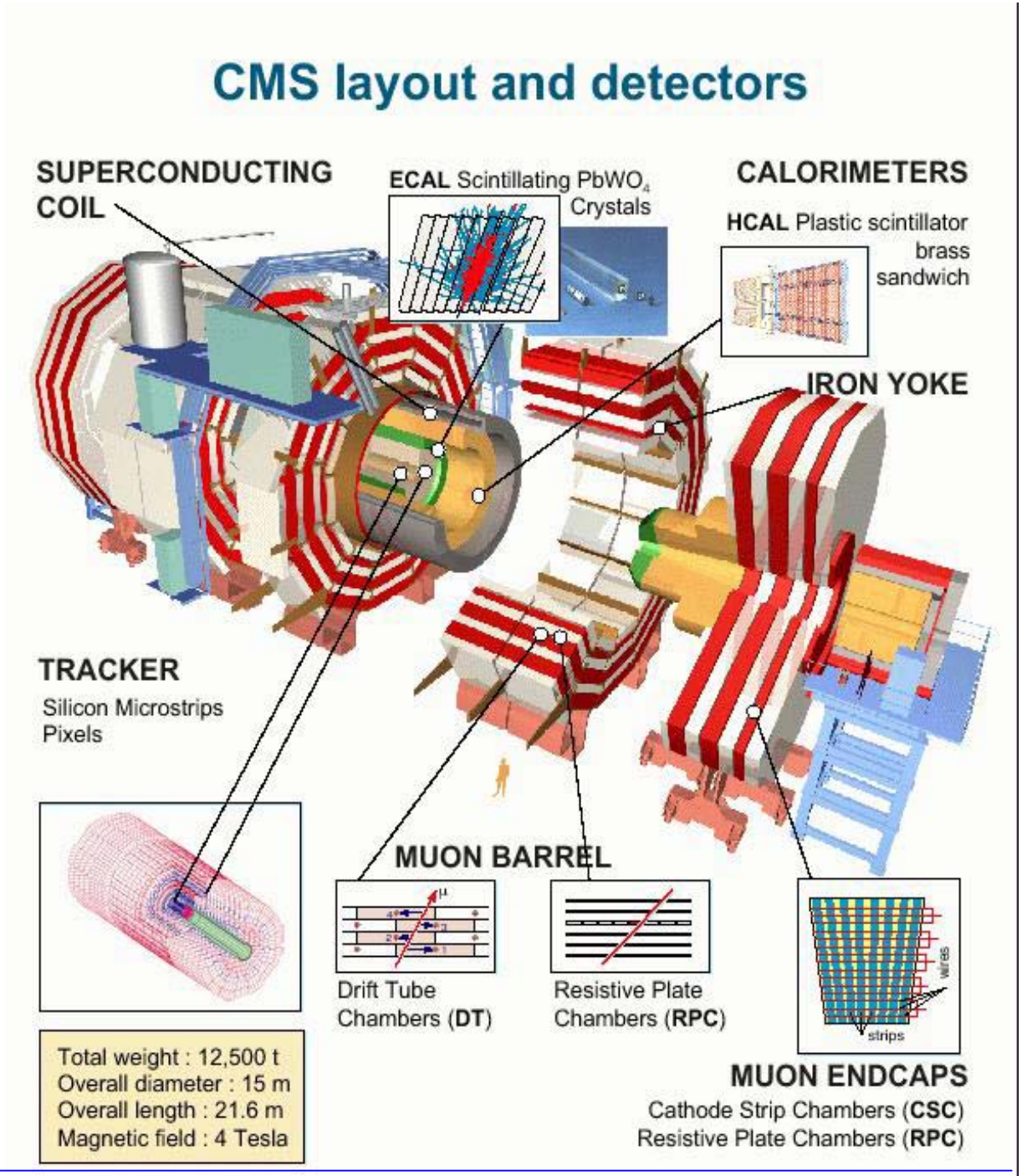
INFN Padova is building DT chambers for CMS experiment. One of these chambers trigger system was tested on 40MHz bunched **test beam** at Cern in May 2003.

First preliminary results are shown.

Compact Muon Solenoid at LHC

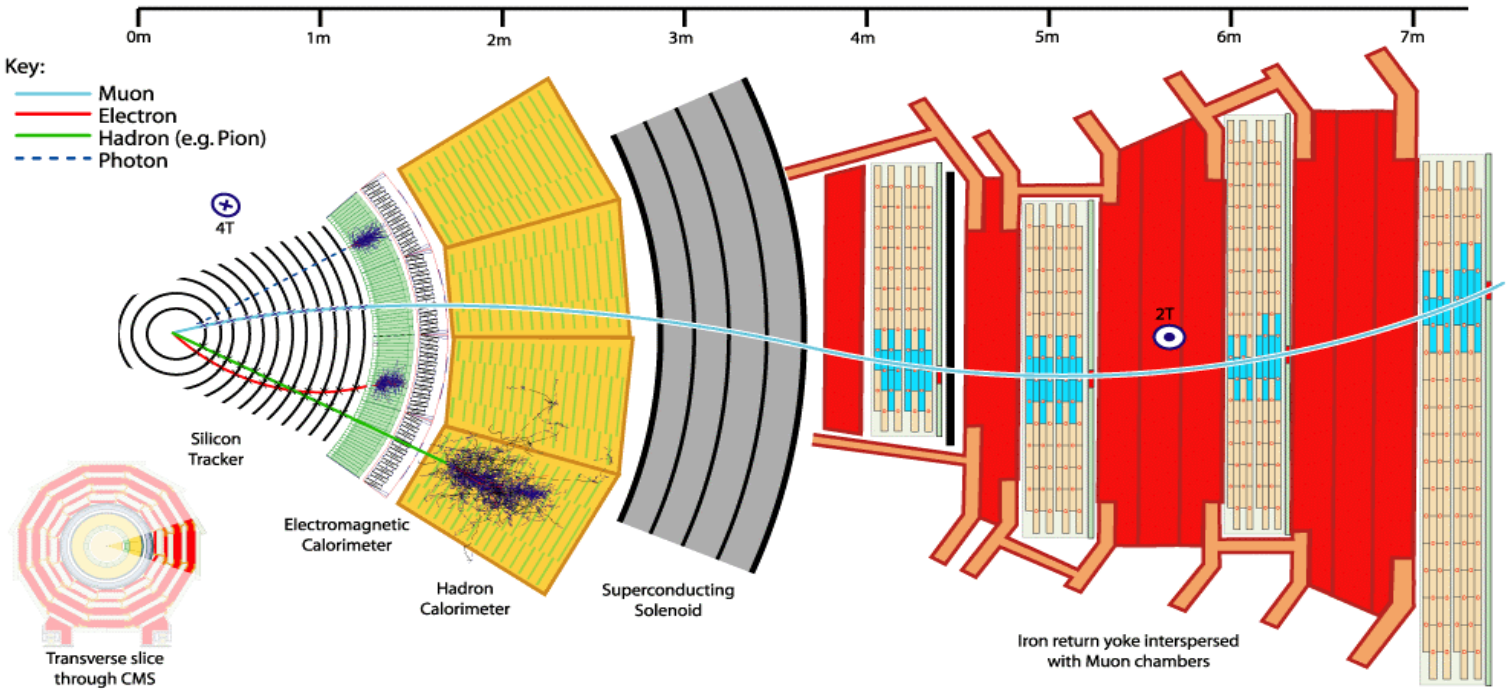
Superconducting Solenoid for *muon detection* with 4 Tesla field strength

- discover Higgs boson in mass range 0.08-1 TeV
- study Quark-Gluon-Plasma formation



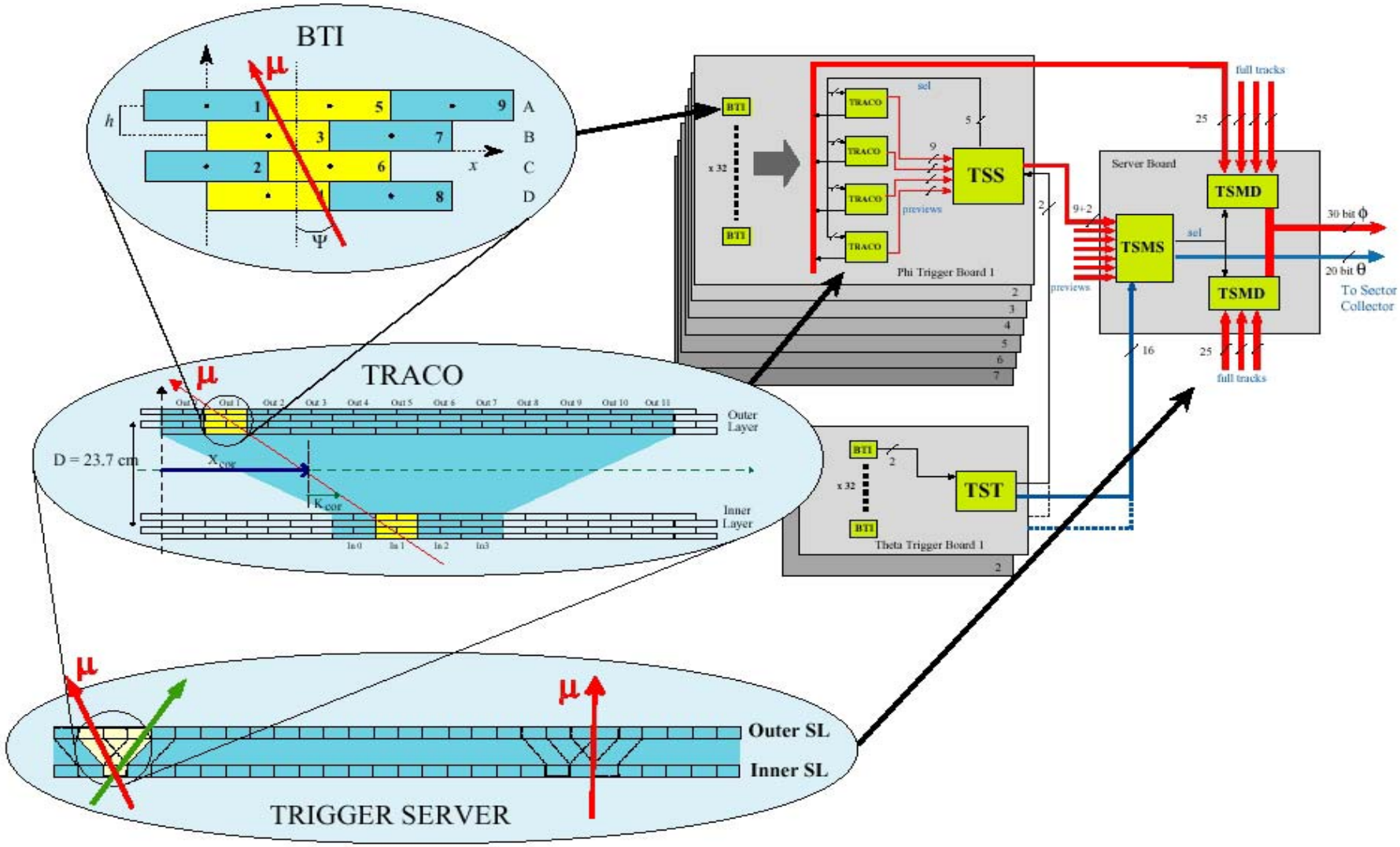
Drift Tubes Chambers

250 chambers and 200000 channels



- muon ID covering up to $|\eta| = 1.1$
- on-line track segments reconstruction along muon track
- momentum resolution 1.0-1.5 %
- unambiguous bunch crossing identification
- muon self-trigger at first level

I Level Trigger



10^9 interaction every second → 100 kHz to the High Level Trigger

I level trigger

12.5 kHz for muon system

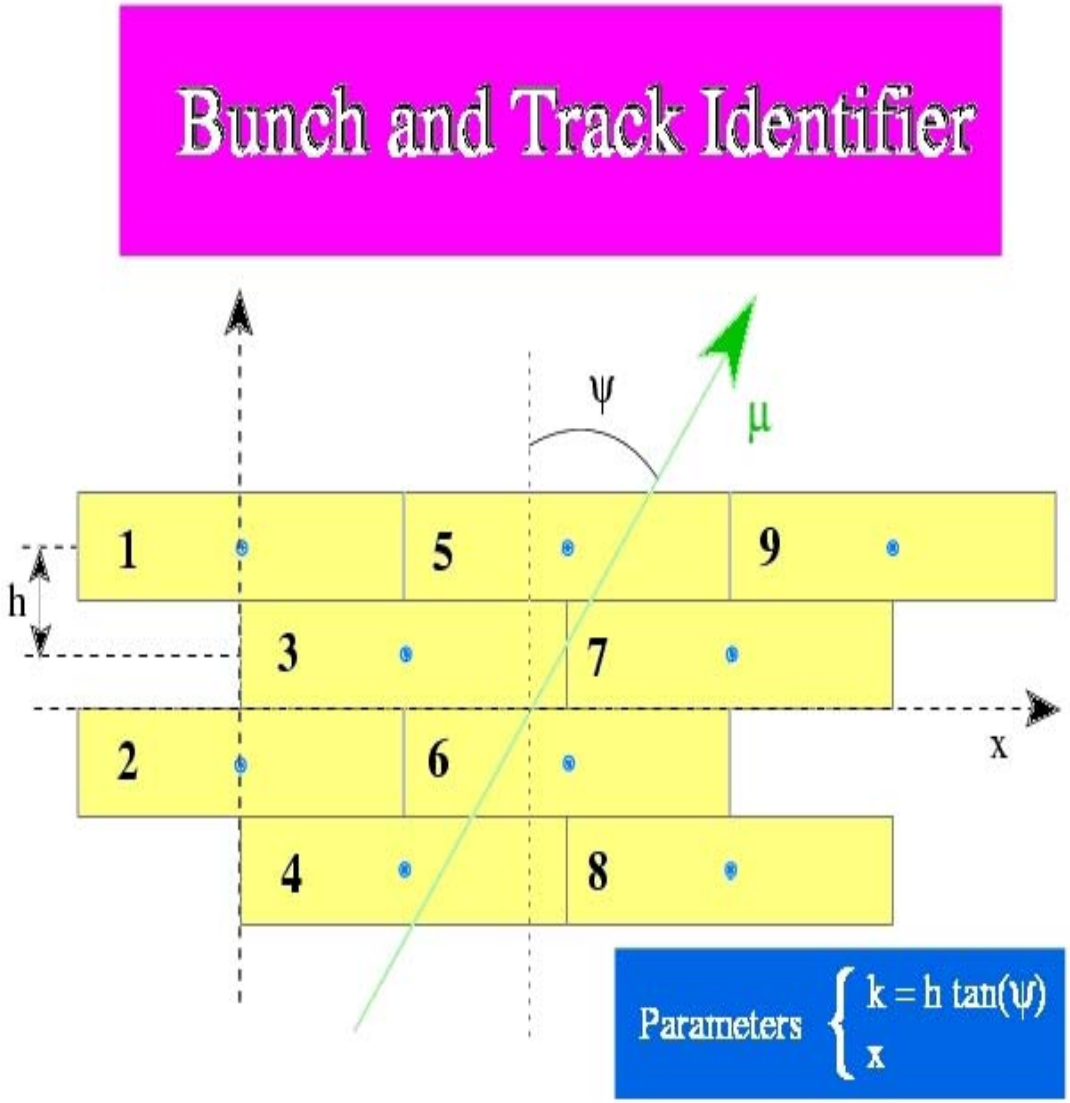
BTI

Measures:

TRACK POSITION

TRACK DIRECTION

BUNCH CROSSING



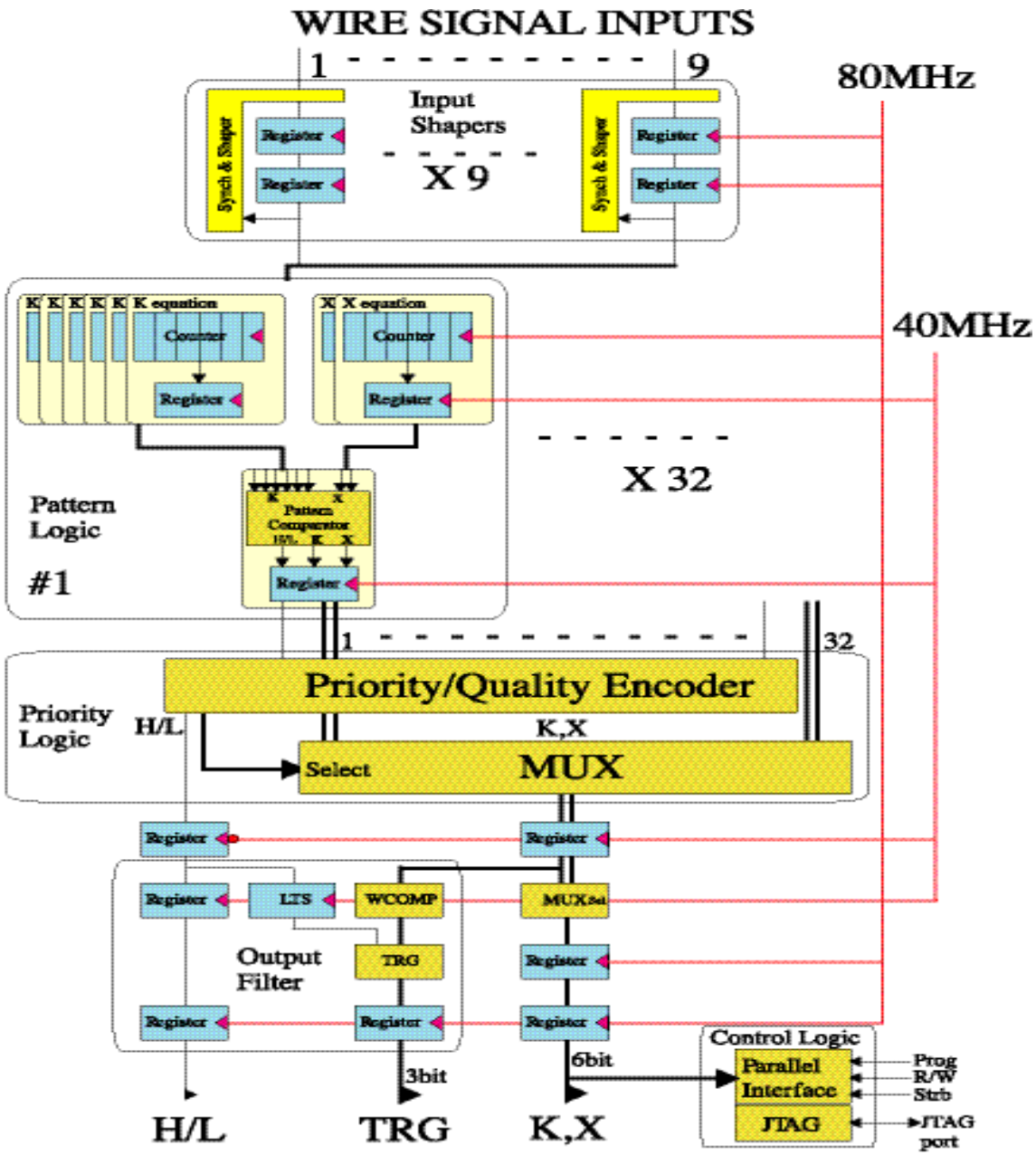
Every 40 MHz cycle:

- hit arrival times sampled
- time distances computed for each pair of wires
- alignment of hits is detected at fix time after bunch crossing

Output trigger type:

HTRG - 4 hits alignment

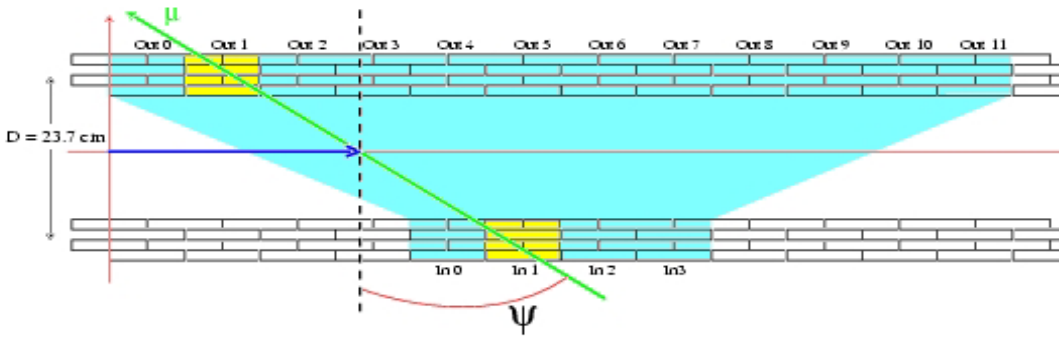
LTRG - 3 hits alignment



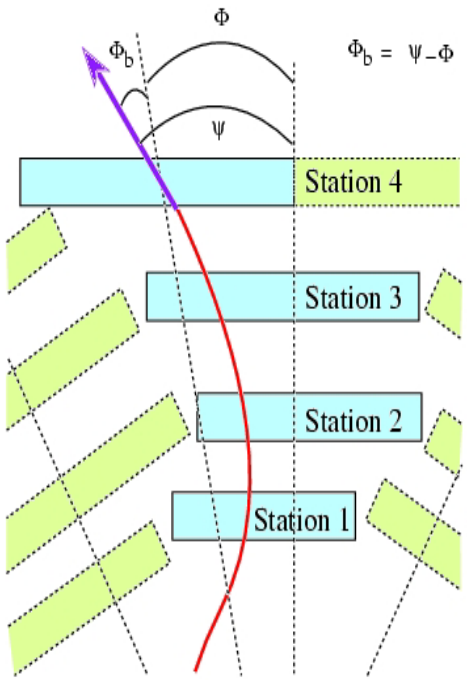
BTI BLOCK SCHEME

TRACO

Track Correlator



Correlates BTIs in the inner and outer Superlayers
Refines the track measurement
(angular resolution 60 mrad ➤ 10 mrad)
Applies noise filtering

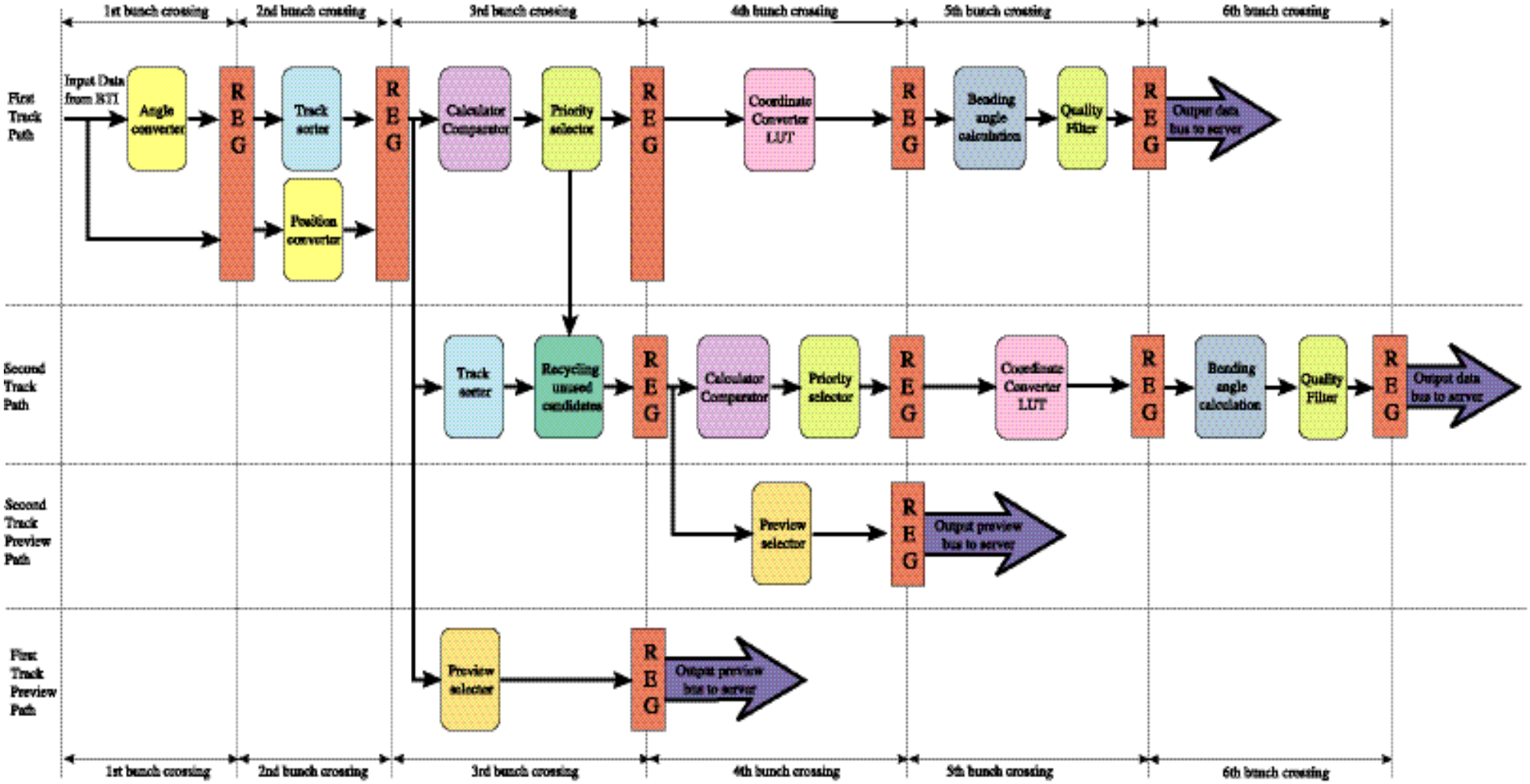


Output parameters

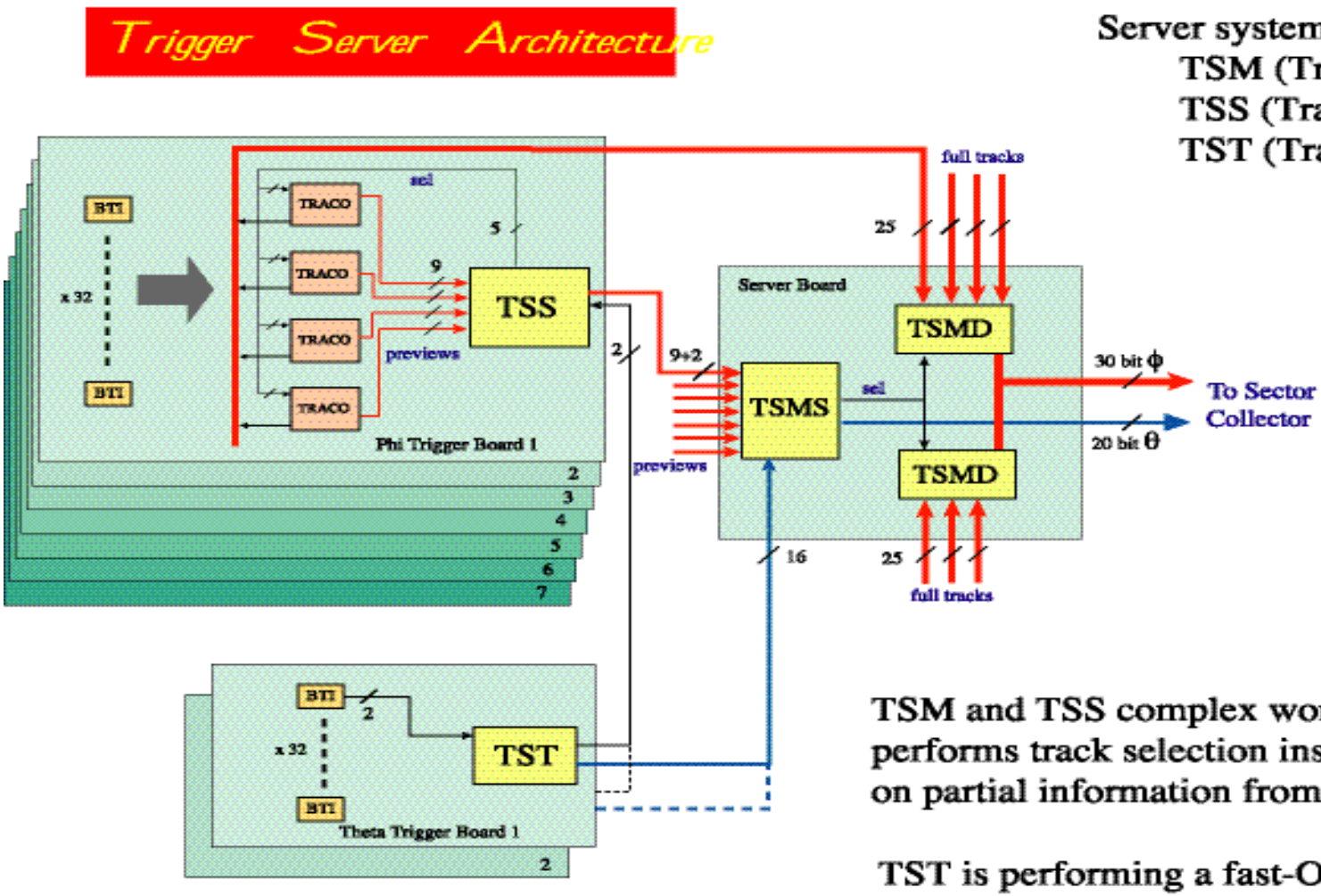
Radial angle Φ (12 bits)
Bending angle Φ_b (10 bits)
Quality flags

- associate portions of tracks between inner and outer BTIs
- selects the best track candidate according to user-defined preferences
- compute X and K of correlated track in TRACO frame
- converts parameters in radial (position in polar coordinates) and bending angle (deviation from radial direction) with Look Up Tables
  - Trigger quality code: correlated **HH, HL, LL** and uncorrelated **Ho, Hi, Lo, Li**

Flow diagram of TRACO operation



Trigger Server



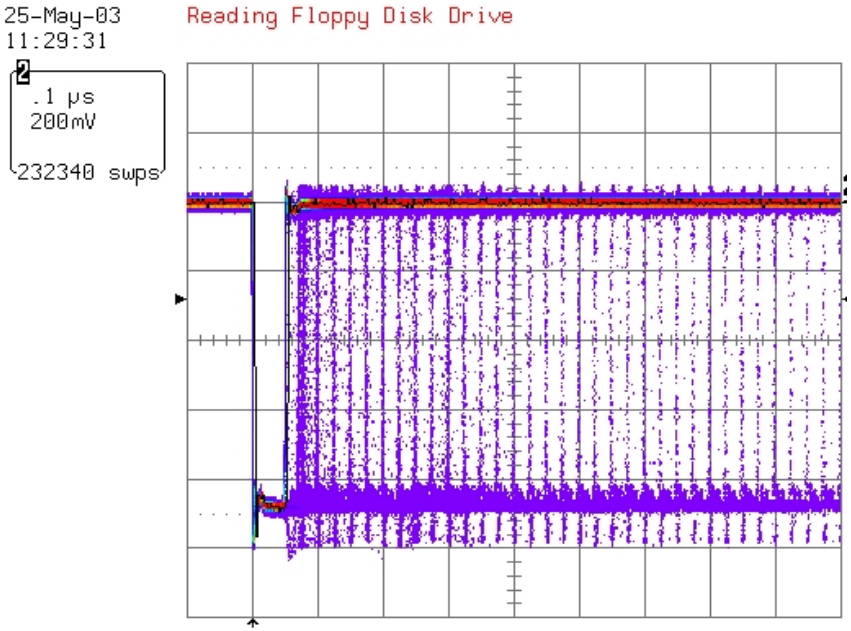
Server system is divided in three parts
- TSM (Track Sorter Master)
- TSS (Track Sorter Slave)
- TST (Track Sorter Theta)

TSM and TSS complex works on the bending plane: performs track selection inside one chamber working on partial information from TRACO (preview)

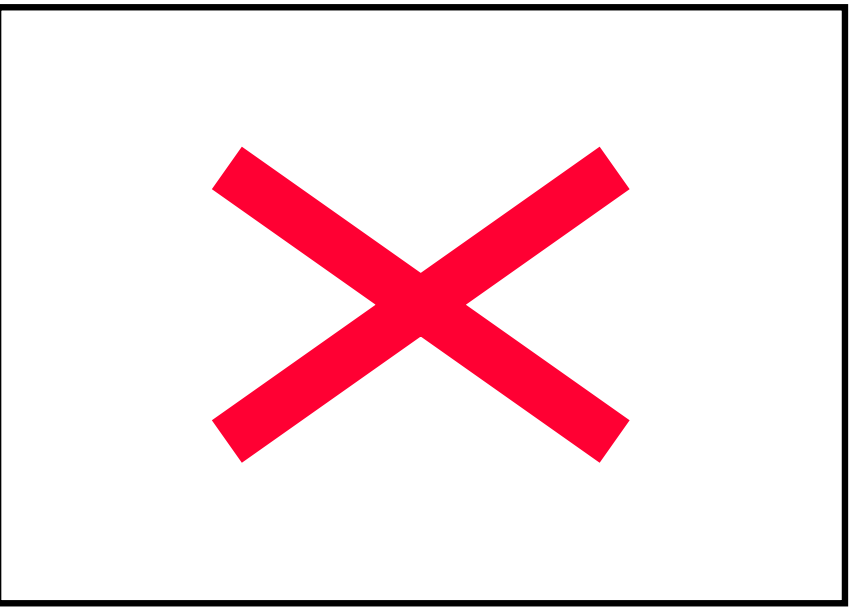
TST is performing a fast-OR of BTI signals in the longitudinal view for TRACO triggers validation

Selection of 2 best track candidates per clock within each chamber to allow multi-muon detection

Test Beam at H6 - North Area



25ns bunched proton beam 400 GeV for 3-5ns
48 bunches (1.2µs) every 22.3µs
2.2 sec spill length
16.8 sec cycle length



Beam intensity 10^6 ppp
~ 0.1 pp bunch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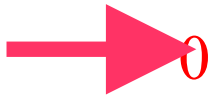
Data Analysis Selection:

- trigger data recorded inside a pattern unit storing information at 40 MHz
- pattern unit start from scintillator signal
- readout data recorded in first 40 locations (slots)

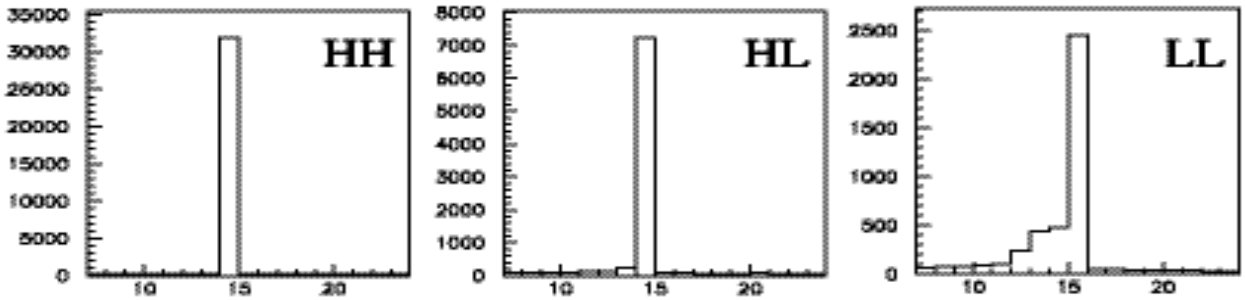
To avoid bias on trigger performance evaluation:

- presence of scintillator signal (with 2 ns tolerance)
- signals within 500ns window on at least 2 cells (to reject beam halo triggers)

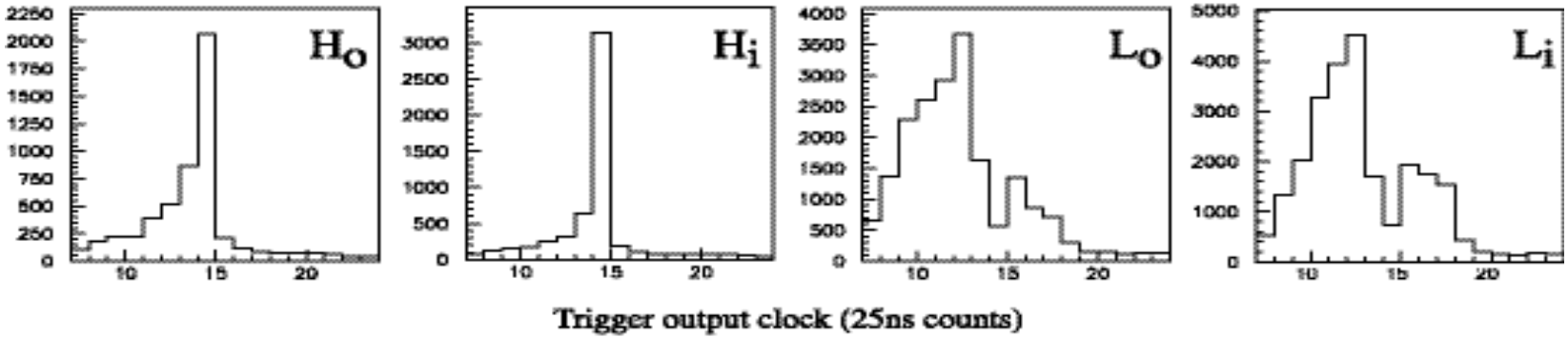
Rejected fraction of events from TDC  0.5 %

Trigger Output Clock

Correlated triggers



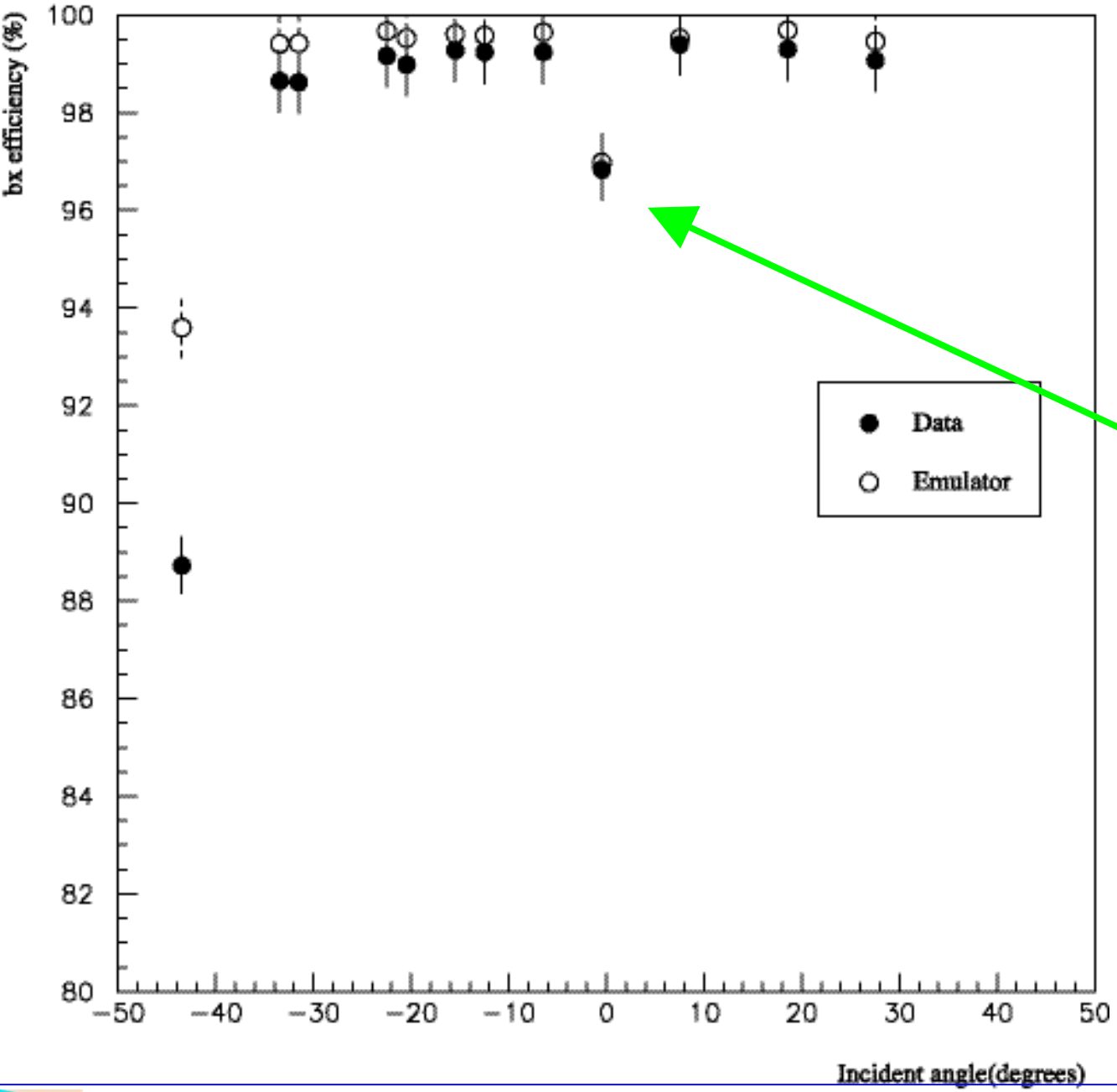
Uncorrelated triggers



triggers vs pattern unit slot → clock 14 is the right one

triggers in other location are "ghosts" or false triggers

BX Efficiency vs Incident Angle - 1



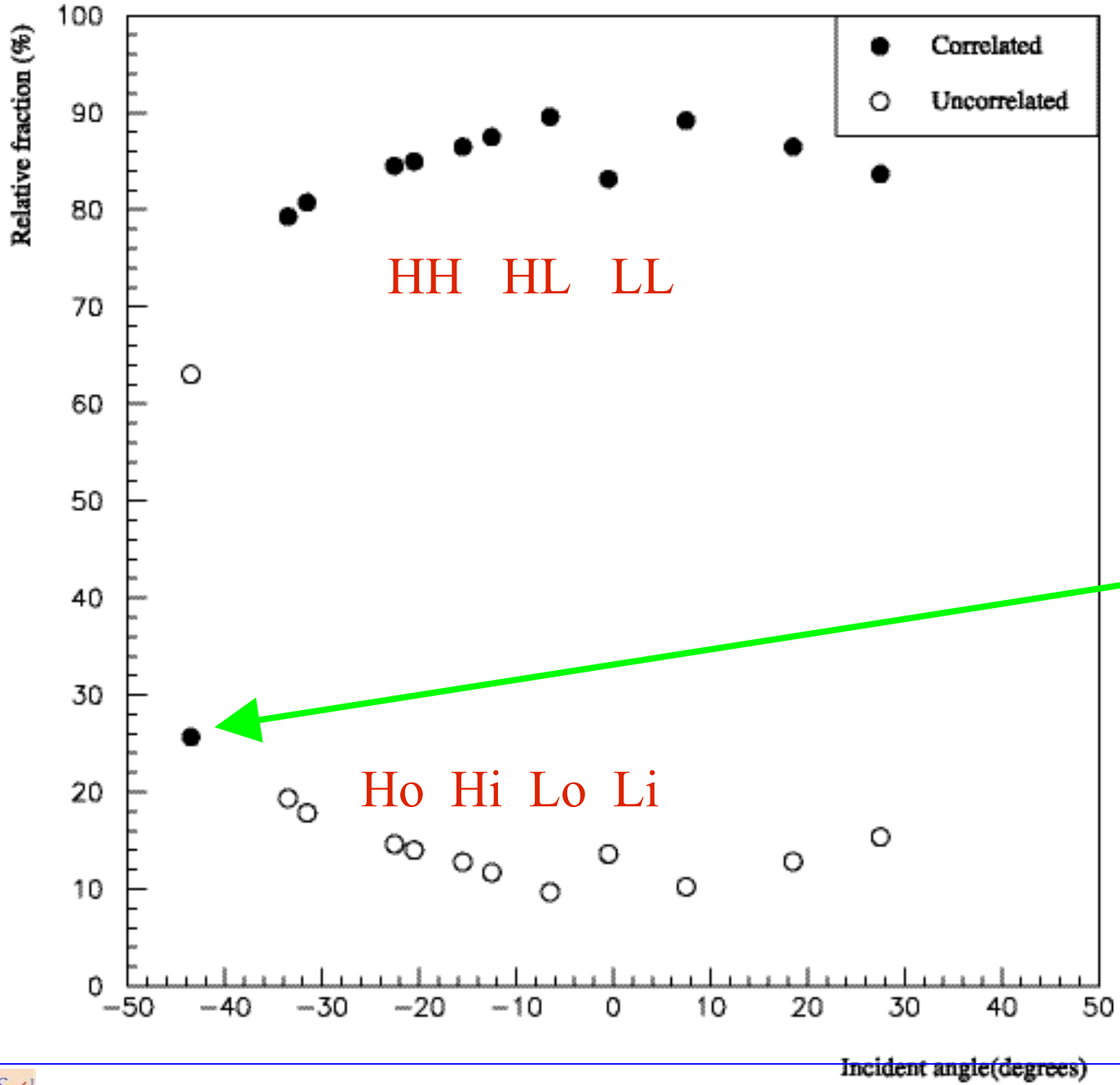
$$\text{efficiency} = \frac{\text{trig. at 14bx}}{\text{all events}}$$

tracks hitting 2 I-beams

~ 98-99 %

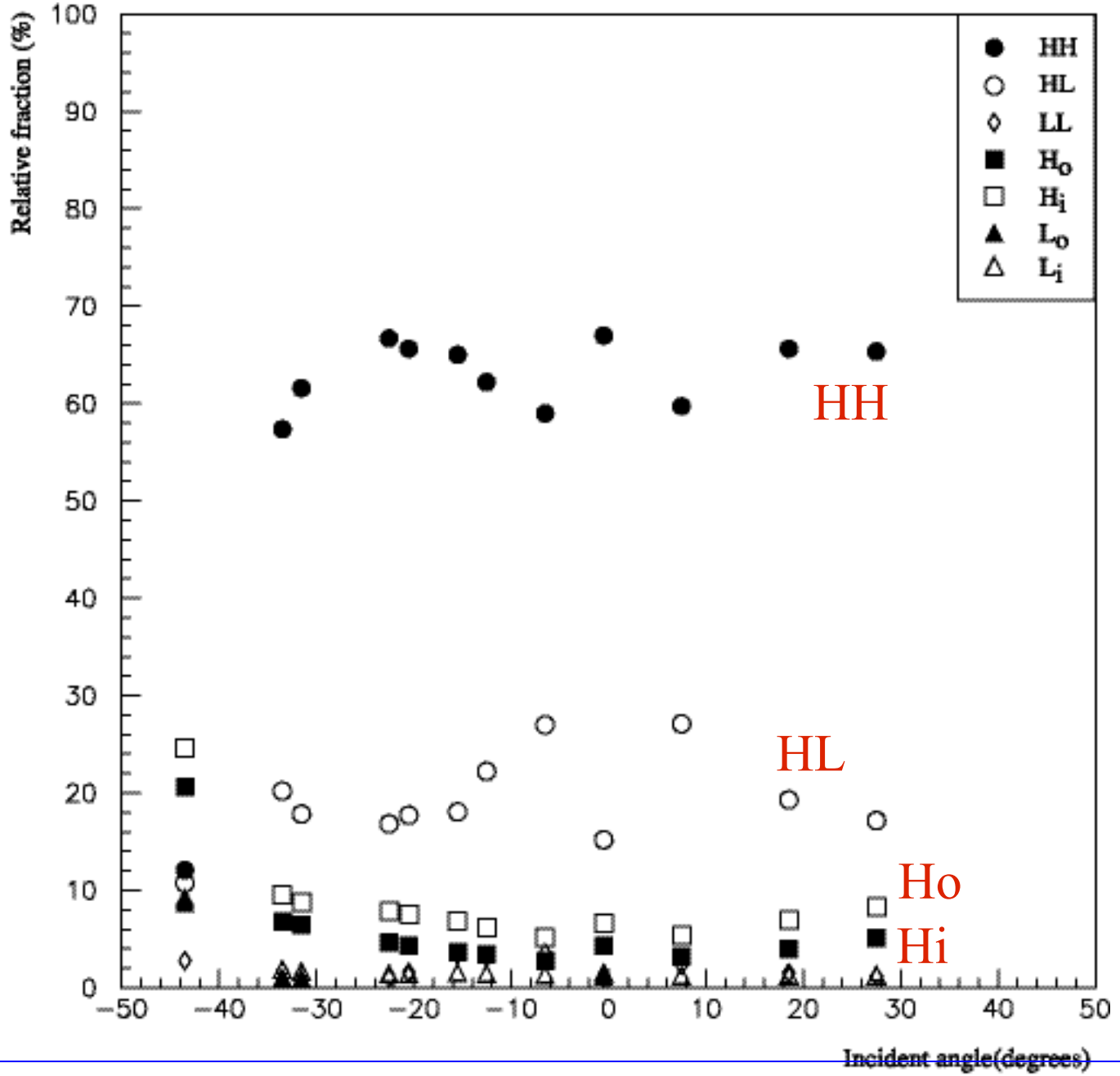
efficiency up to 35^0

BX Efficiency -2

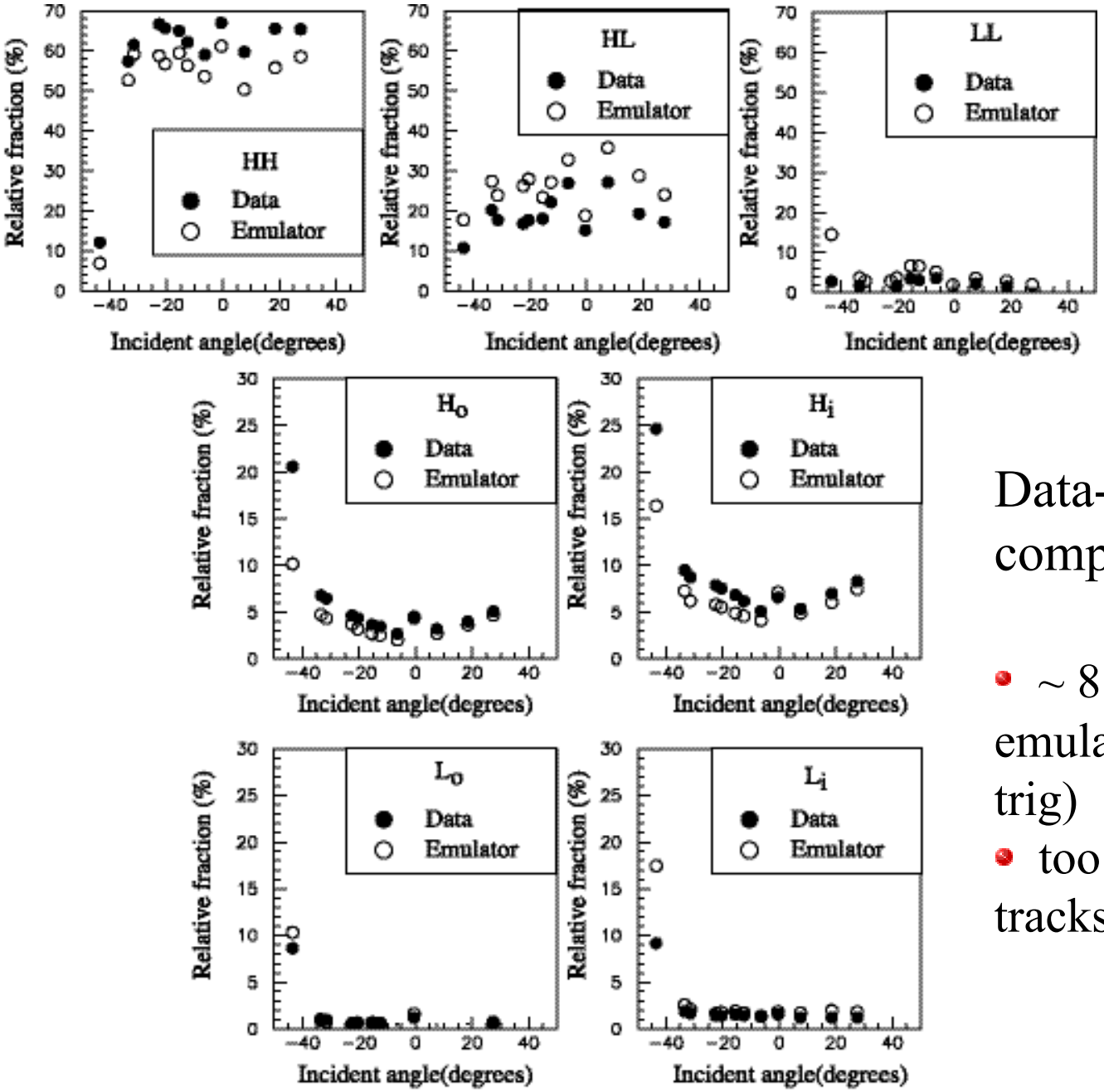


drop of correlated efficiency at large angles due to geometrical cuts (single BTI 56º traco 42º)

BX Efficiency - 3



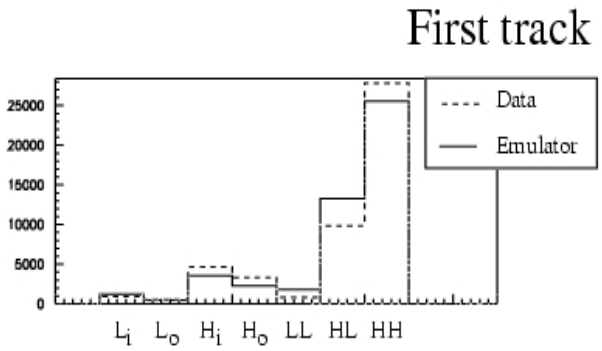
BX Efficiency - 4



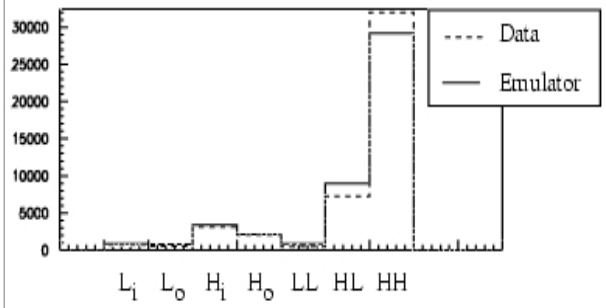
Data-emulator comparison:

- ~ 8 % HH trig deficit in emulator (compensated by HL trig)
- too large amount of second tracks in emulator

BX First Track Efficiency

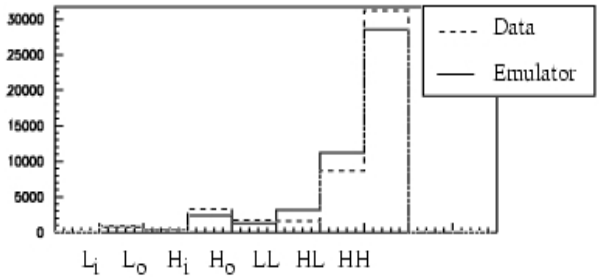


Incident angle -35 degrees

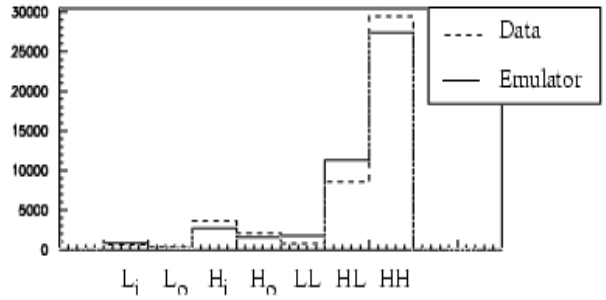


Incident angle 0 degrees

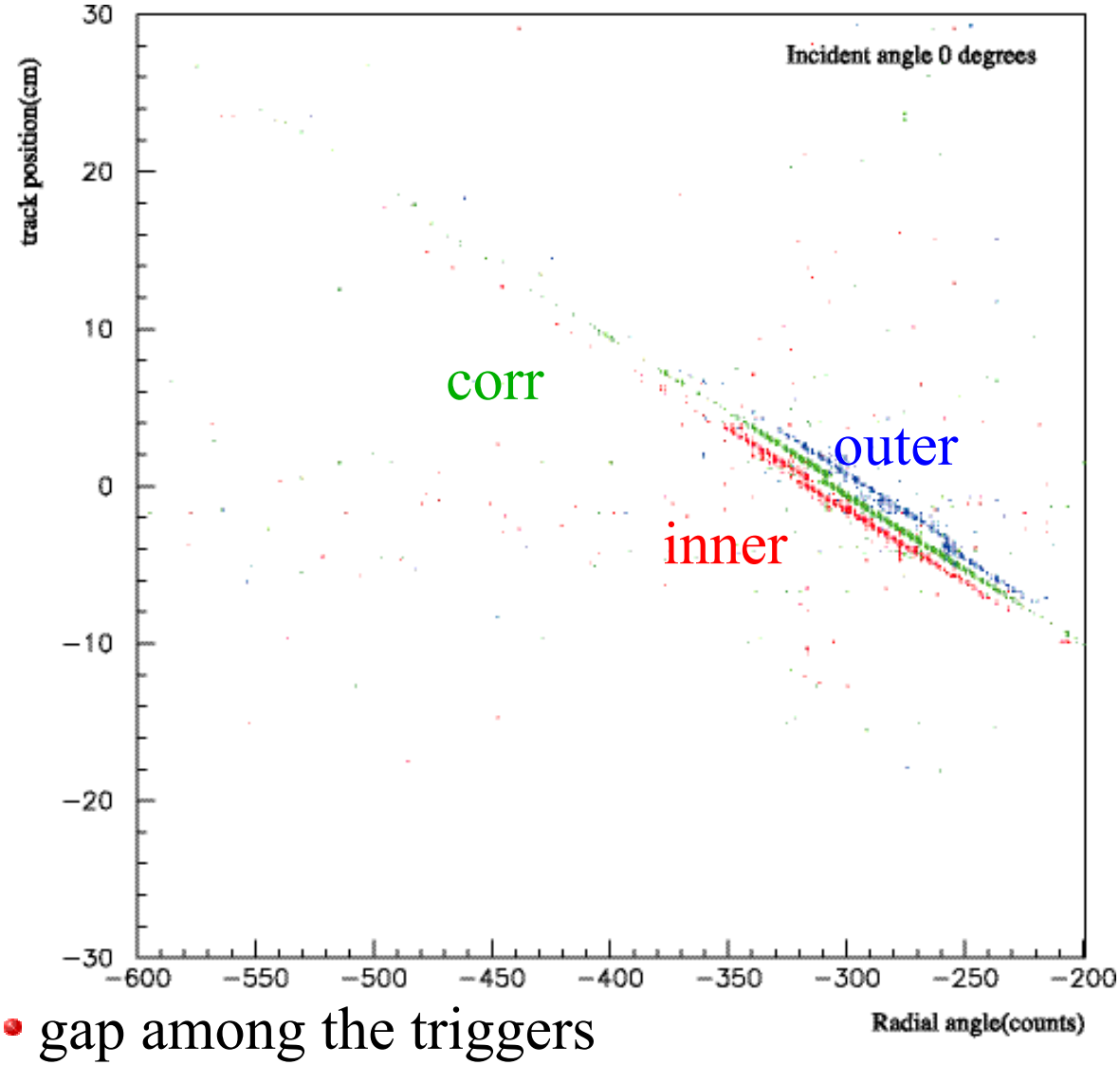
Incident angle -15 degrees



Incident angle 20 degrees



Fit vs Trigger Output - 1



position from fit

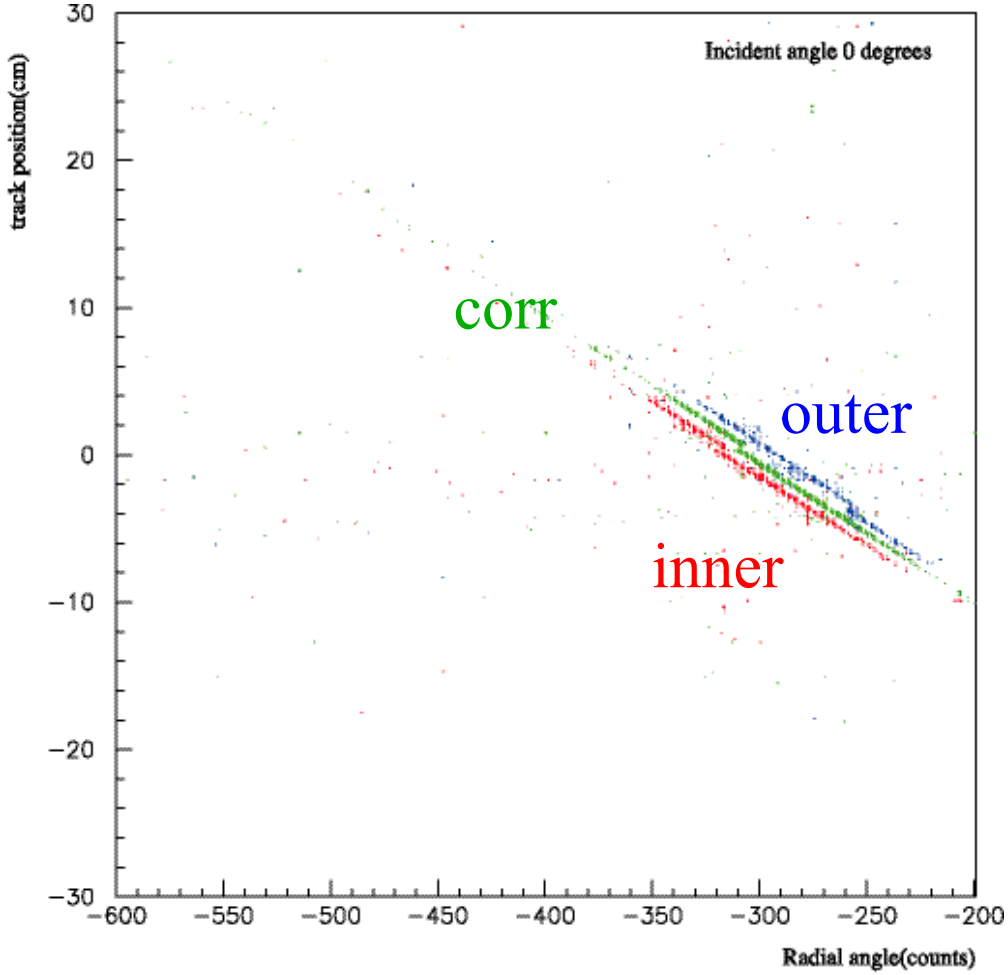
vs

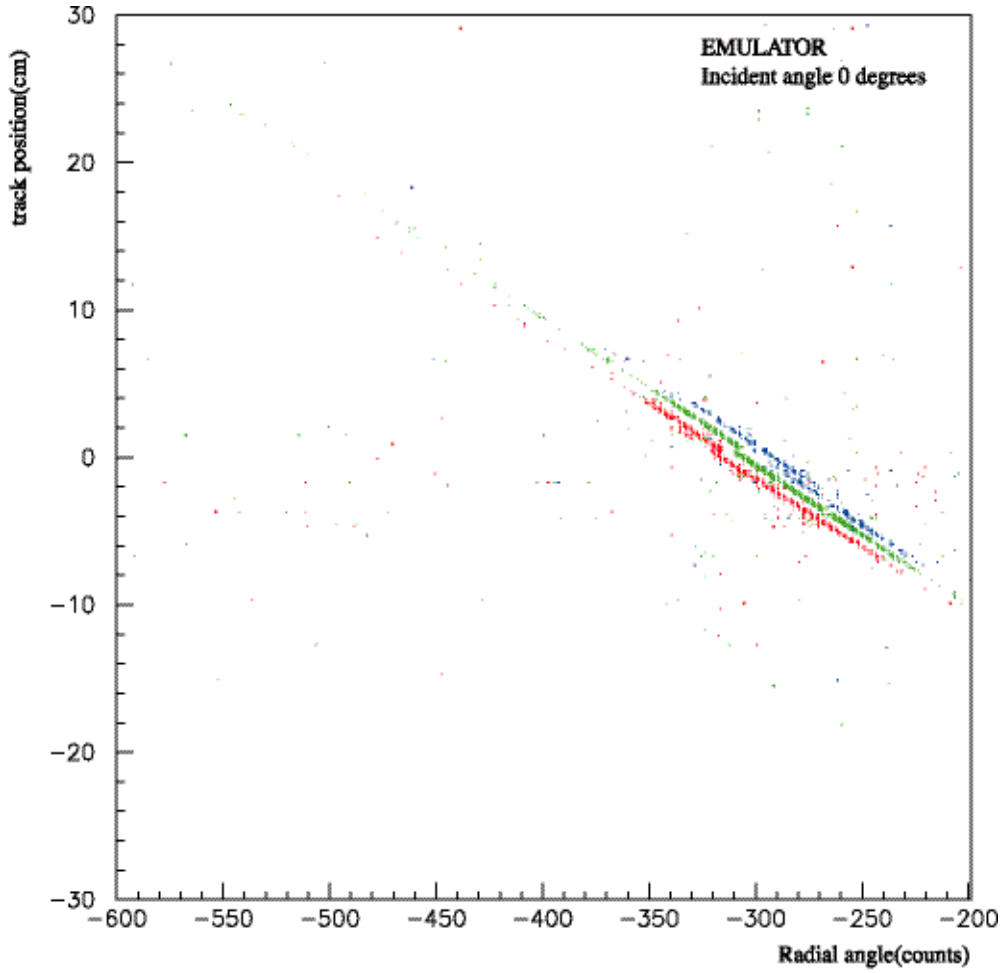
radial angle from trigger

- gap among the triggers
- broken lines: border between traco 9 and 10

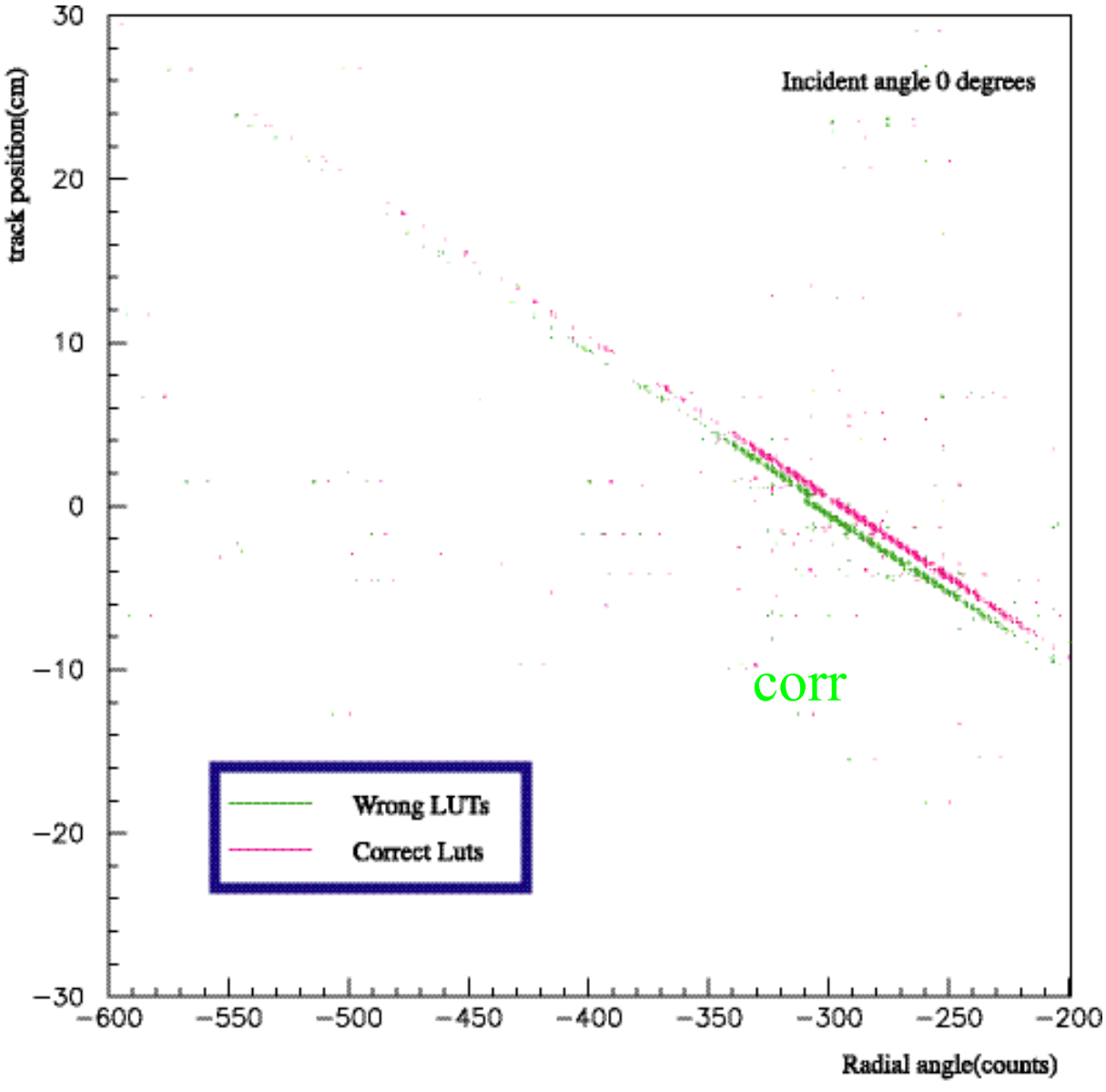
Fit vs Trigger comparison - 2

emulation shows the same behaviour !



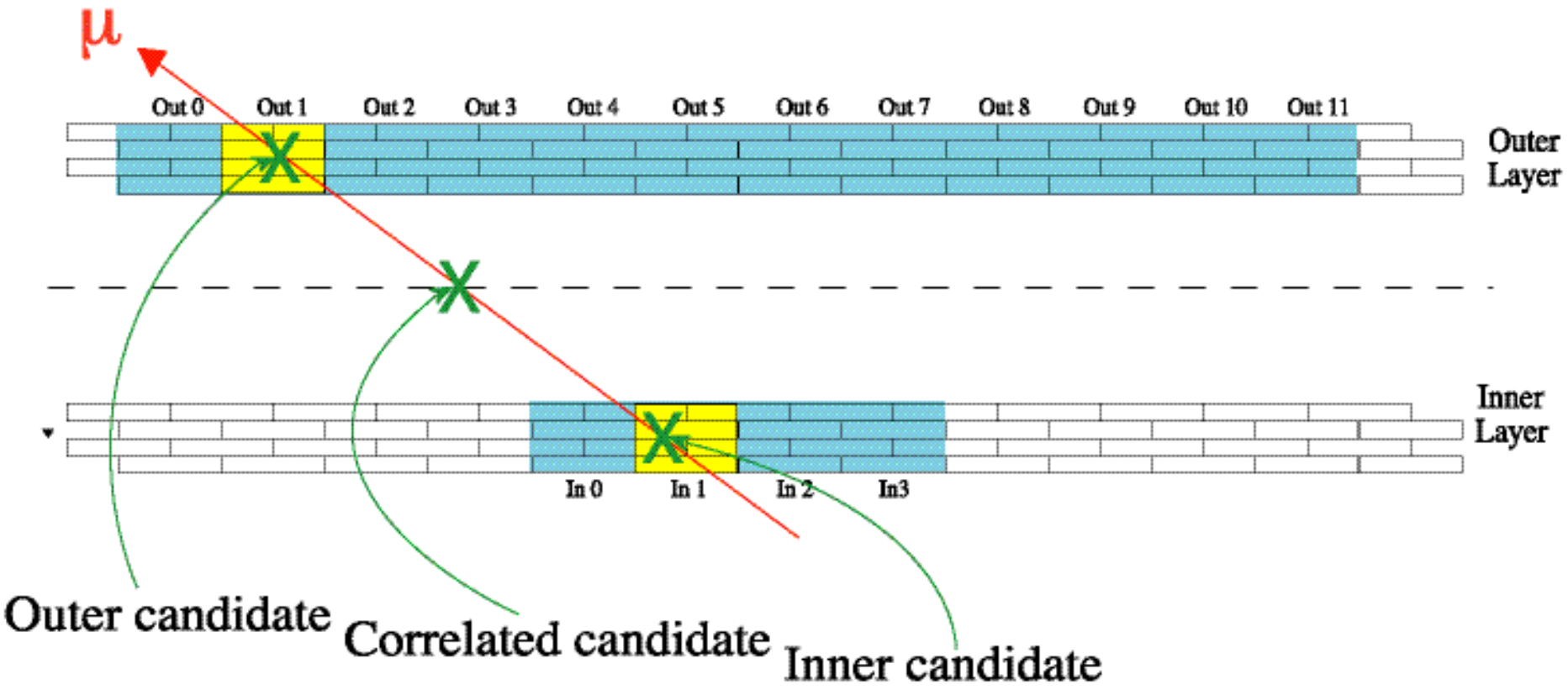


Fit vs Trigger Comparison - 3



emulation with correct LUTs
shows
the right correlation

Fit vs Trigger Comparison - 4

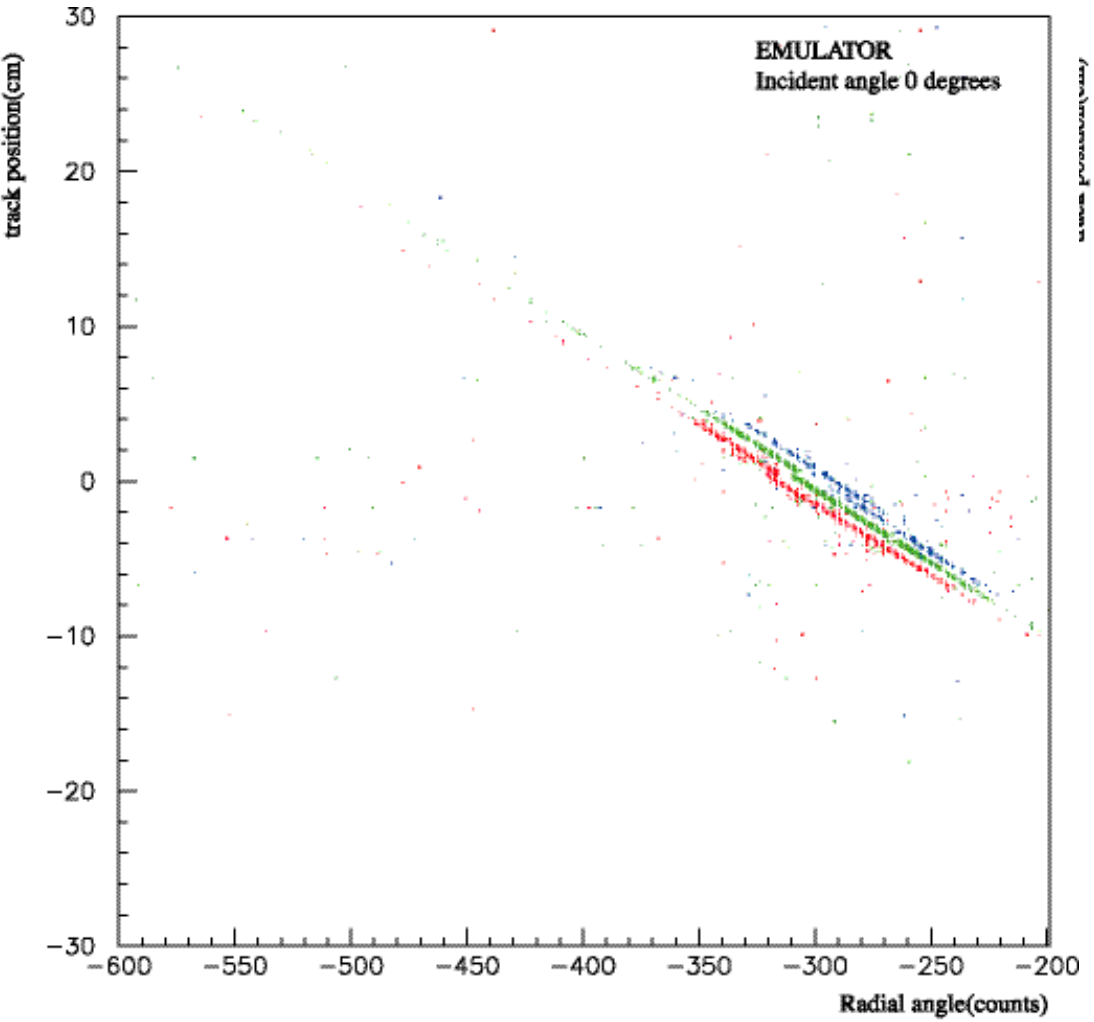


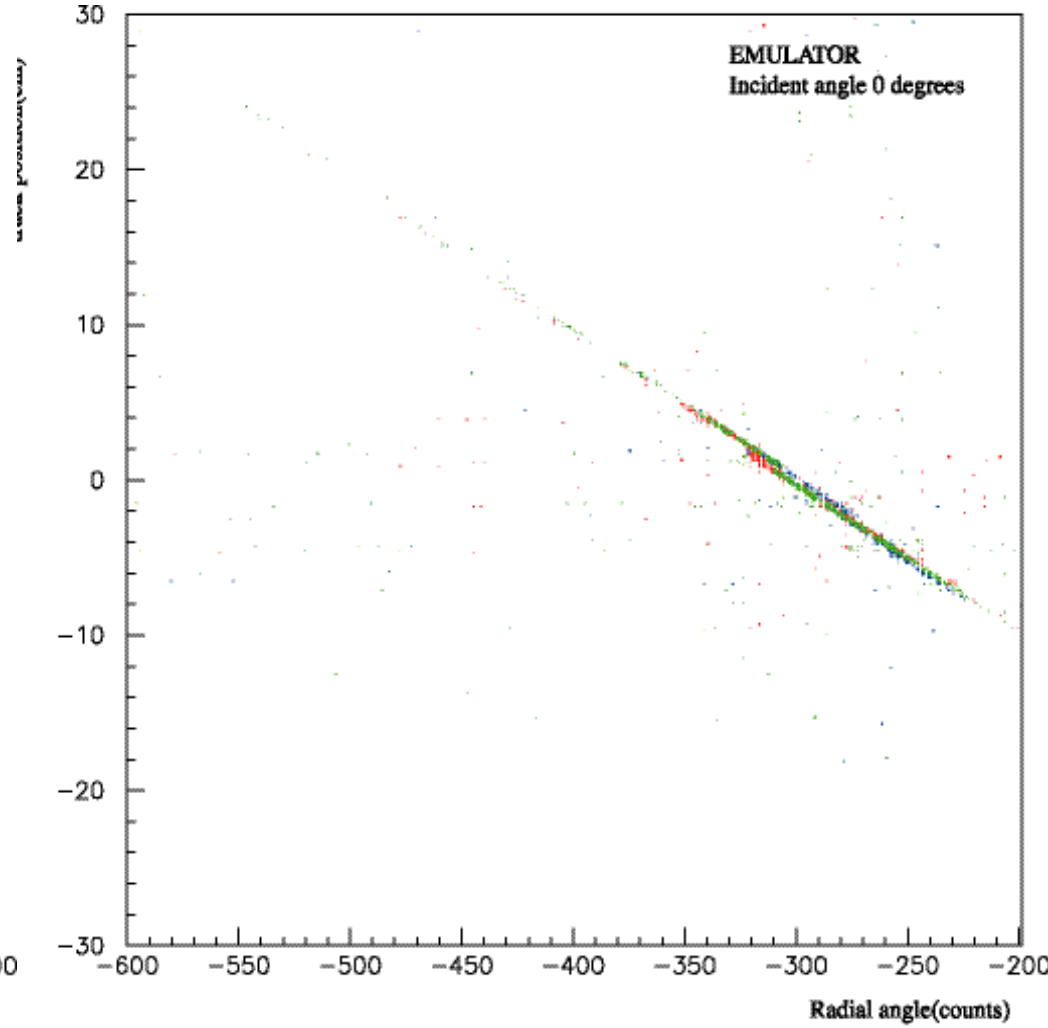
- TRACO Look Up Tables are computed in different positions depending on candidate quality
- Track fit from Drift times is always performed at chamber center
- LUTs and fit use different reference frames

⇒ Need extrapolation and frame conversion before comparison

Fit vs Trigger Comparison -5

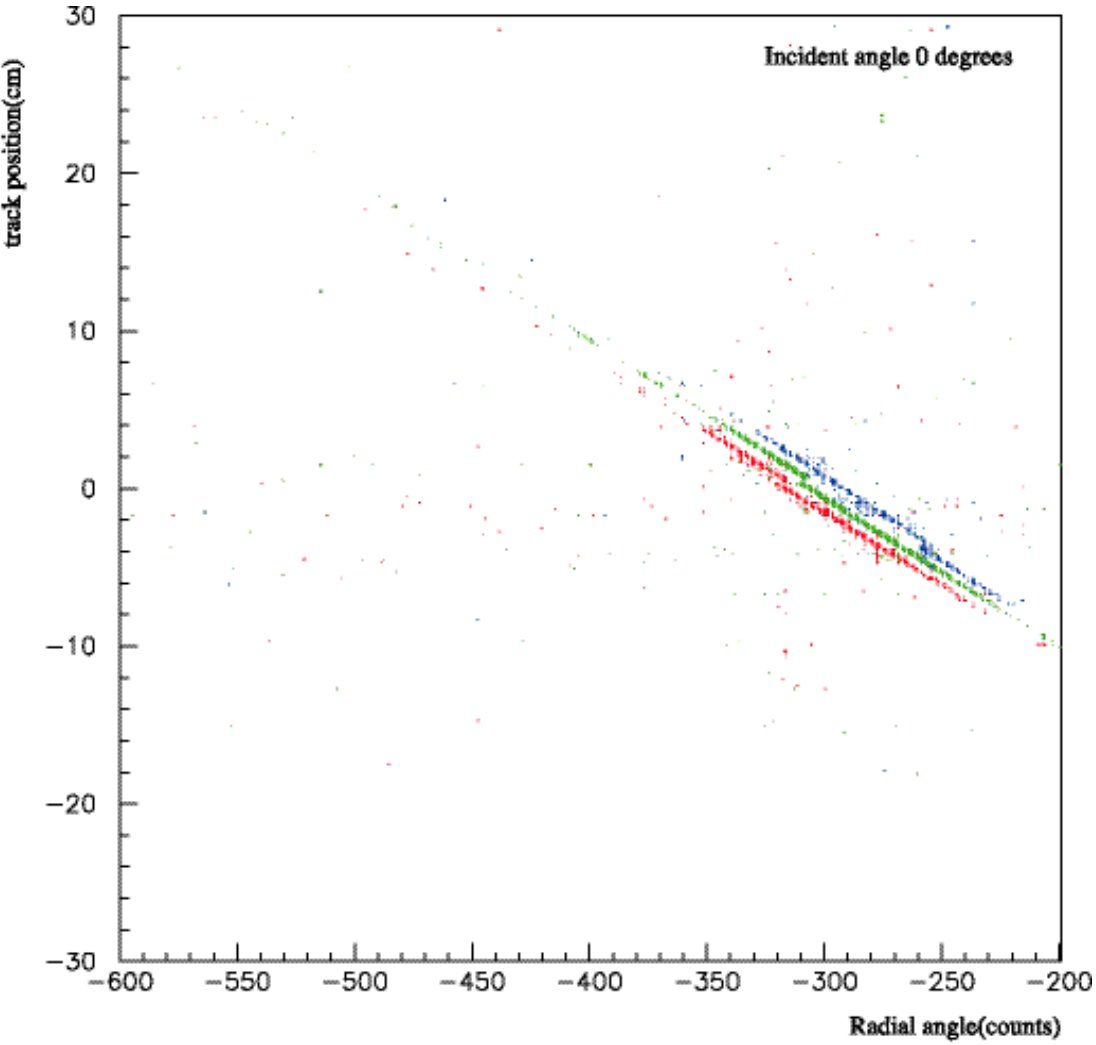
after fitted track extrapolation

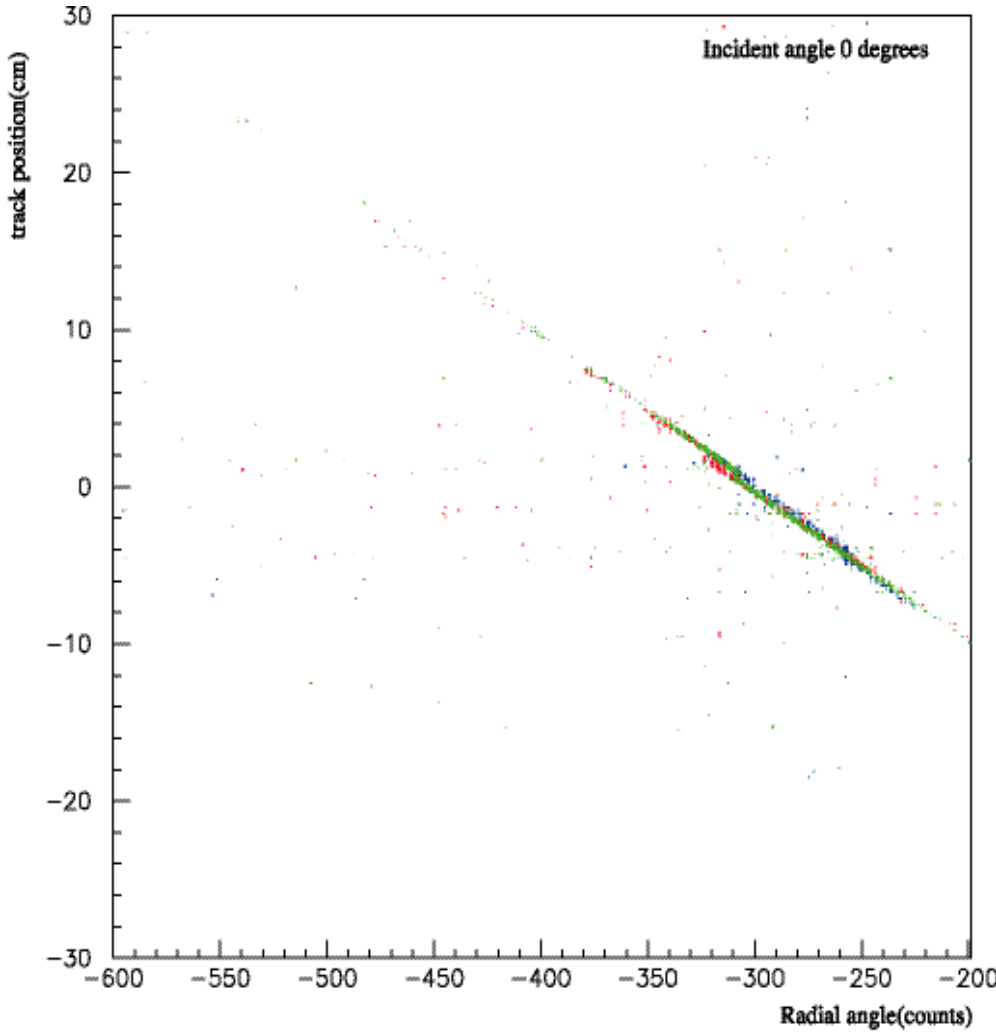




Fit vs Trigger comparison - 6

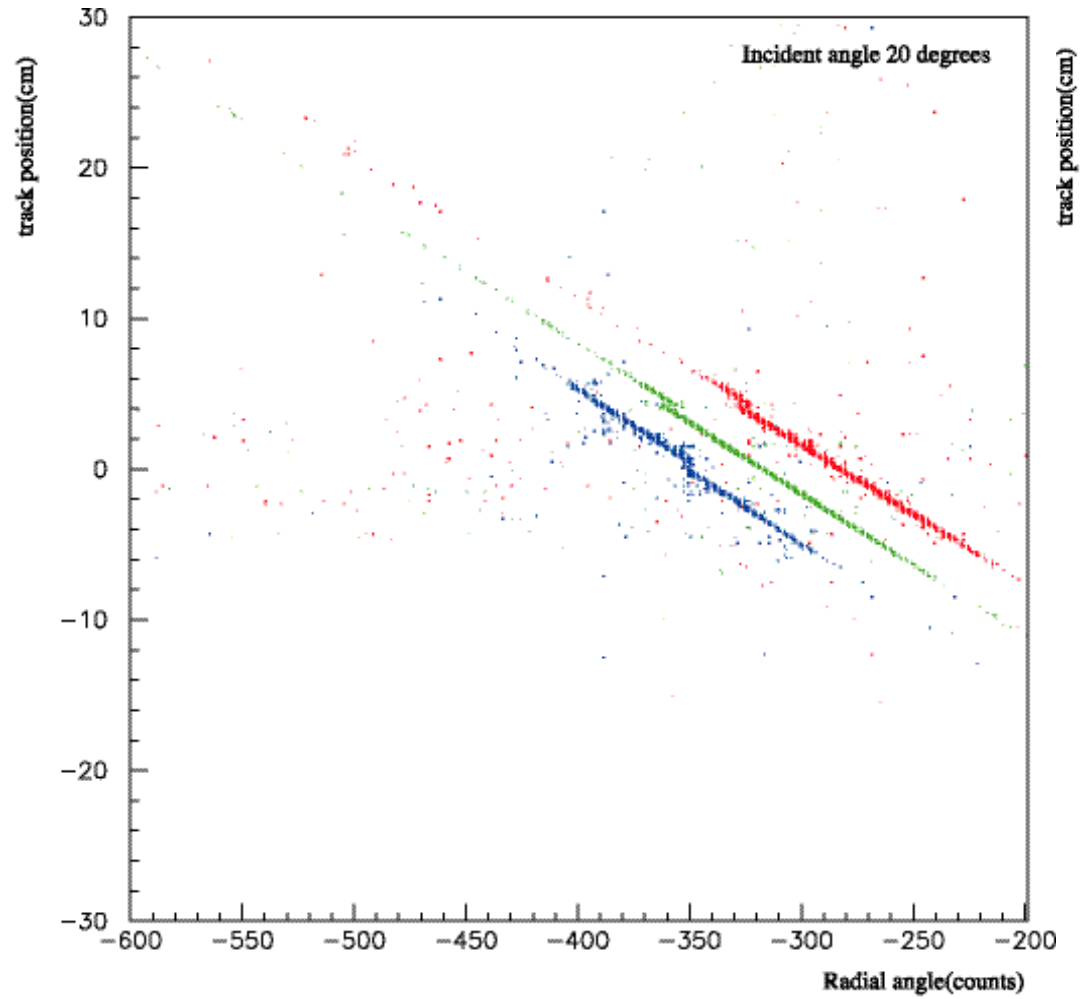
extrapolation at 0°

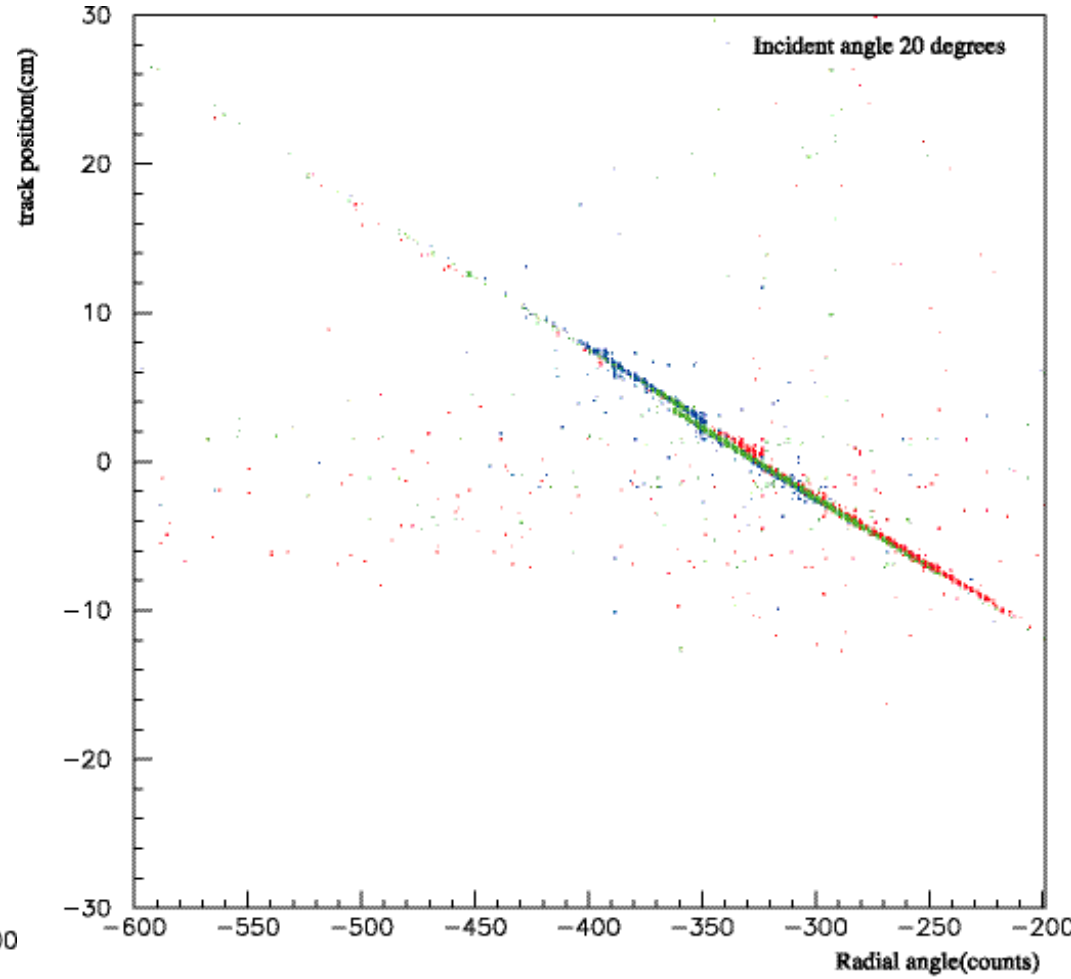




Fit vs Trigger comparison - 7

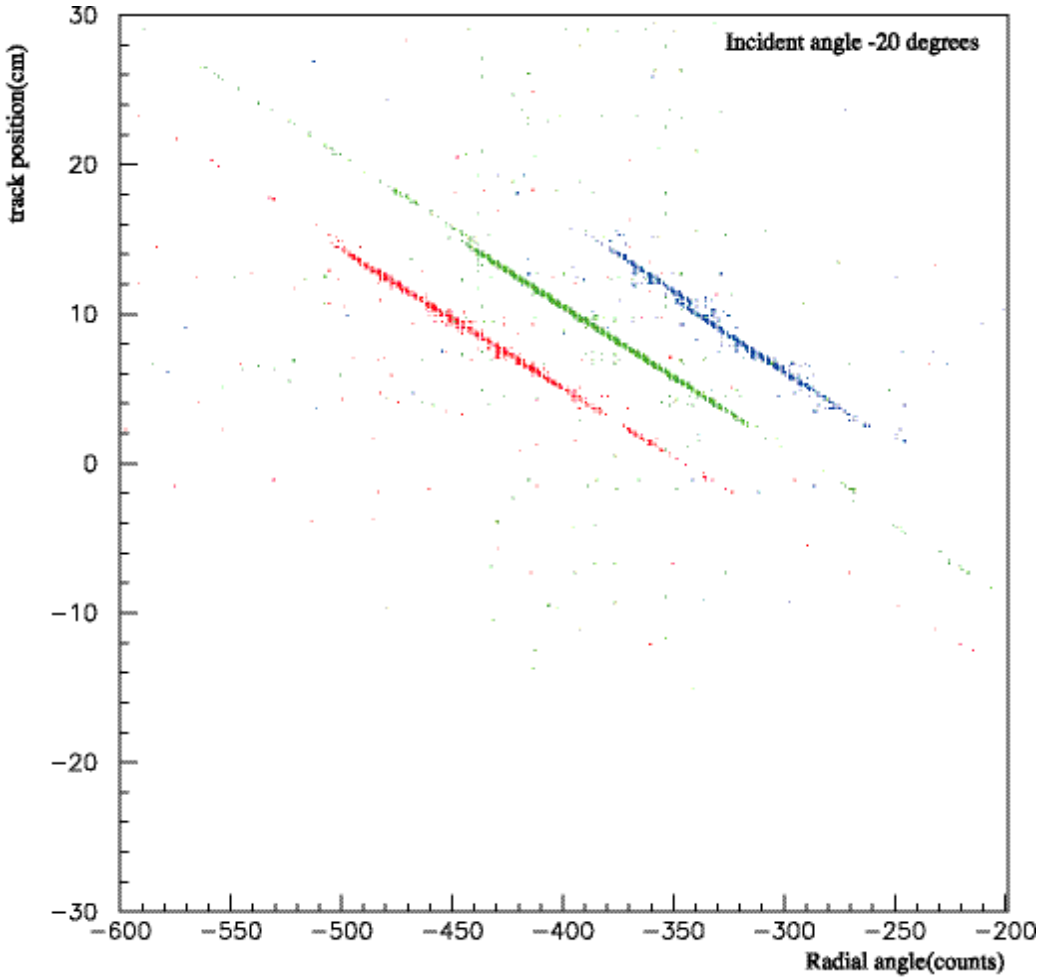
extrapolation at 20^o

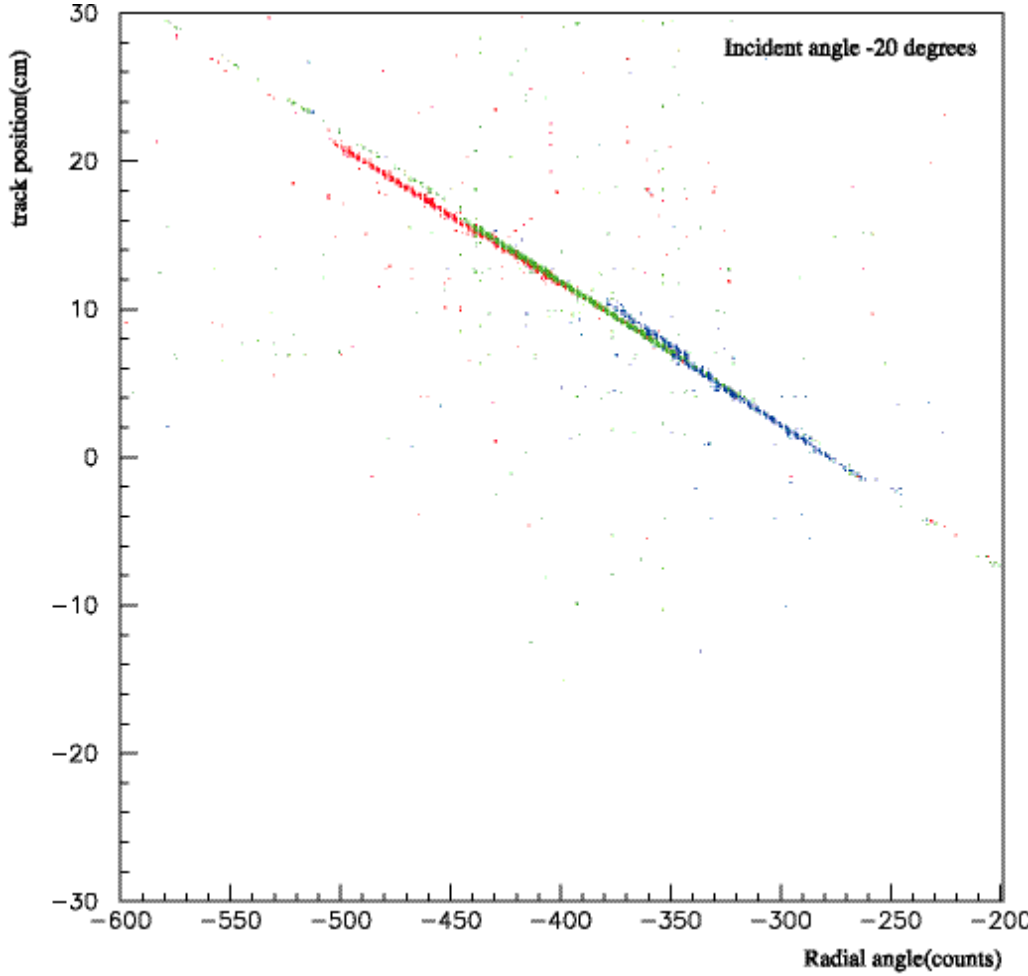




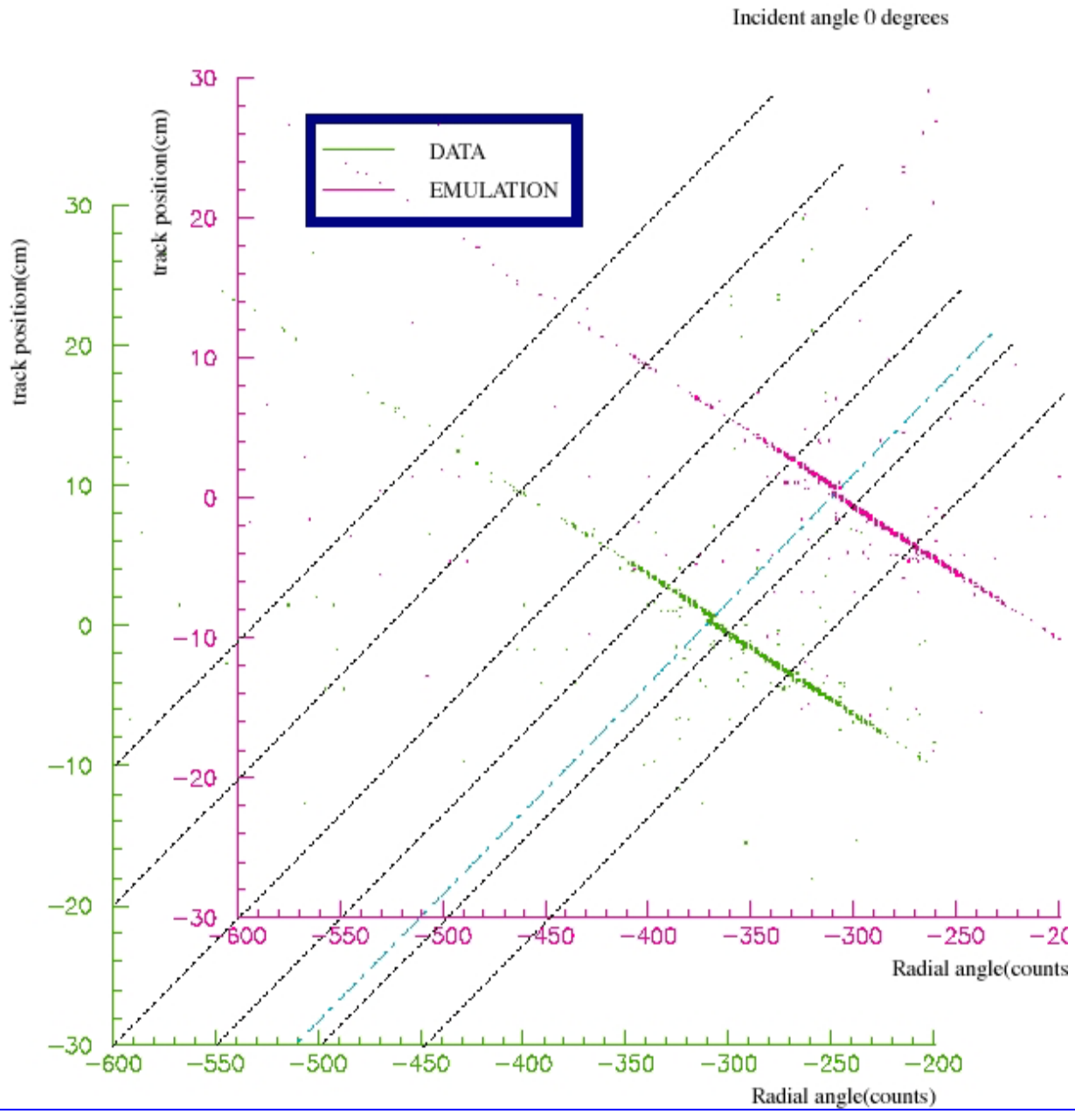
Fit vs Trigger comparison - 8

extrapolation at -20^{o}



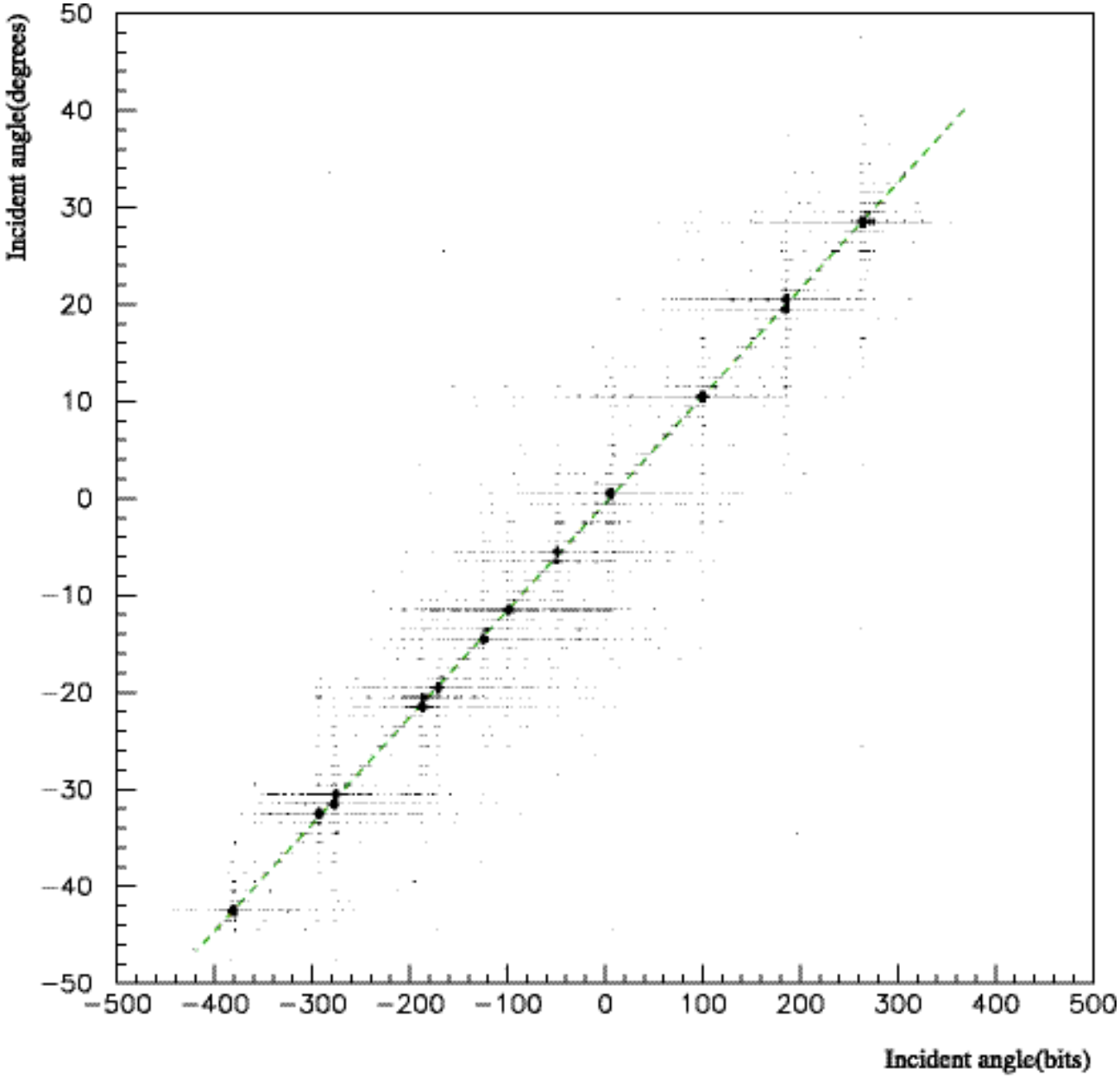


Data / Emulation comparison



same behaviour !

Fit vs Trigger incident angle

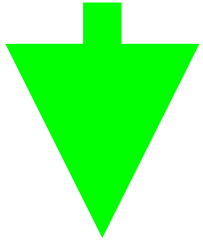


incident angle
(computed from bending)
vs
incident angle from fit
(no magn.field bending!)

very nice correlation

Test Beam results:

- good integration of several hard/software devices
- complete information about performance of trigger algorithms
- good trigger performance
- emulator behaviour close to hardware results



muon local drift tube trigger in CMS substantially correct