K_s (and e±) PXD rescue

formerly known as „6-layer online tracking“

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für Bildung
und Forschung

What is this about ?

- ONLINE tracking (Onsen, DATCON, HLT)

- PXD DAQ is actively deleting PXD raw data (if no ROI generated)
  $\rightarrow$ if deleted, PXD hits will never reach tape
  currently planned: CLUSTER RESCUE
  low $p_T \rightarrow$ high dE/dx $\rightarrow$ high cluster charge
  requires a threshold,
  today: seed pixel charge 1.8 x $dE/dx|_{min}$

- but not only low p_T leads to non-ROI
  - HLT
    - track finder requires 3 hits in 4 SVD layers
  - DATCON
    - requirement on the vertex
      (x=0,y=0) is reference point in conformal transformation

PXD Data Acquisition and Reduction System

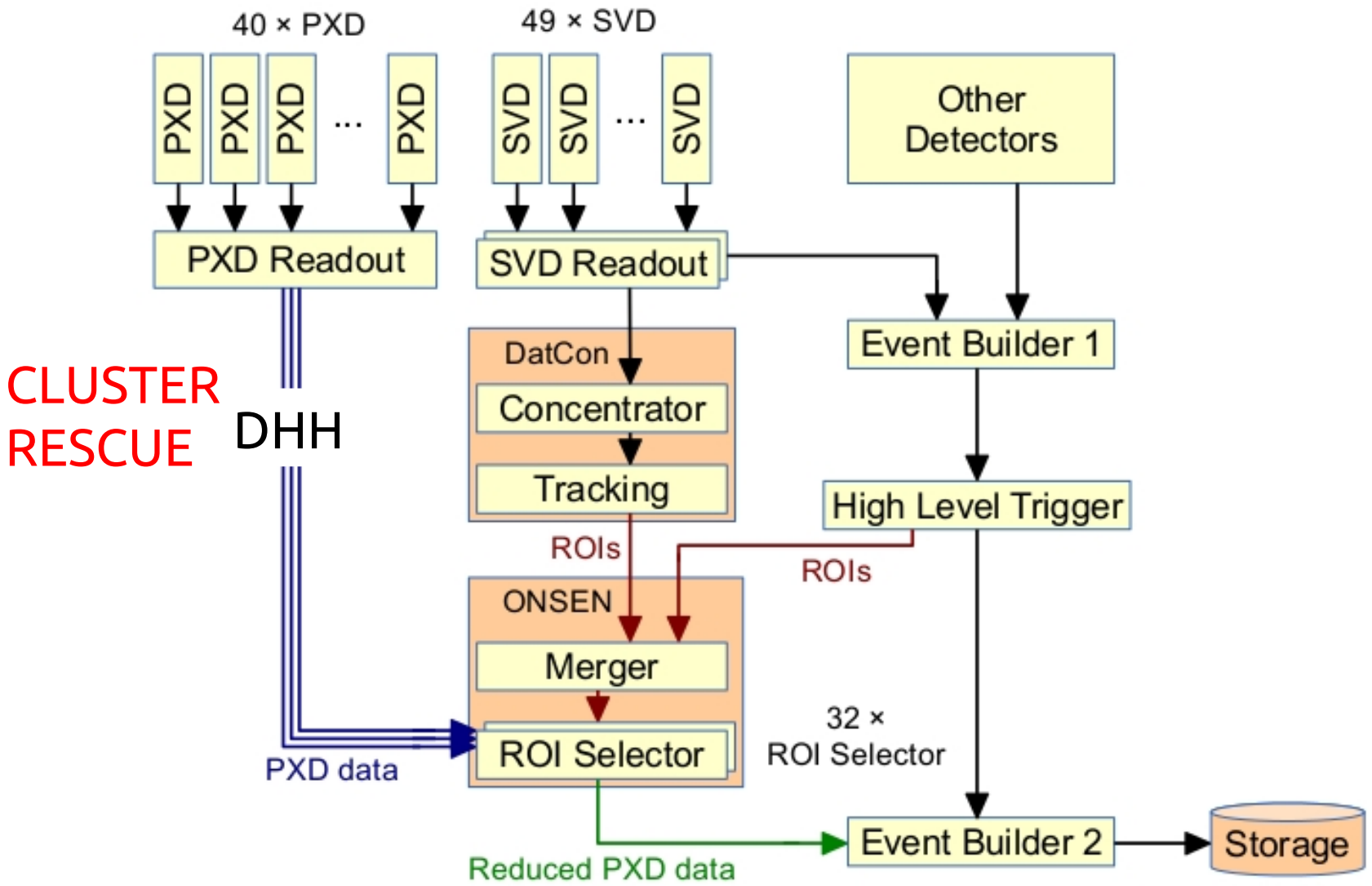
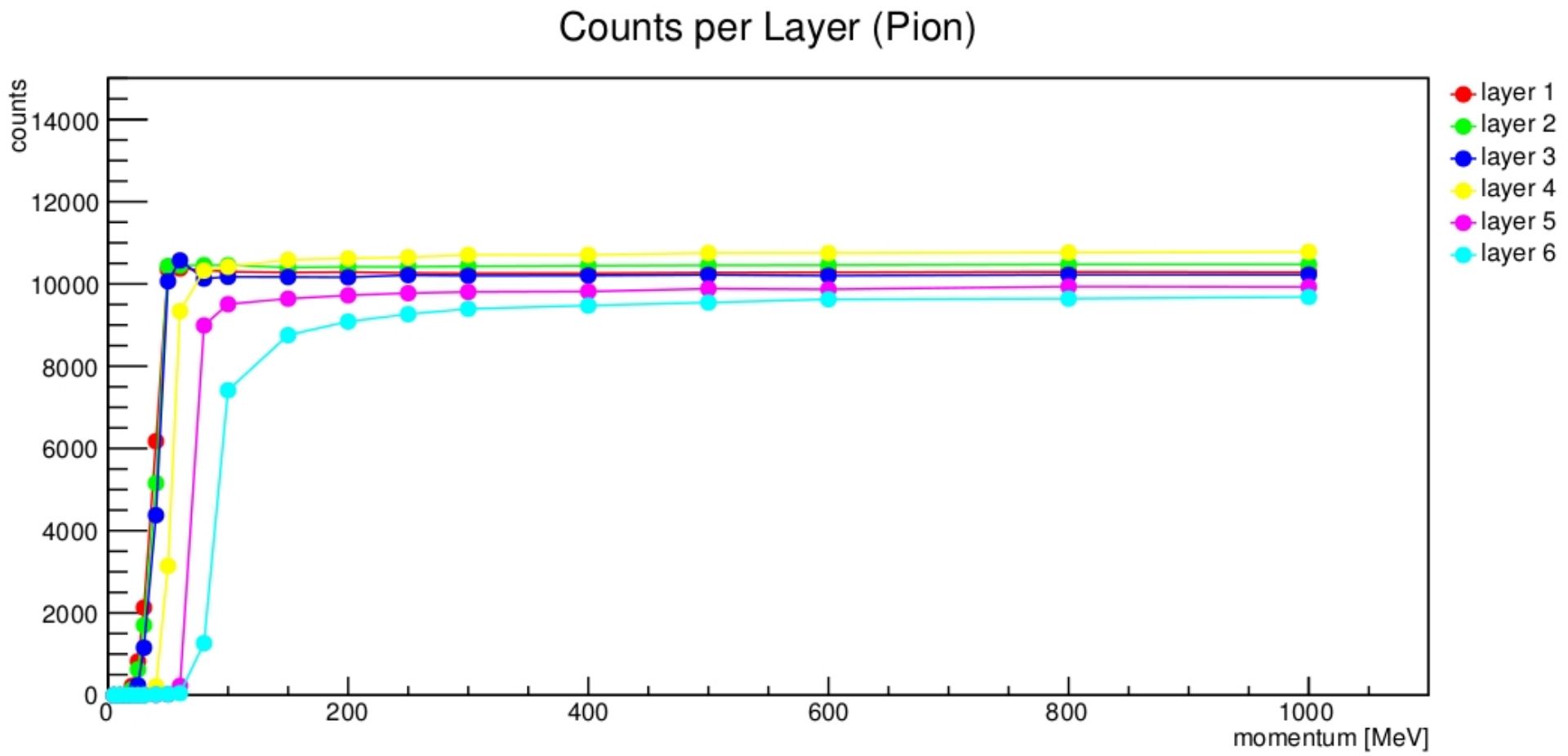
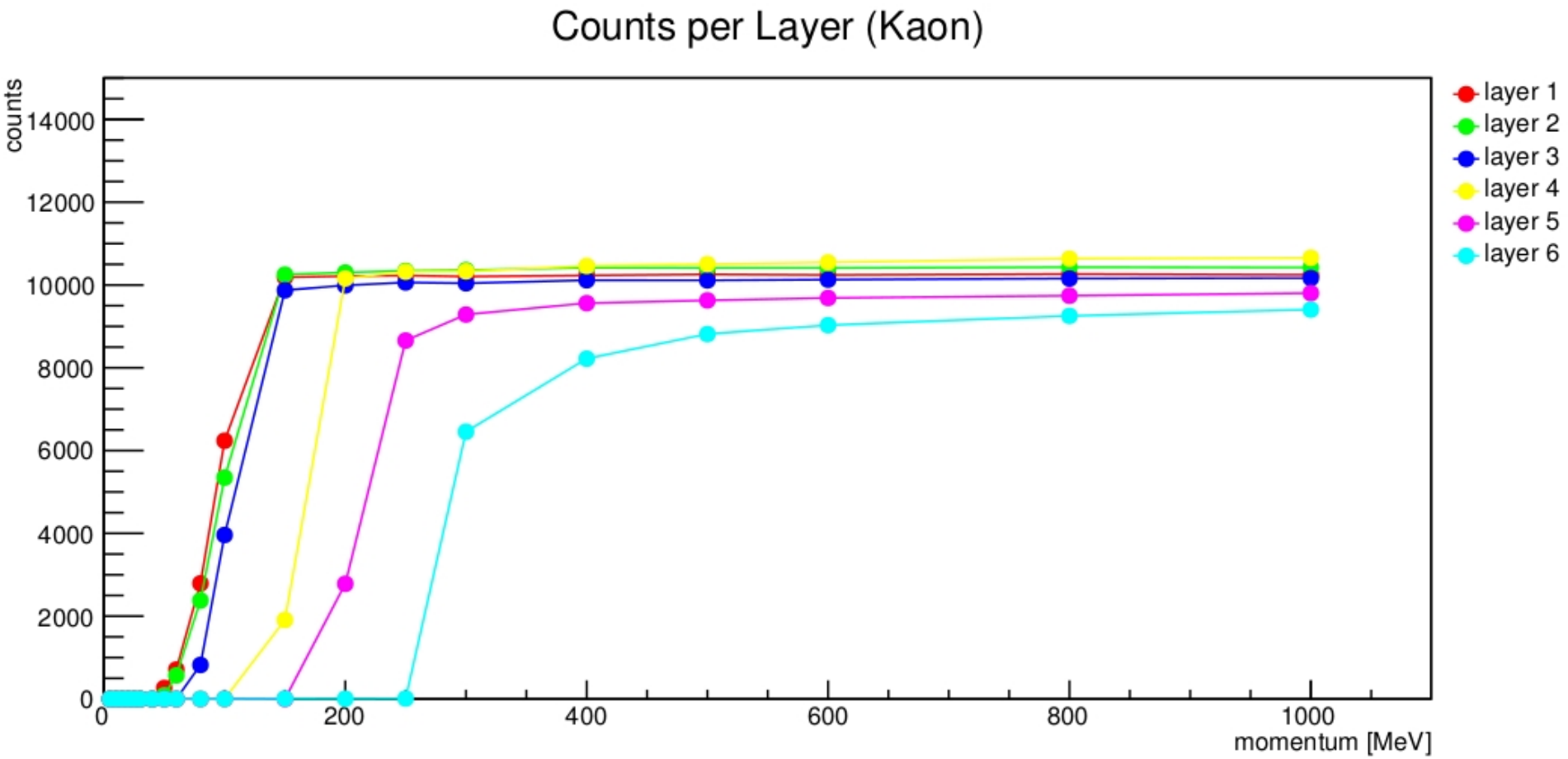


Diagram of the Belle II VXD DAQ for setup at KEK

Today: no algorithm yet, but „counting VXD layers“
Example: single charged pions from primary vertex (box generator)



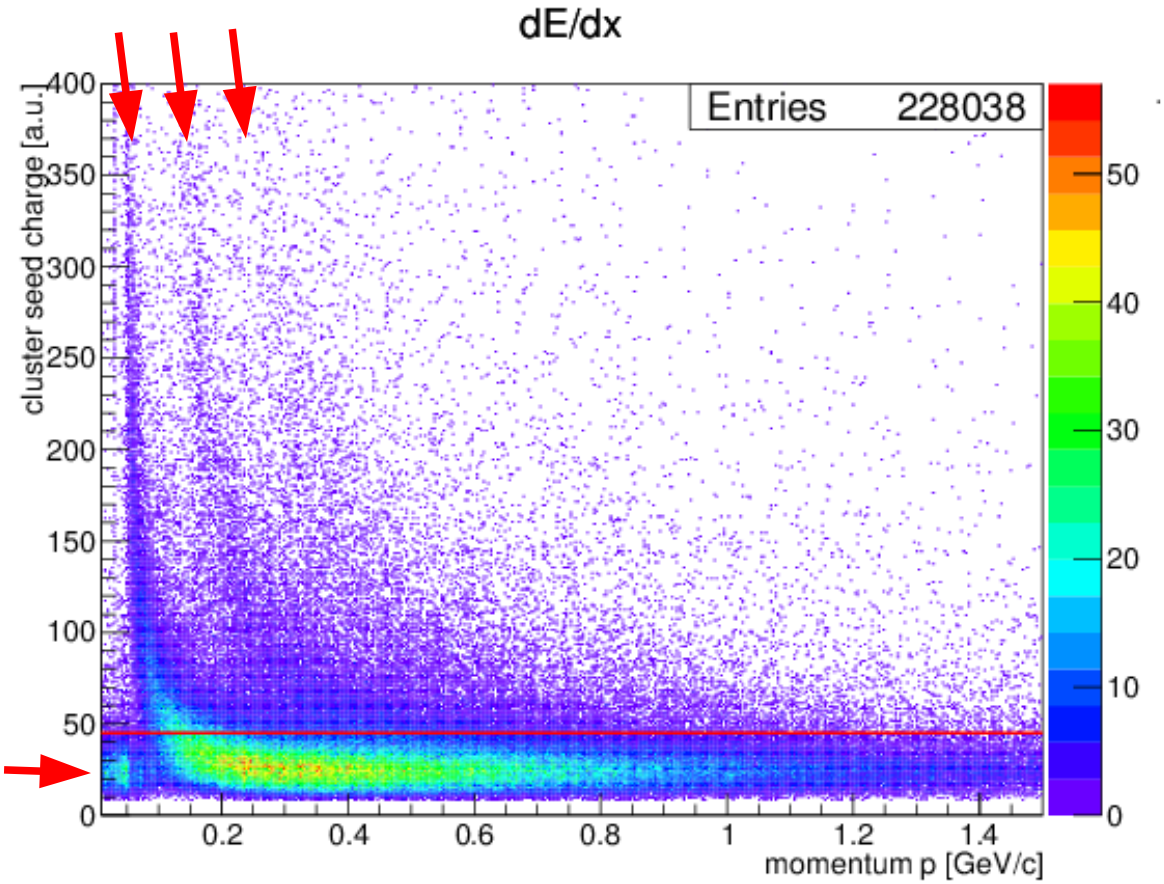
Low pT „turn-on“ effect is more significant for kaons



however, almost all of „lost“ PXD clusters
are recovered by CR (dE/dx is large enough)
was also conclusion of VXD-only tracking SeeVogh meeting 14.07.2014

Energy Loss in PXD

pions kaons protons



no cluster rescue

„CLUSTER RESCUE" (Karlsruhe): factor 1.8 x minimum ionizing

→ today: require cluster seed charge of 45

K_s Rescue

what is the problem ?

$K_s \rightarrow \pi+ \pi-$

if 1 pion less than 3 hits in SVD and cluster charge too low
then $\rightarrow$ no PXD RAW hits for that pion
$\rightarrow$ worse vertex resolution for complete K_s
(still, SVD hits will be on tape)
$\rightarrow$ probable worse Δz for time-dependent CPV

on the next few slides:

inclusive B decays with basf2

10.000 events

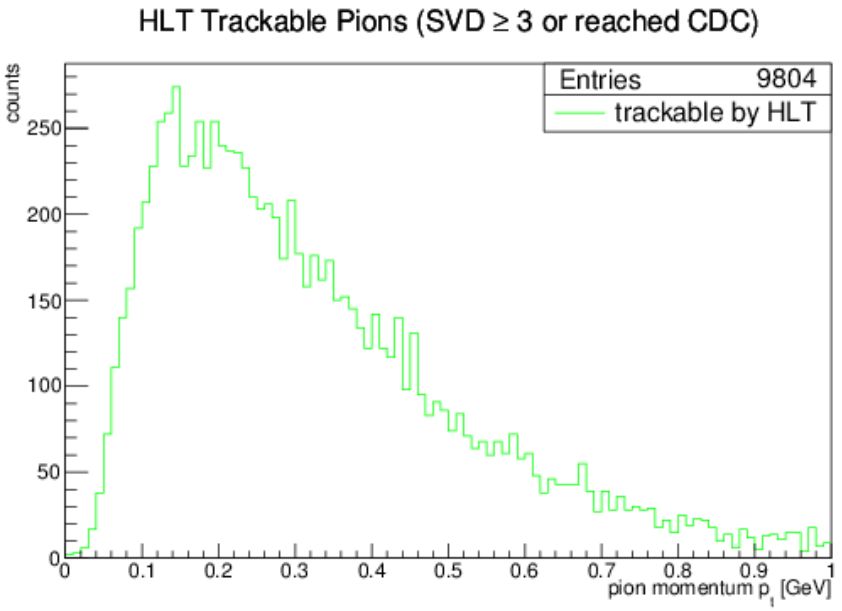
cluster rescue at 1.8 x $dE/dx|_{min}$
in absolute numbers: 45 (for example events)

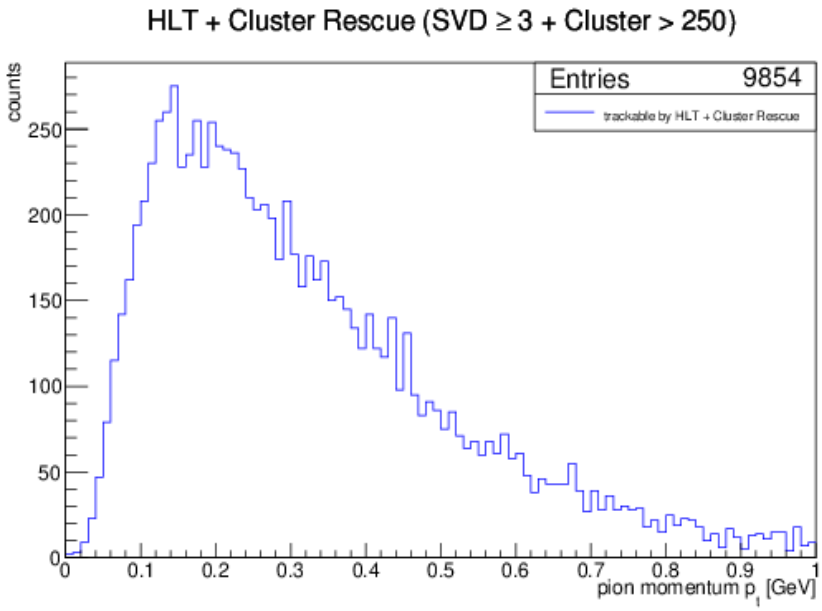
$\pi^{\pm}$ trackable by

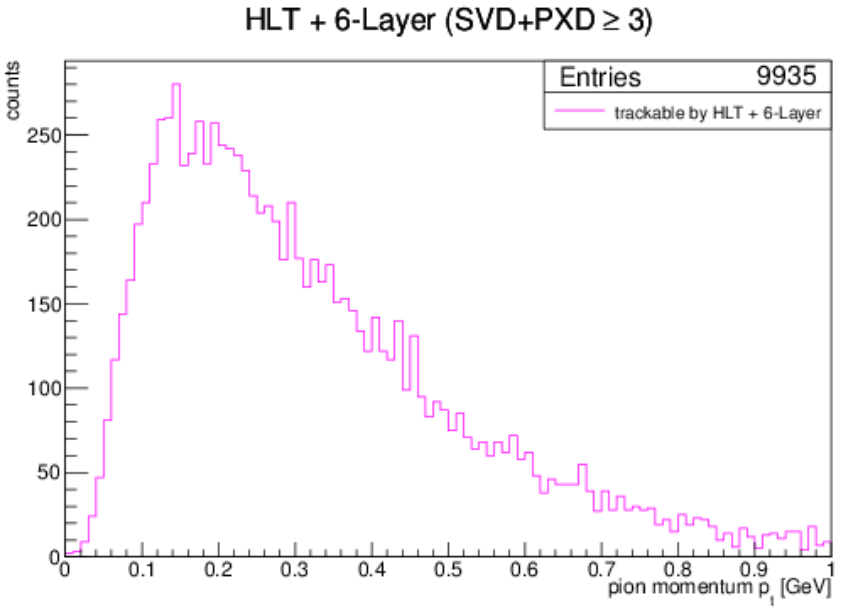
HLT/DATCON

HLT/DATCON + Cluster Rescue

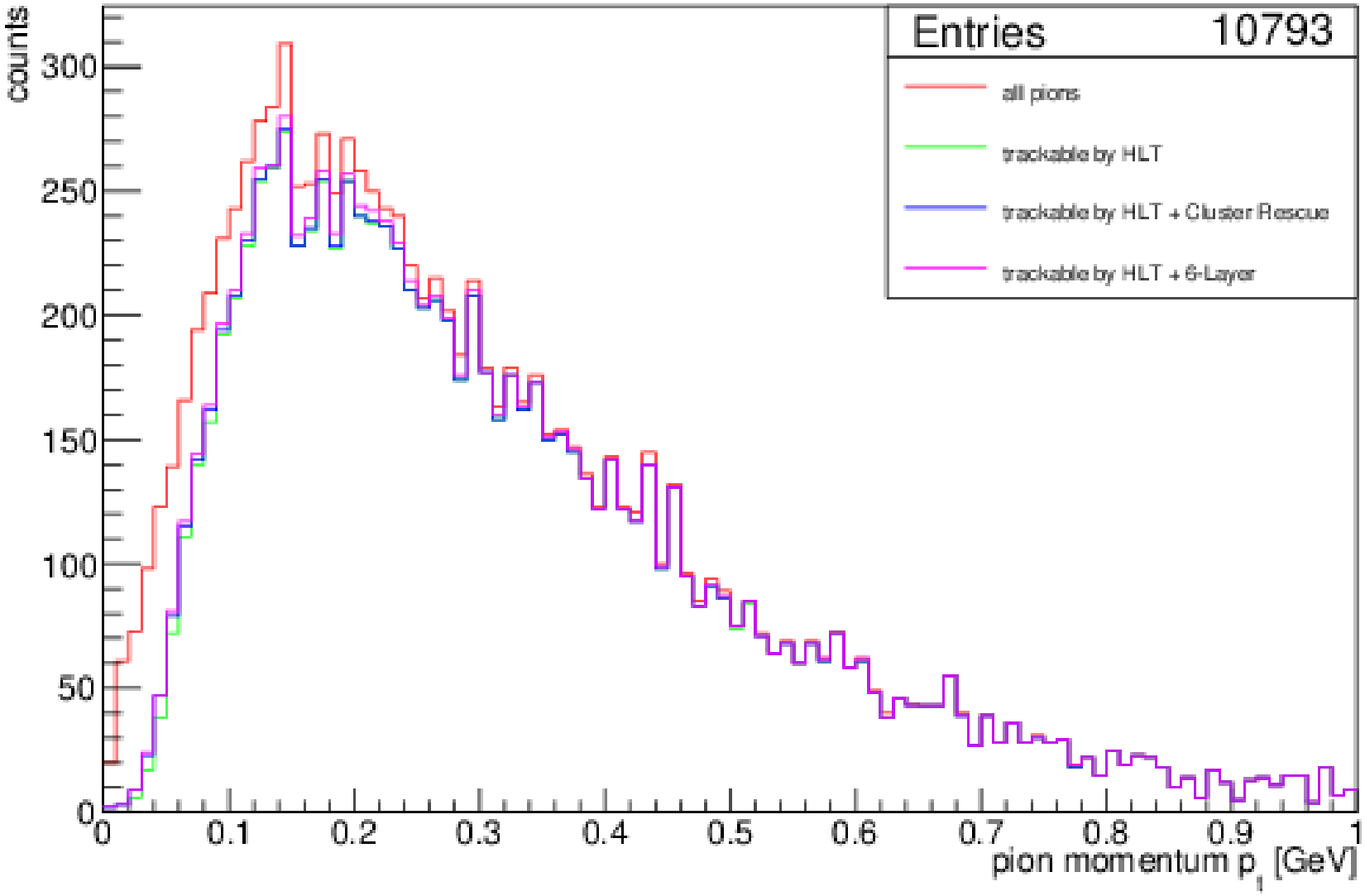
HLT/DATCON + 6-Layer



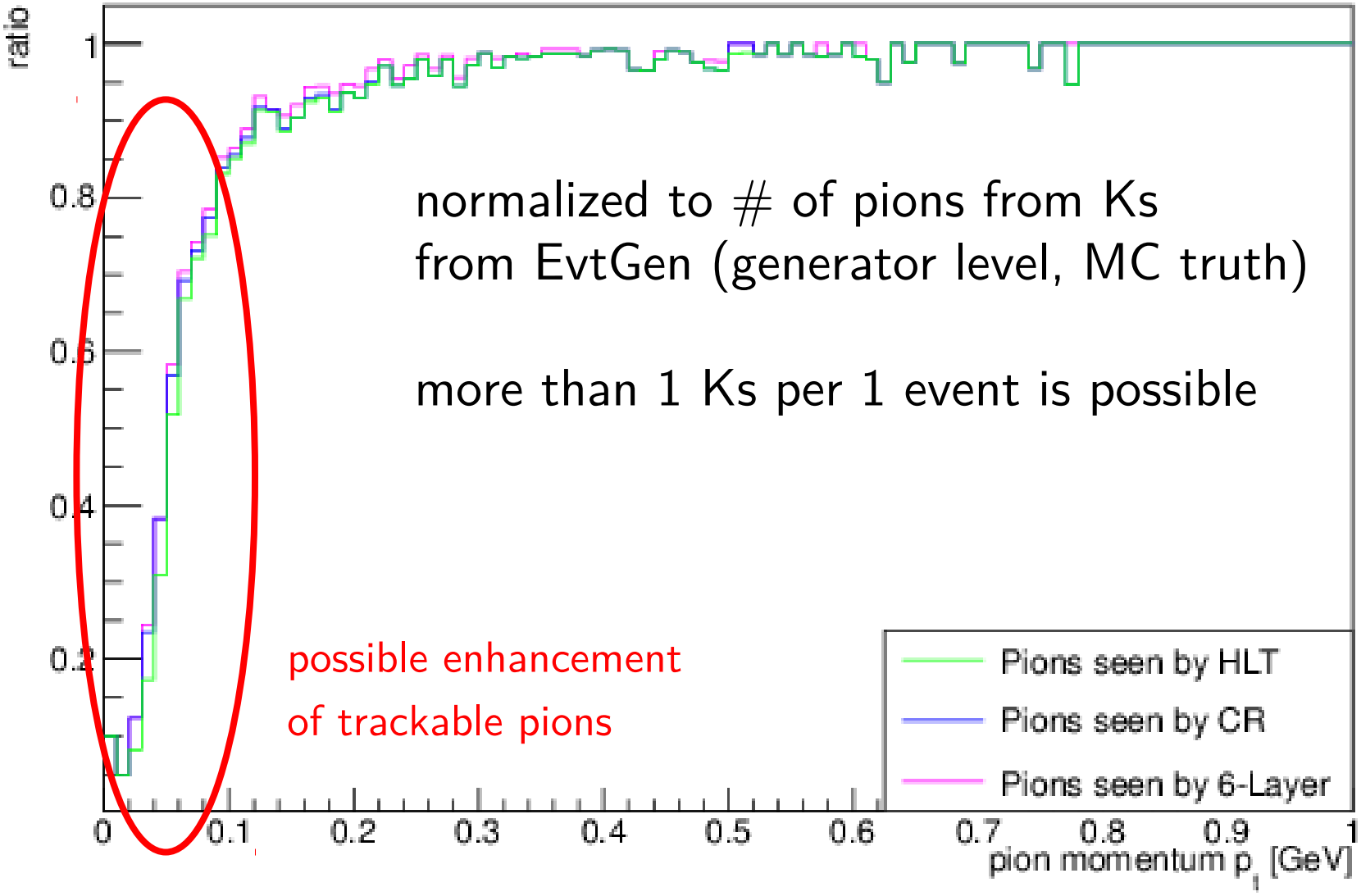




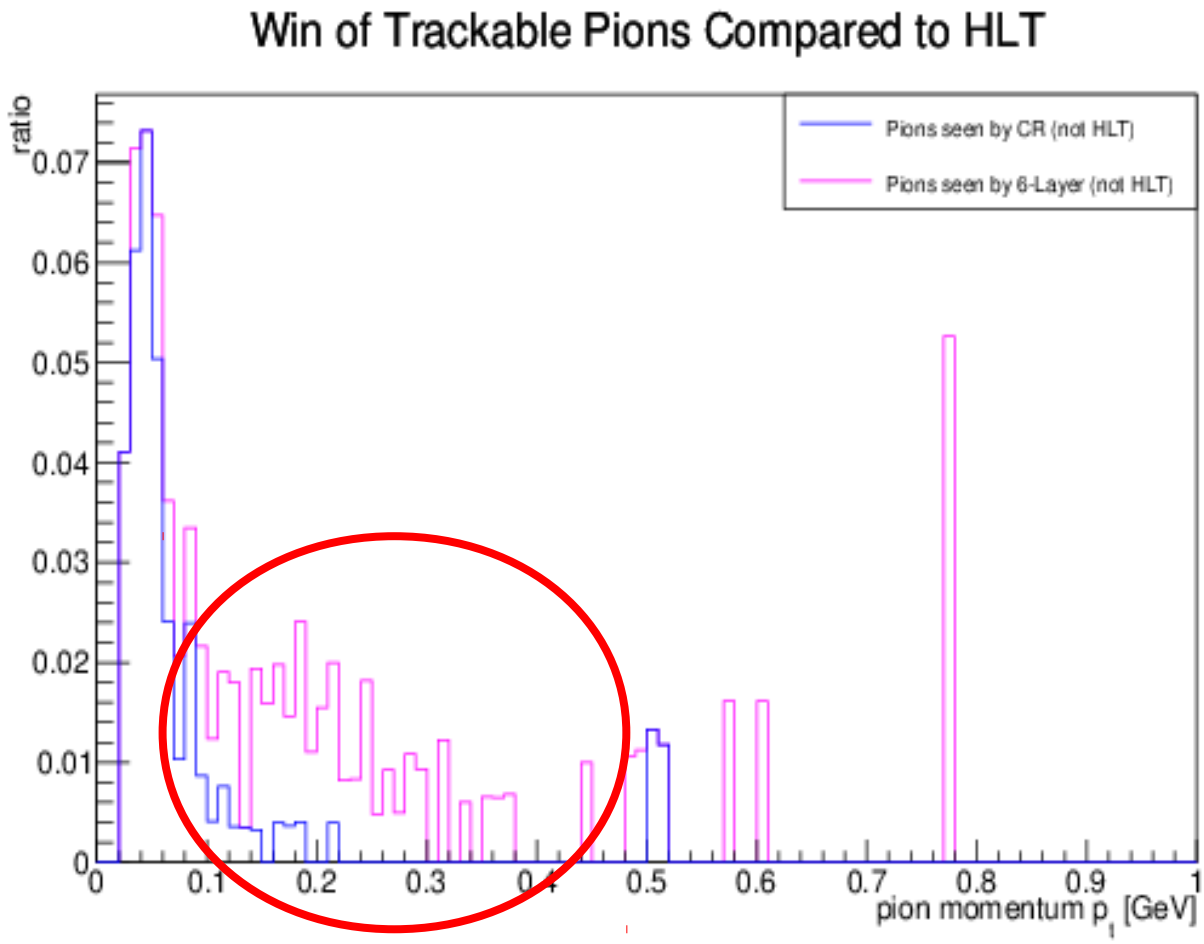
Trackable Pions



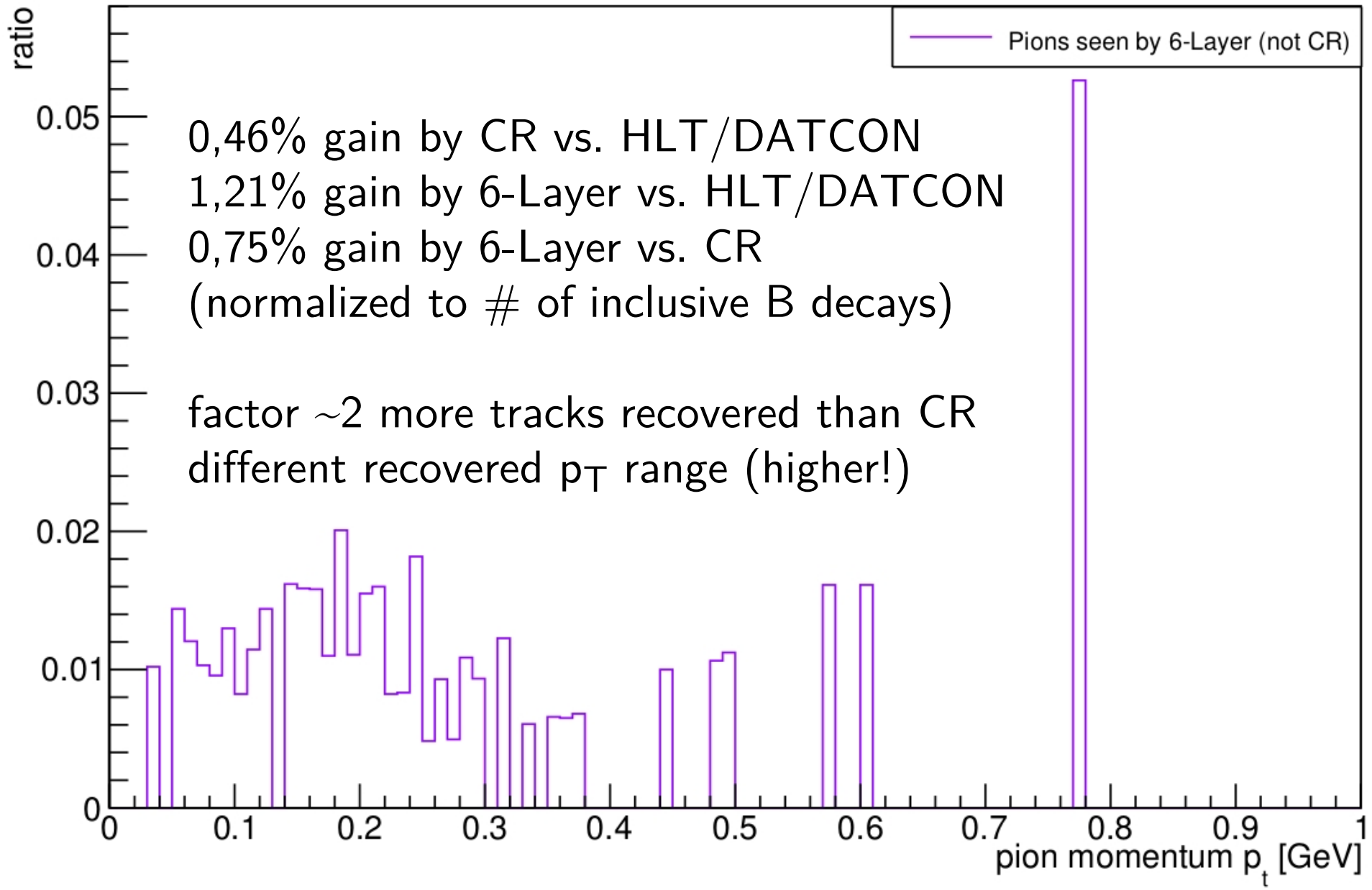
Ratio of Trackable Pions



Possible enhancement of trackable pions with 6-Layer-Tracking for p_T of 100 - 300 MeV

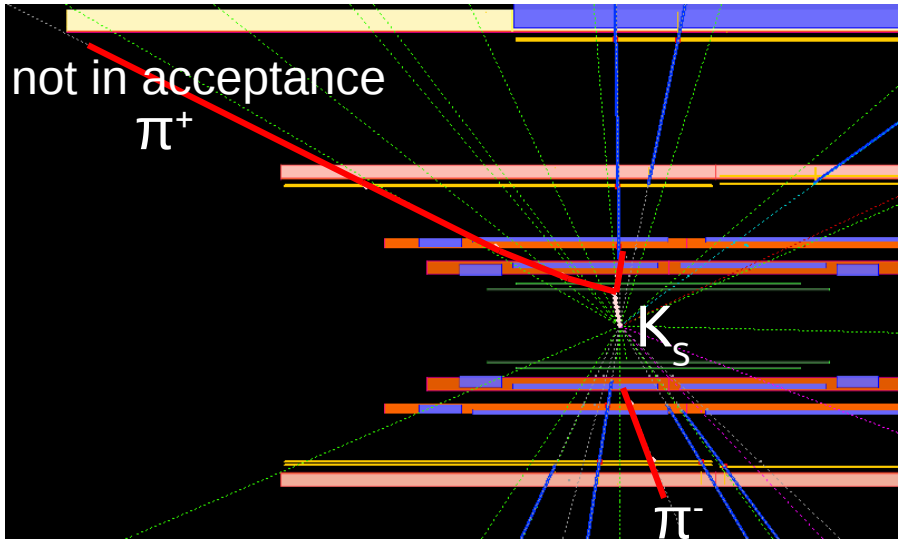


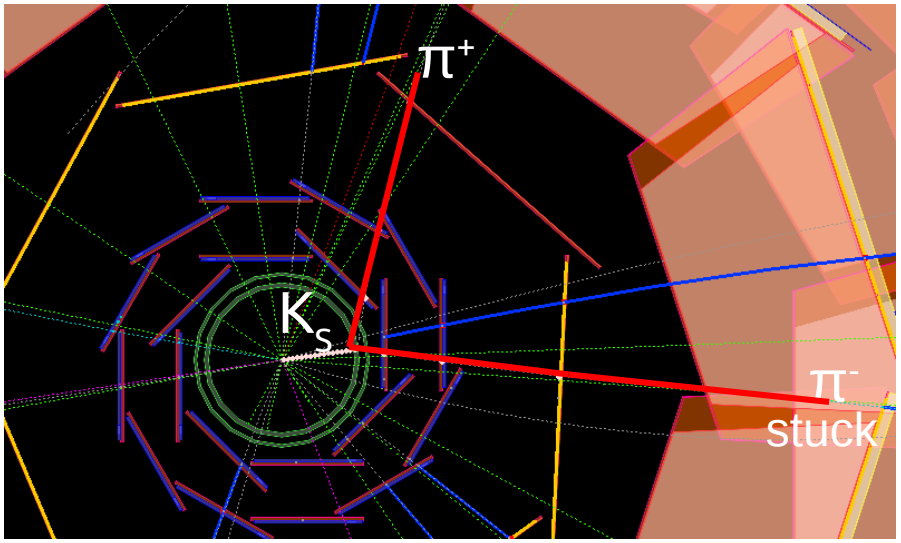
Win of Trackable Pions 6-Layer Compared to Cluster Rescue



0,46% gain by CR vs. HLT/DATCON
1,21% gain by 6-Layer vs. HLT/DATCON
0,75% gain by 6-Layer vs. CR
(normalized to # of inclusive B decays)

factor ~2 more tracks recovered than CR
different recovered p_T range (higher!)





π^+: p_T=89 MeV π^-: p_T=292 MeV

geometric issue:

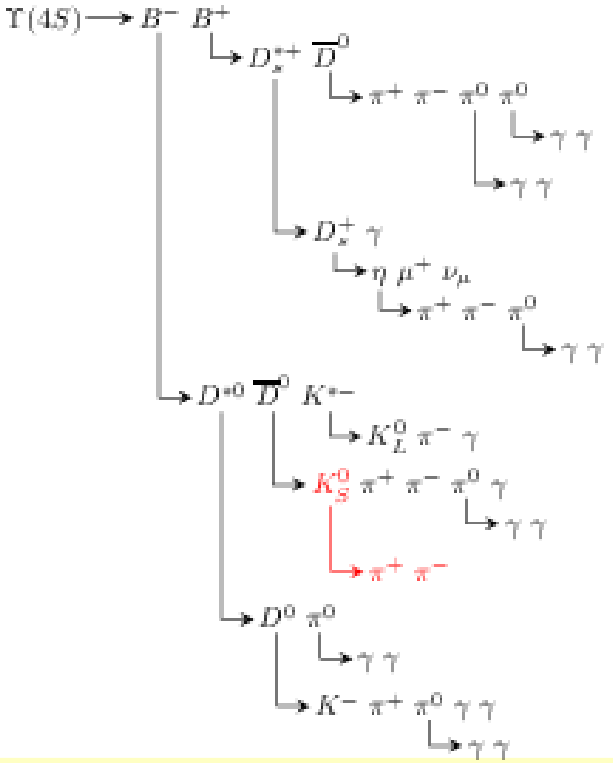
π^+ leaves acceptance after 1st SVD layer

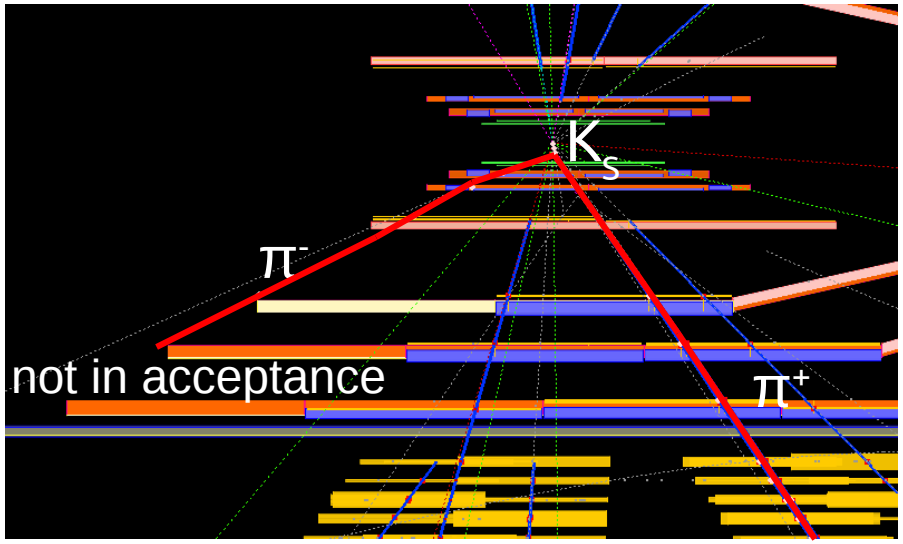
π^- gets stuck in 2nd SVD layer (only 3 hits)

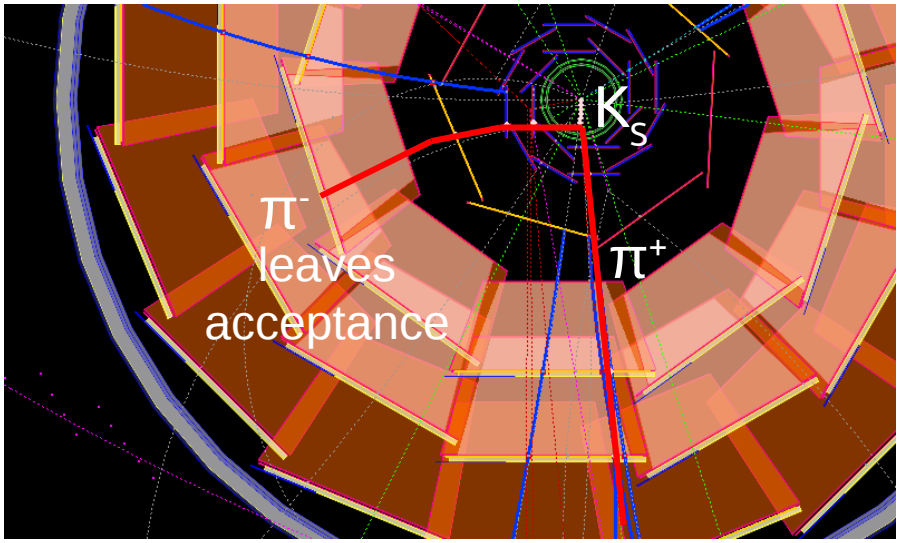
Cluster Rescue (seed charges):

π^+: 26 and 41 (both below threshold)

π^-: 47 and 13 (inner layer rescued by CR)







π^+: p_T=281 MeV π^-: p_T=66 MeV

geometric issue:

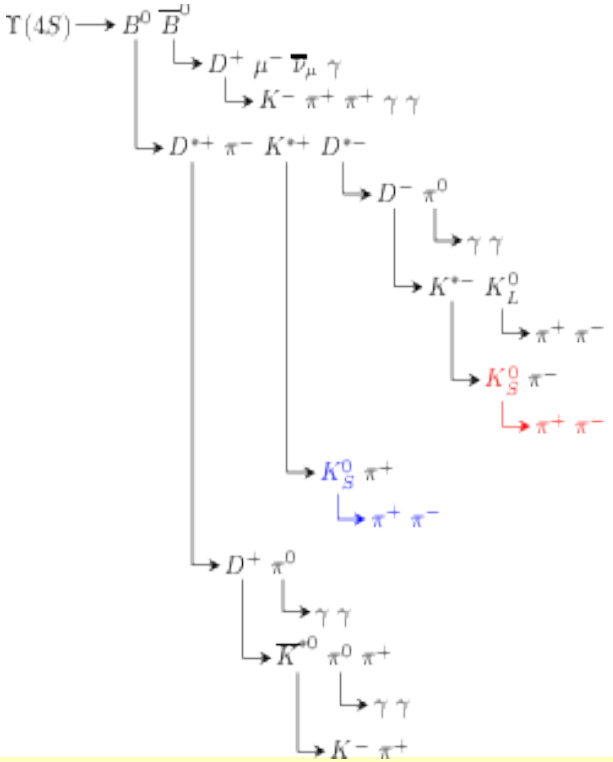
π^+ reaches CDC => trackable by HLT

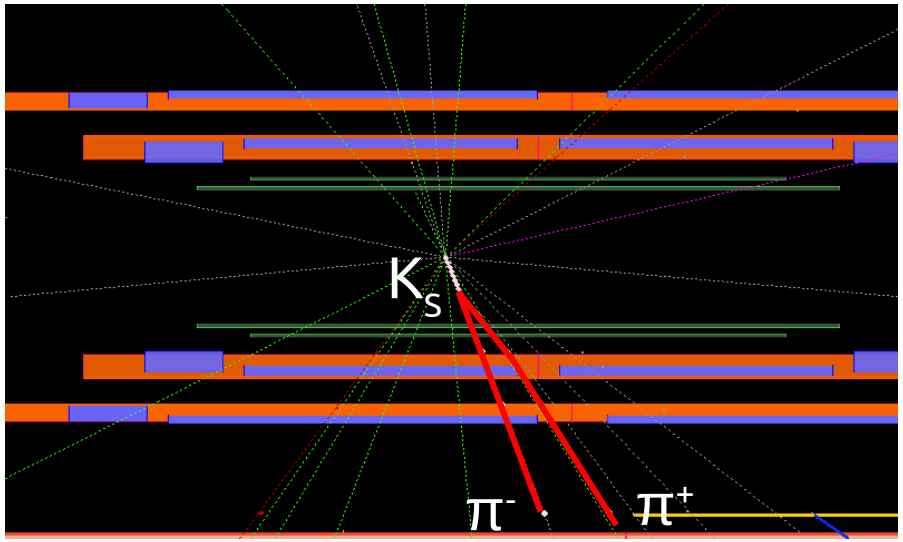
π^- leaves acceptance after 2nd SVD layer

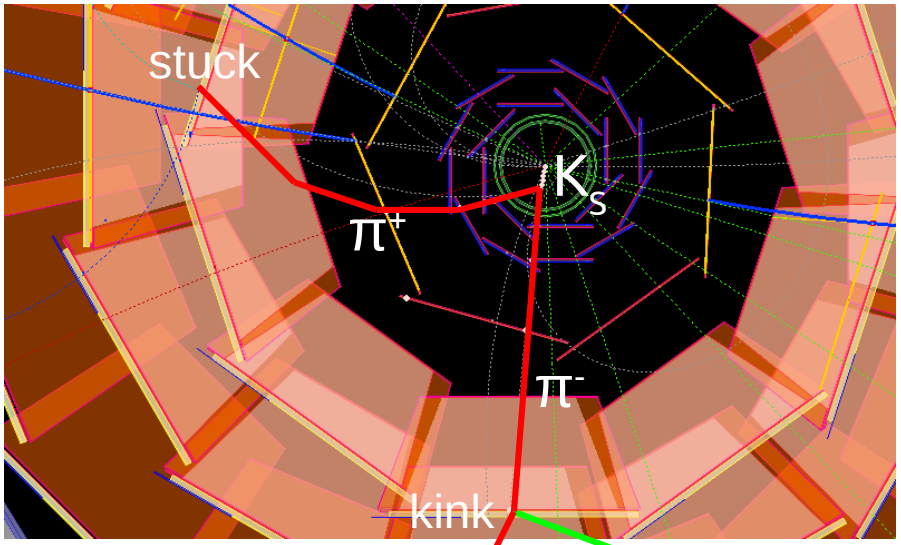
Cluster Rescue (seed charges):

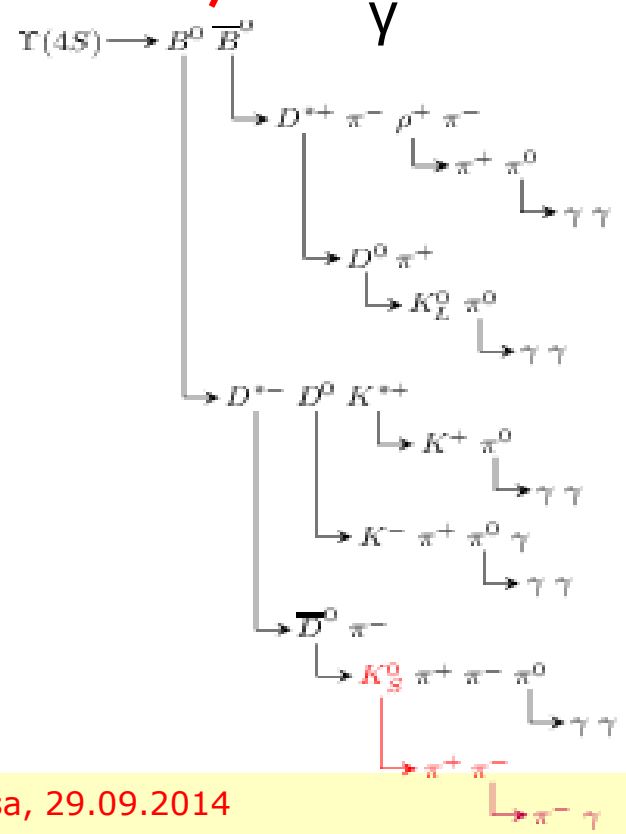
π^+: 22 and 14 (both below threshold)

π^-: 34 and 55 (outer layer rescued by CR)









γ

π^+: p_T=48 MeV π^-: p_T=771 MeV

geometric issue:

π^+ gets stuck in 2nd SVD layer

π^- gets kink in 2nd SVD layer

Cluster Rescue (seed charges):

π^+: 132, 140 and 251 (all rescued by CR)

π^-: 20 and 21 (both below threshold)

Three groups of particles are recovered by 6-layer:

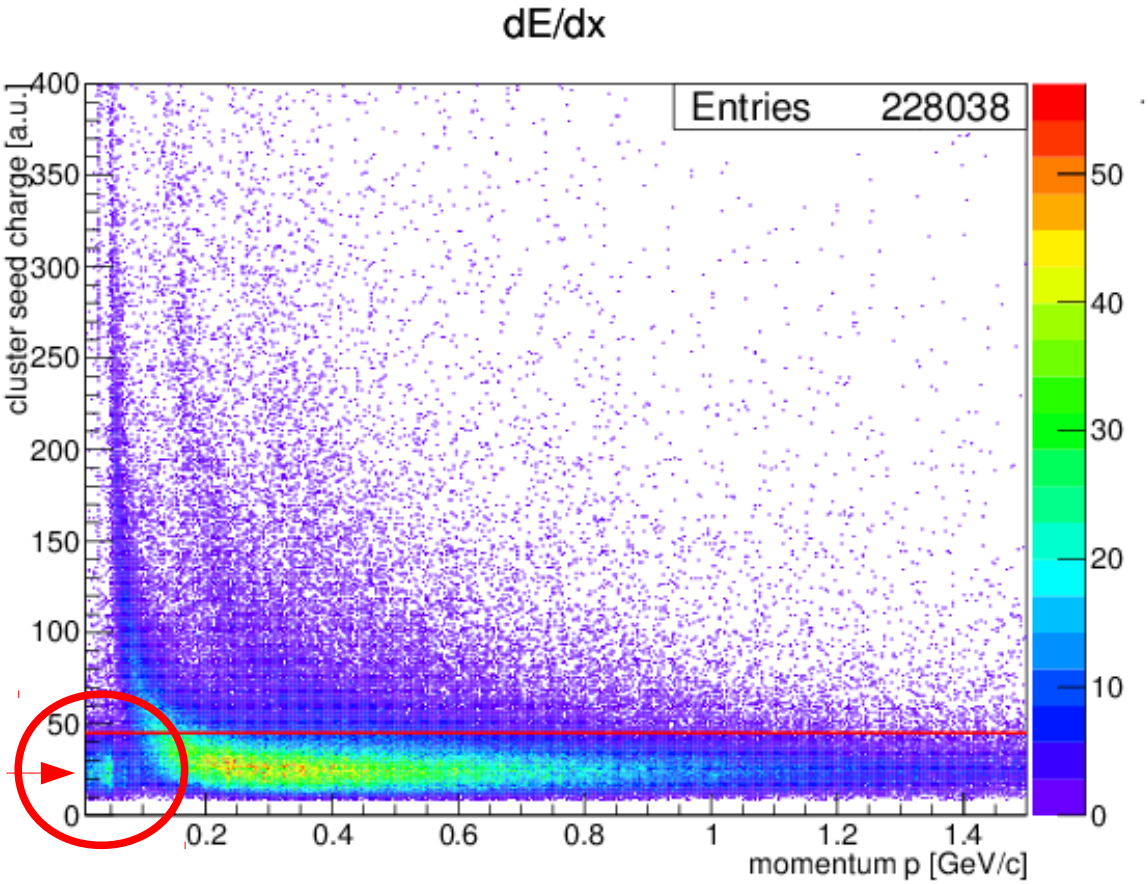
1. secondary vertex and K_s boost
   cause $\pi^{\pm}$ tracks leaving the acceptance
2. flat angle can cause small seed charge
   elongated cluster
   CR may fail
   (but cluster shape may also be input to CR)
3. pion is absorbed (nuclear interaction),
   or forms a „kink“

$\rightarrow$ there are <3 layers fired in SVD,
but in all cases there are ≥ 3 layers fired in PXD+SVD
$\rightarrow$ rescue

$e^{\pm}$ Rescue

no cluster simulations yet
problem: PXD clusterizer does not run,
if box generator is used instead of EvtGen

Energy Loss in PXD



$e^{\pm}$

no cluster rescue

Cluster Rescue:factor 1.8 x minimum ionizing

→ cluster seed charge of 45

$e^{\pm}$ Rescue

in B decays, $e^{\pm}$ with low pT$<$100 MeV are not important

however, in some other NP channels
e.g. dark photon search e+e– $\rightarrow$ e+e– e+e– e+e–
lower momentum cut it 50 MeV
(information from I. Jaegle)

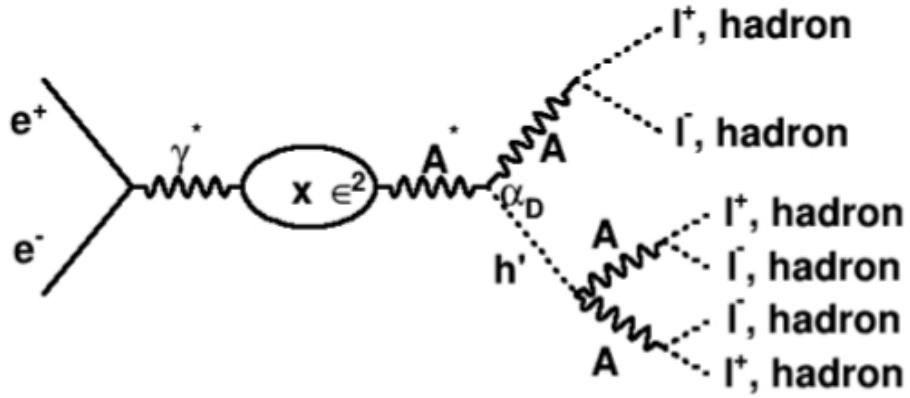
recovery by CR is not possible

possible approach in 6-layer tracking:
displaced z-vertex for multi-curlers

Searches for dark photons and dark Higgs at Belle

Presented today for the first time, a new limit in the search for a dark photon and a dark Higgs with:

- A and h' prompt
- $m_{h'} > 2m_A$
- $0.1 < m_A < 3.5$ GeV/c^2 and $0.2 < m_{h'} < 10.5$ GeV/c^2



α_D: dark sector constant
ϵ^2: kinetic mixing

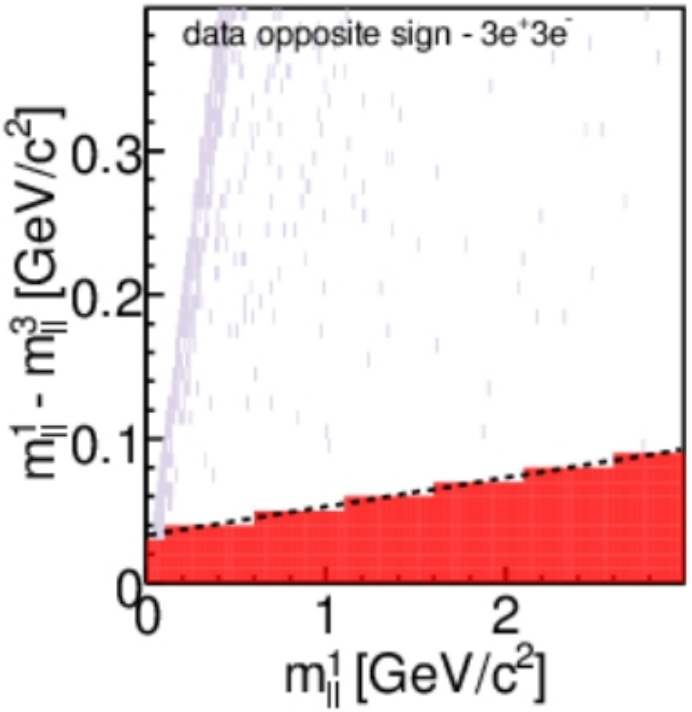
- 10 exclusive channels: $3e^+3e^-$, $3\mu^+3\mu^-$, $2e^+2e^-\mu^+\mu^-$, $2\mu^+2\mu^-e^+e^-$, $3\pi^+3\pi^-$, $2\pi^+2\pi^-e^+e^-$, $2\pi^+2\pi^-\mu^+\mu^-$ $2e^+2e^-\pi^+\pi^-$, $2\mu^+2\mu^-\pi^+\pi^-$, $e^+e^-\mu^+\mu^-\pi^+\pi^-$
- 3 inclusive channels for $m_A > 1.1$ GeV/c^2:$2e^+2e^-X$, $2\mu^+2\mu^-X$, $e^+e^-\mu^+\mu^-X$

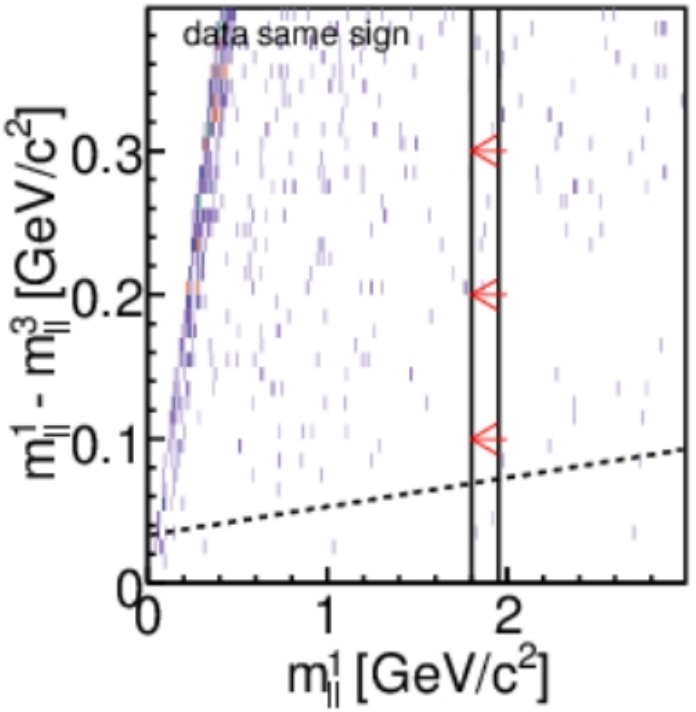
If $\alpha_D = 1$, Higgs-strahlung channel most sensitive to A

Background estimation with signal box blinded - part I

Data driven background estimation

- estimate background using "same sign" events $e^+e^- \to Ah' \to A(l^+l^+)A(l^+l^+)A(l^-l^-)$
- order masses of lepton pairs $m^1_{ll} > m^2_{ll} > m^3_{ll}$ and plot $m^1_{ll} - m^3_{ll}$ vs. m^1_{ll}
- select region in m_{ll} and predict background there using same sign
  - $e^+e^- \to 3e^+3e^-$





Hardware Implementation

most appropriate location is Onsen, as all PXD data are there,
but:
(a) combinatorics is too high for all PXD hits and all SVD hits
(b) resources on ONSEN FPGA are limited

$\rightarrow$ needs additional ONSEN-DATCON protocol
send only SVD hits for a subset of tracks
(e.g. displaced vertex)

$\rightarrow$ needs new algorithm
first idea: use (x,y) of 1st PXD layer as reference hit
for conformal map on DATCON

plan: apply for BMBF funding for algorithm study and prototype study
(no investment $\rightarrow$ we will not replace any hardware for now!)

There are more advantages to have a „backup method“

CR has limitations:

(1) dynamic range limited by e.g. common mode noise
    6-bit range (?)
(2) gain variation, chip by chip
    (corrected later offline, but cluster rescue is online)

Summary

6-layer may recover order(1.2%) of K_s in inclusive B decays
(K_s not required on generator level)
$\rightarrow$ ~480.000 K_s per day (@ nominal luminosity)
(which otherwise have no PXD raw data)

factor order(~2) more rescued tracks vs. CR
p_T is higher than CR (p_T=100-300 MeV)

what would be new for DATCON/Onsen ?
$\rightarrow$ secondary vertex (xy for K_s, z for e$\pm$) in algorithm