finding kinks in the TPC
a first report

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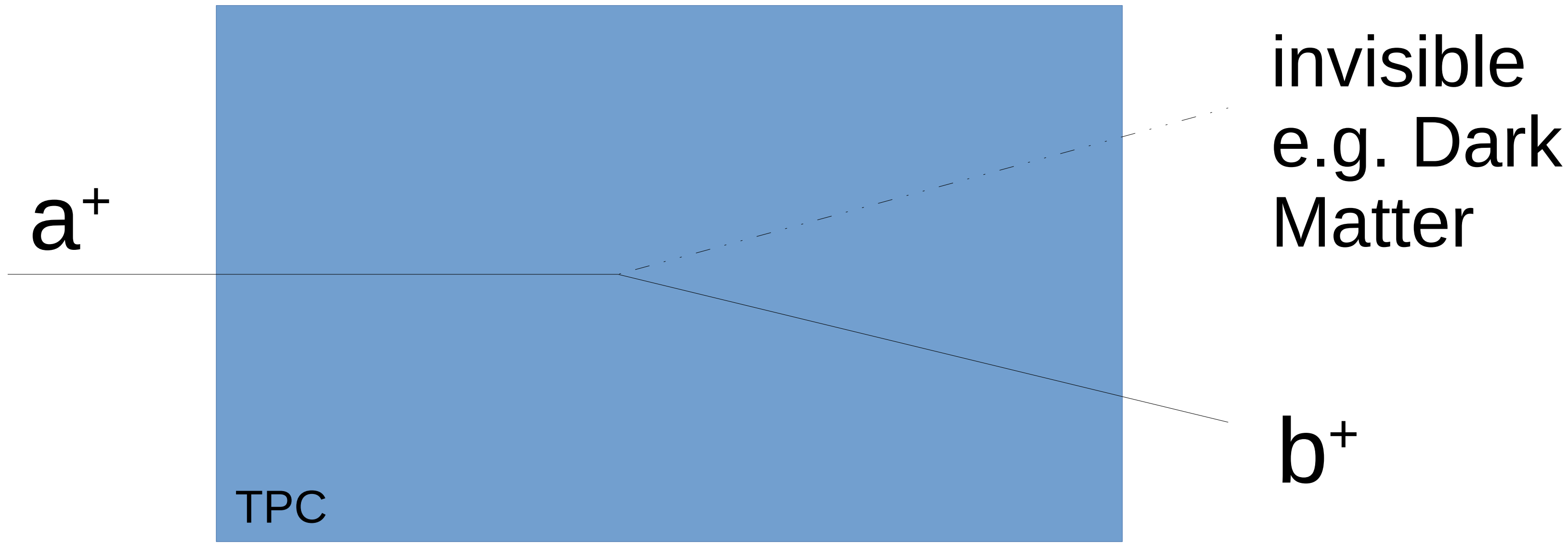
many BSM models have signatures such as



if decay occurs in TPC, can it be identified?

probably depends on size of kink,
and therefore on $\Delta m = m_a - m_b$

simulated in MSSM

$e^+ e^- \rightarrow \chi_2^+ \chi_2^-$

$\chi_2^{+/-} \rightarrow \chi_1^{+/-}$ + invisible [$Z \rightarrow$ nu nu]

E_{CM} = 250 GeV

$m_{\chi 2}$ = 110 GeV

$m_{\chi 1}$ = 109.8 / 109.0 / 105.0 / 100.0 GeV

χ_2^+ lifetime adjusted to often decay in TPC

whizard (no ISR or beamstrahlung)

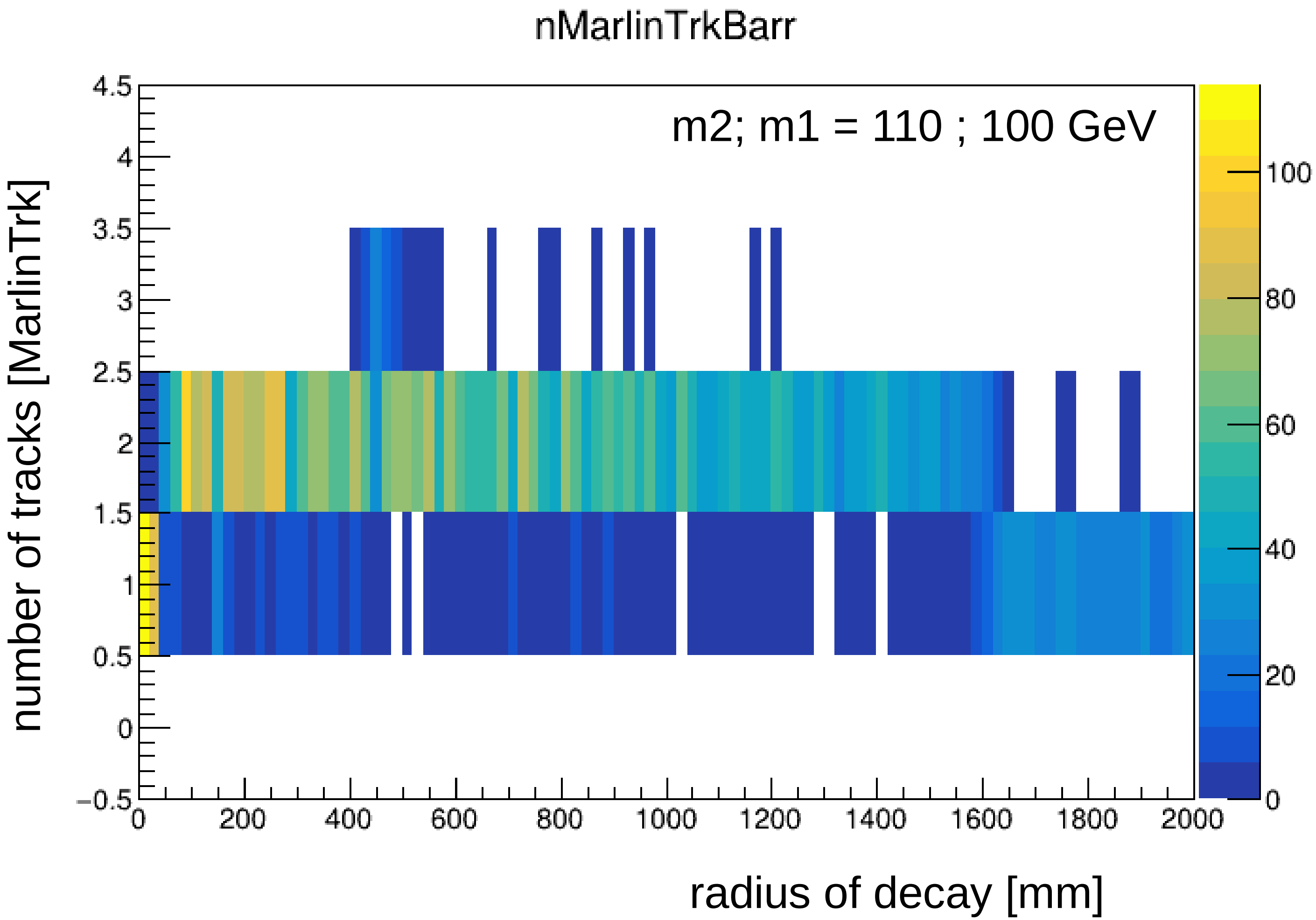
ilcsoft v02-02

detector simulation (ILC_l5_v02)

Marlin reconstruction (detector o1, no overlay)

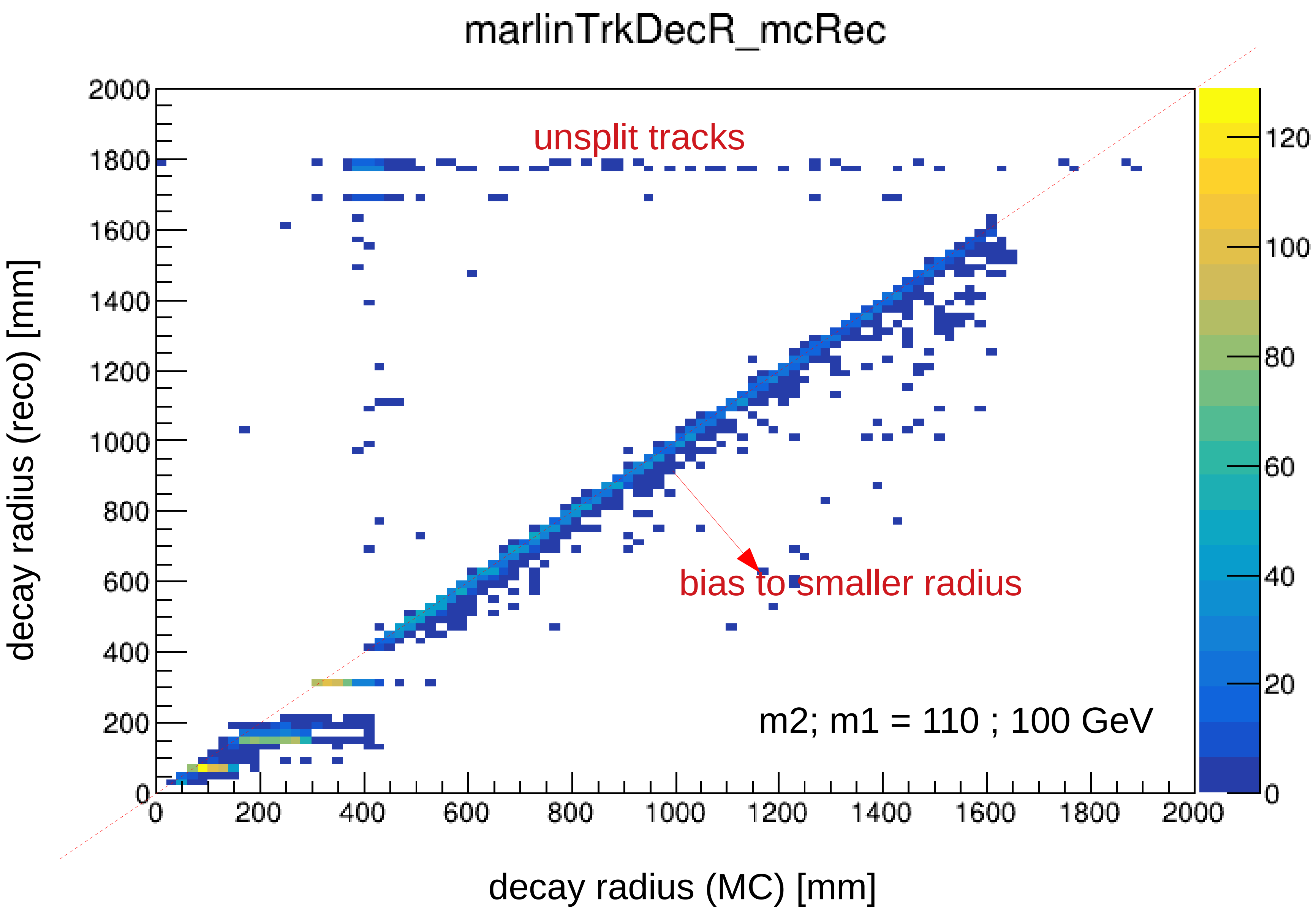
how does standard reco do ?

count number of reconstructed tracks (MarlinTrk collection) matched to the (χ_2 χ_1) pair

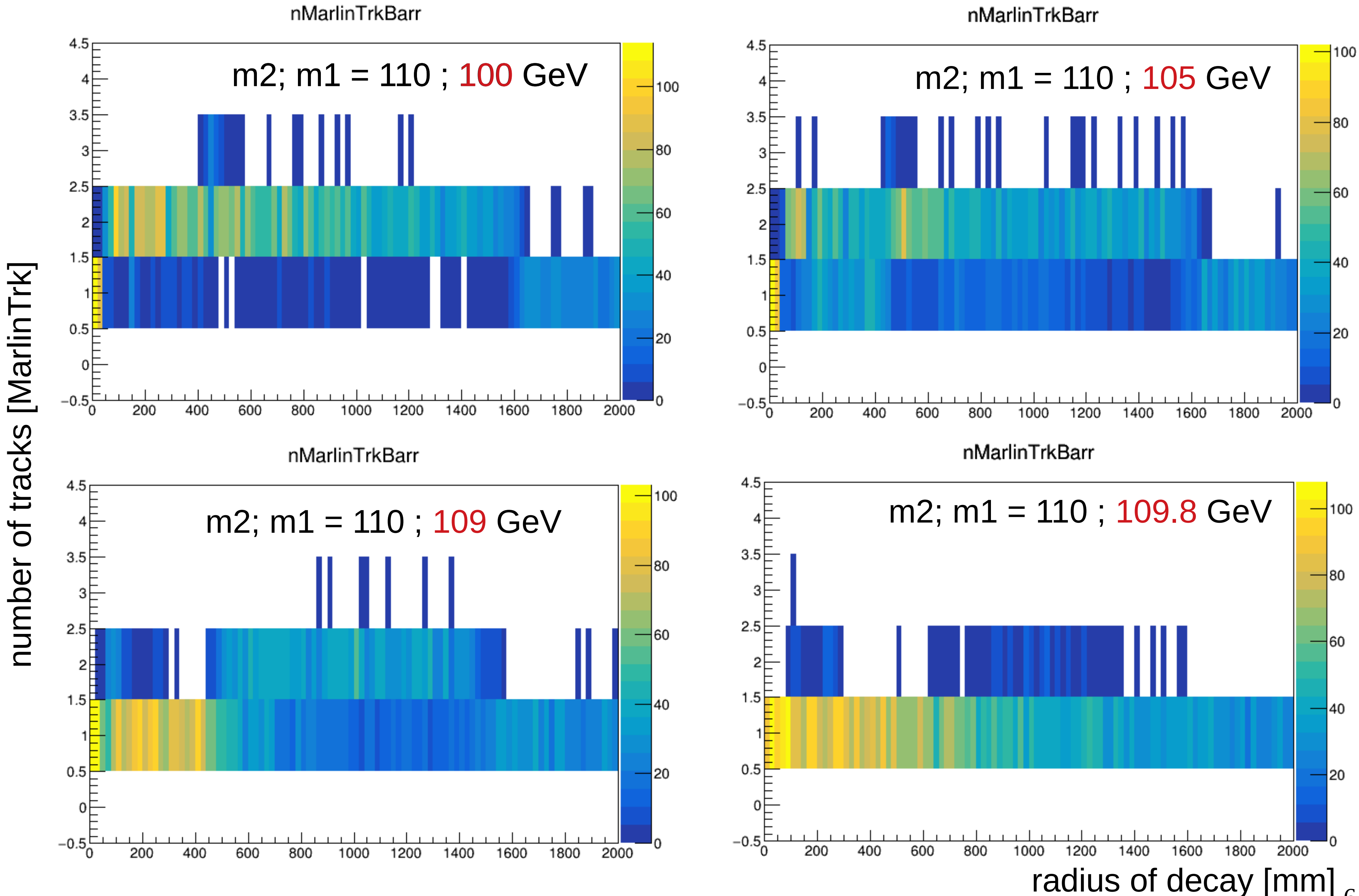


reasonably good efficiency to reconstruct 2 separate tracks

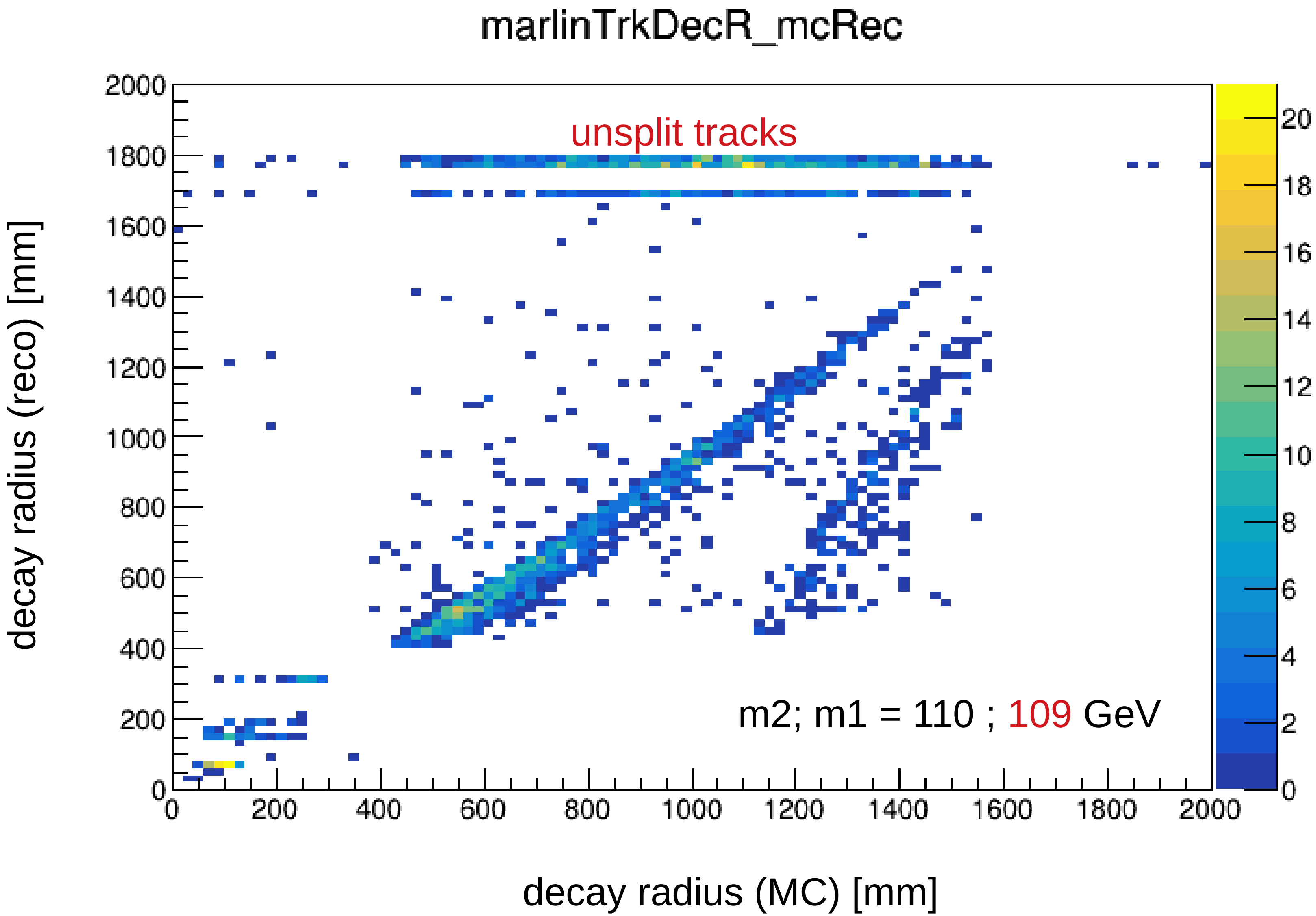
position of the break between tracks (standard MarlinTrk reco)



how does standard reco do ?



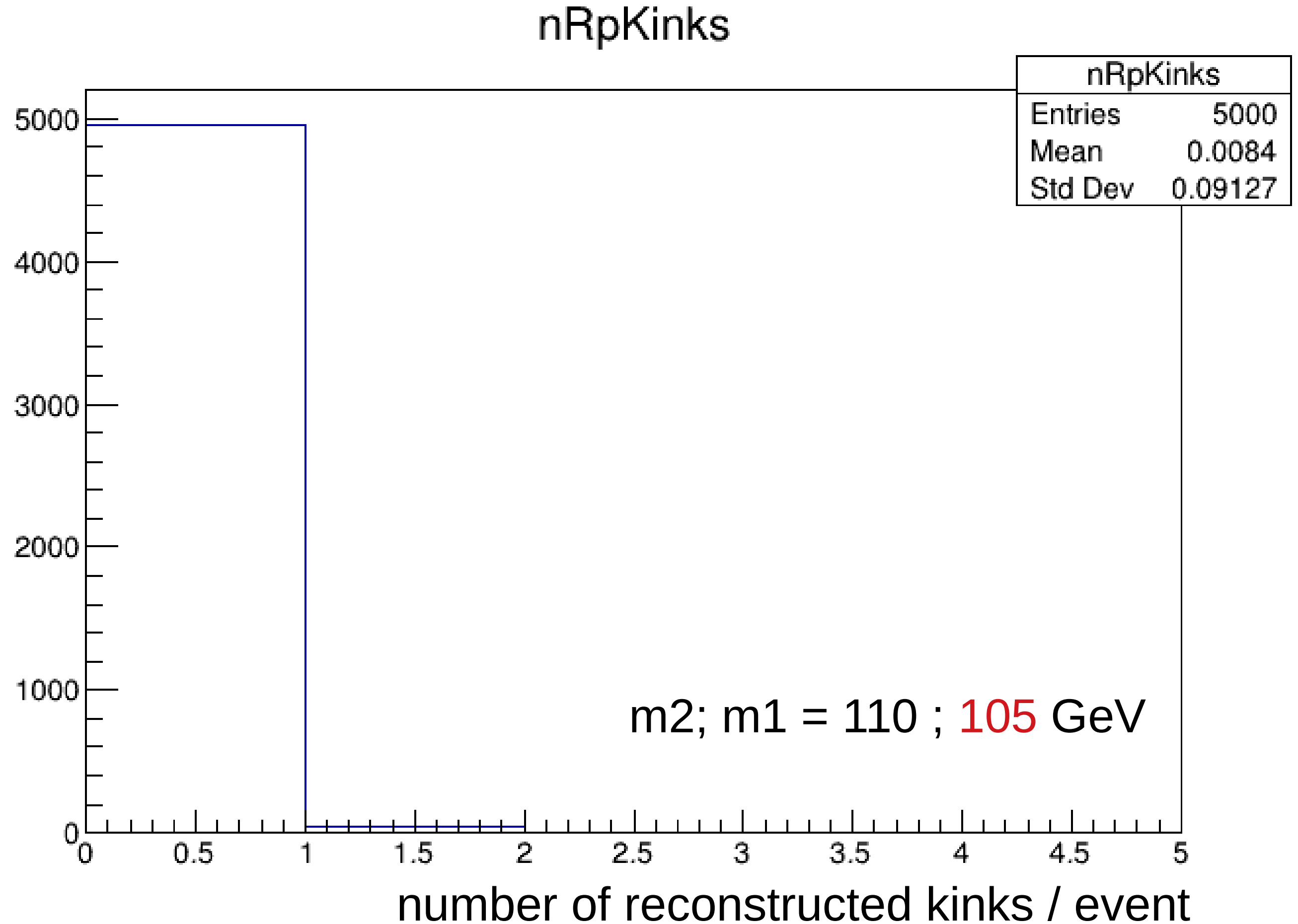
less efficient at smaller mass differences



less precise at smaller mass differences

we do run a kink-finder in production

it doesn't identify many:



I haven't spent much effort trying to work out why...

try an alternative approach, dedicated to kink finding

hit finding: for now use MC links

→ identify hits produced by [χ_2 χ_1] pair

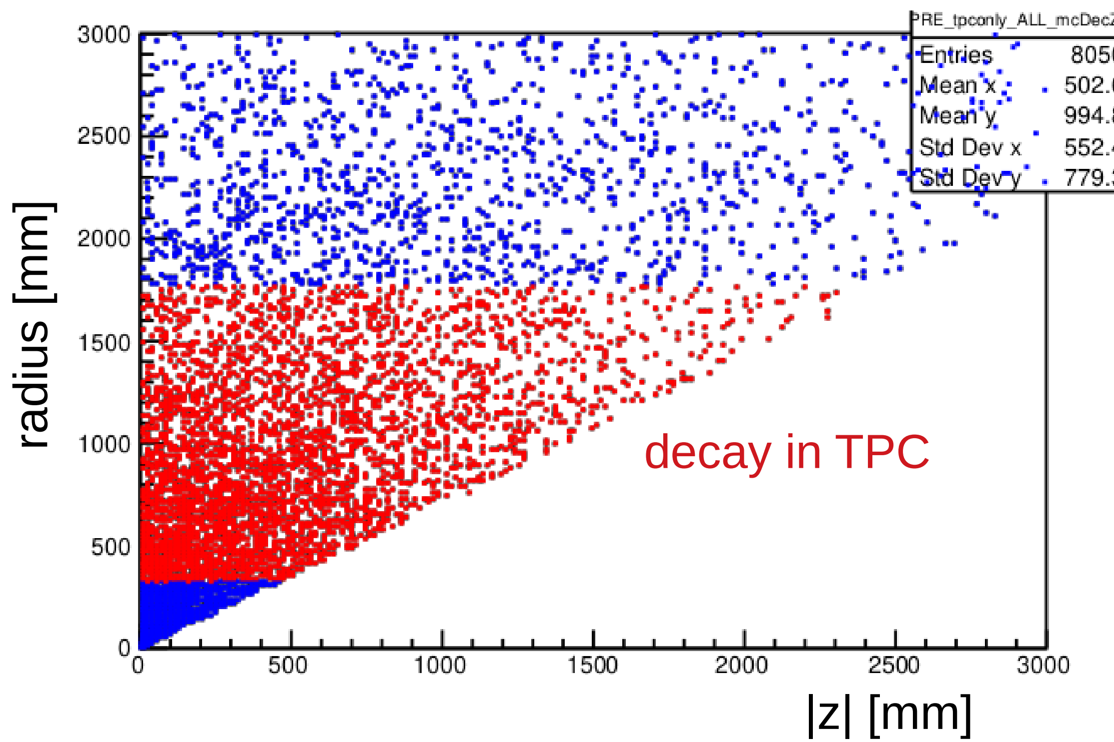
(but not by which of χ_2 , χ_1)

preselection:

exactly 2 silicon tracks/event

[χ_2 χ_1] pair associated to at least 200 TPC hits

decay point of χ_2 for preselected decays



1. fit all TPC hits (KalTest)

- use track state at last hit of Silicon track as initial guess
- add TPC hits (in order of increasing radius)
- (don’t yet use SET)

- look at chisq of this track, and Prob(chisq, nDOF)

2. then look for a kink

in → out track

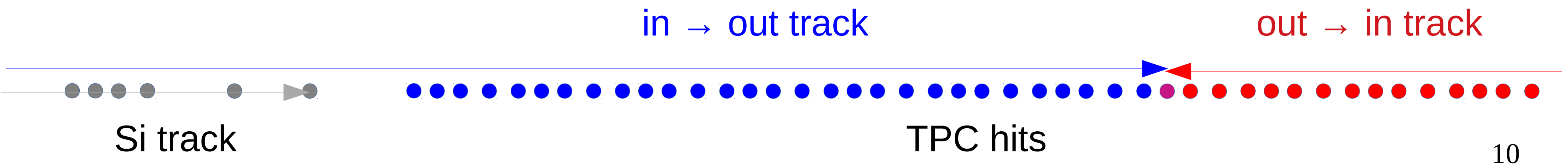
initial guess: track state at last hit of Silicon track
add&fit TPC hits one-by-one, in order of increasing radius
record [track state, chi2, nDoF] at each hit

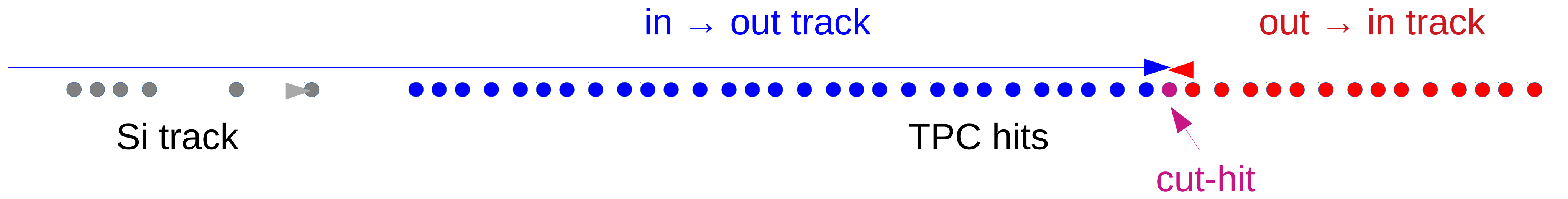
out → in track

starting from outer TPC hits, move inwards
add TPC hits one-by-one
record [track state, chi2, nDoF] at each hit

also do this not using SiTrack info: “TPConly”

at each TPC hit, we now have track parameters when it is
- outermost hit of in → out track
- innermost hit of out → in track



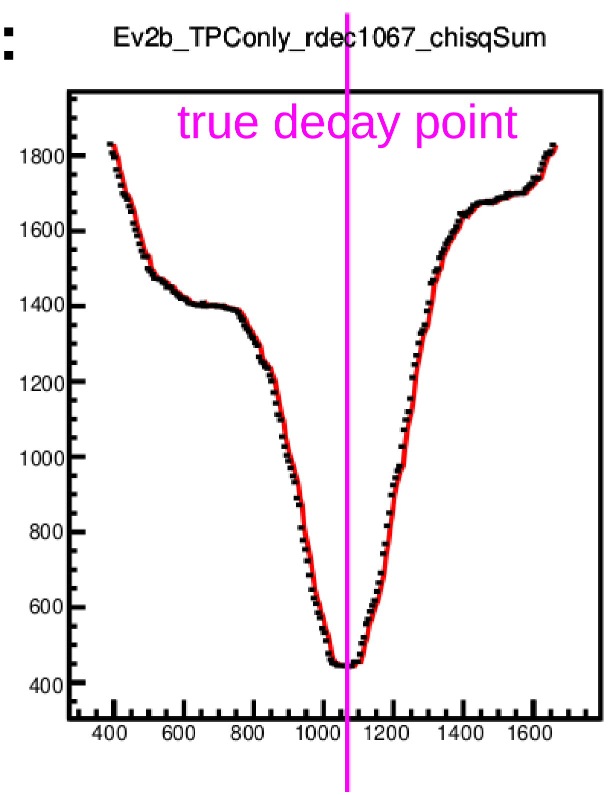


at each TPC hit, have two tracks, with a common "cut-hit"

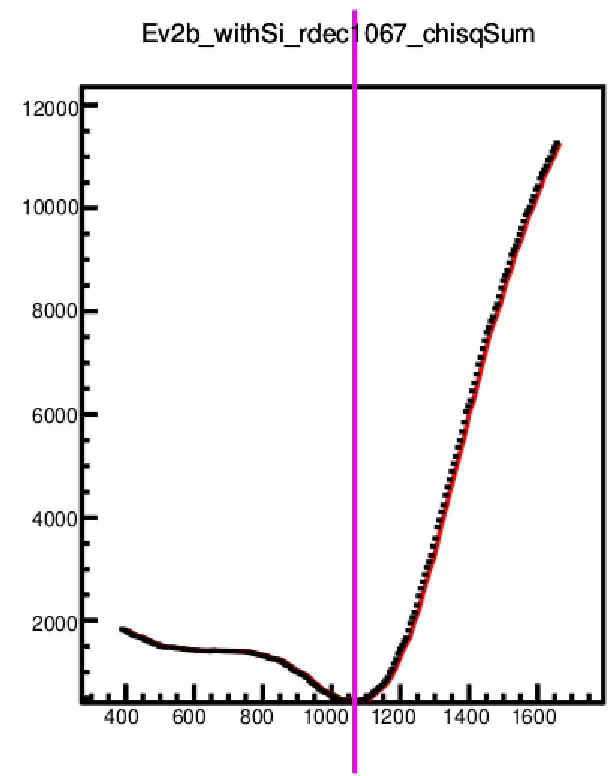
e.g. one decay:

sum of the two tracks' fit chiSq

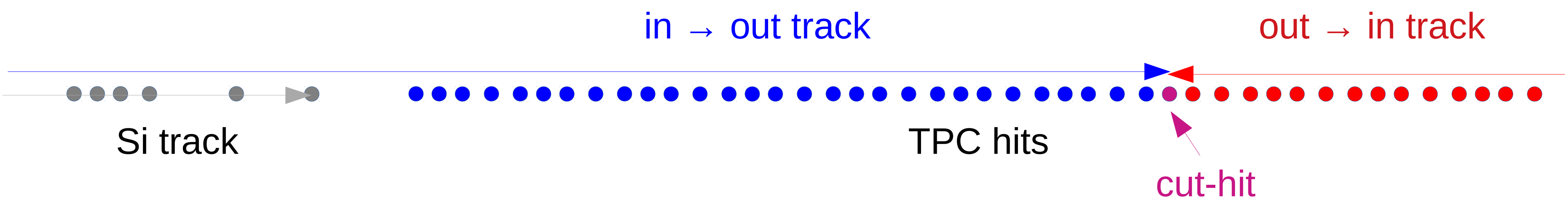
TPC only



SiTrack + TPC



radius of cut-hit [mm]



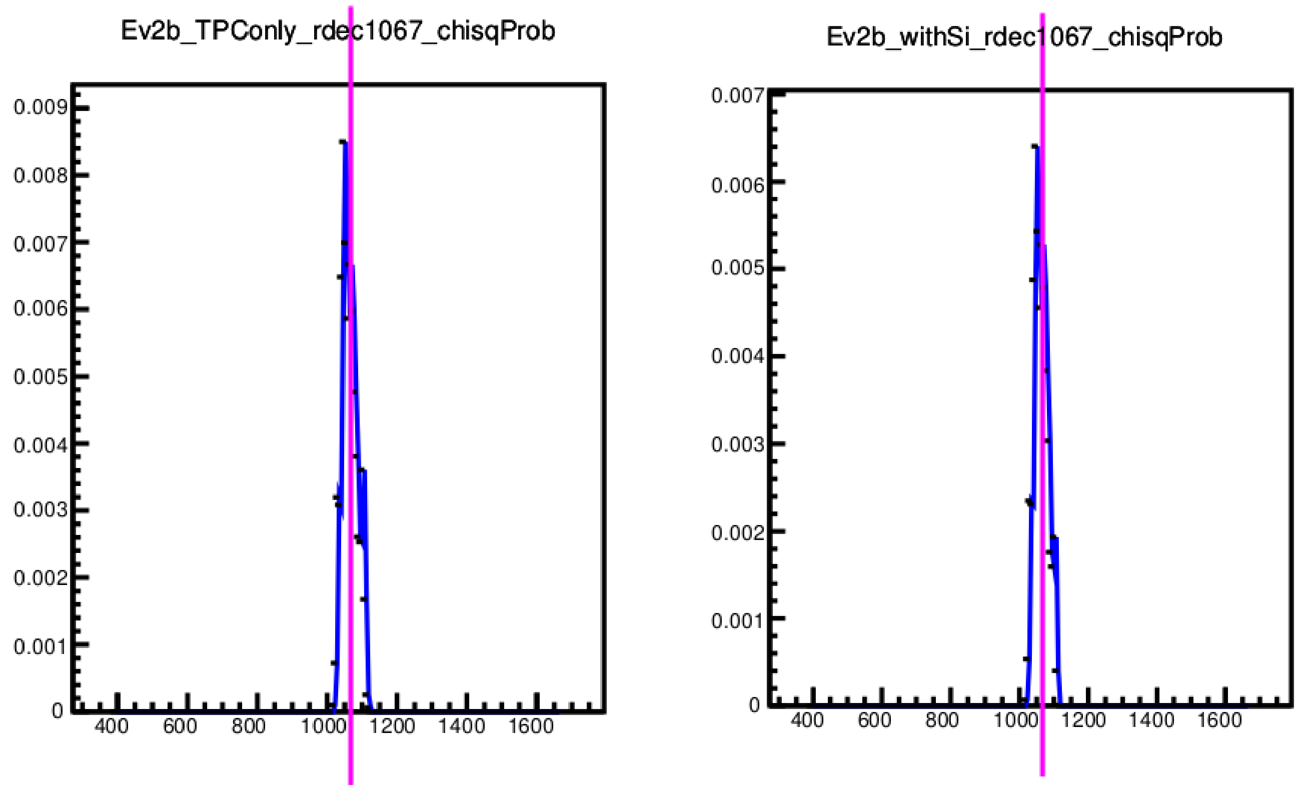
at each TPC hit, have two tracks, with a common "cut-hit"

product of track
chisq probabilities

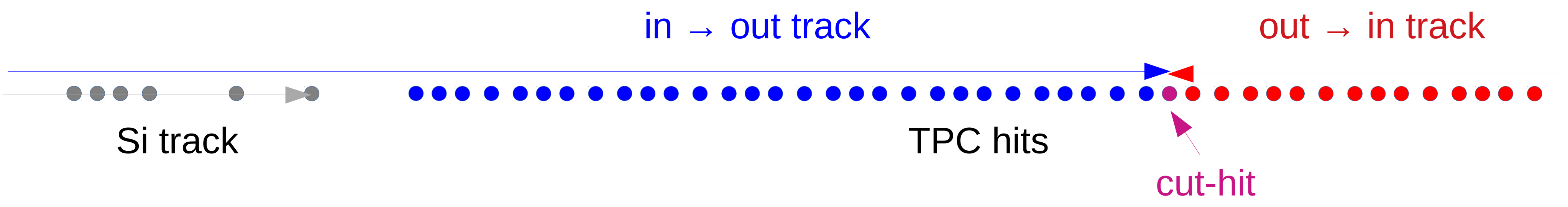
prob (chisq1, ndf1)
x
prob (chisq2, ndf2)

TPC only

SiTrack + TPC

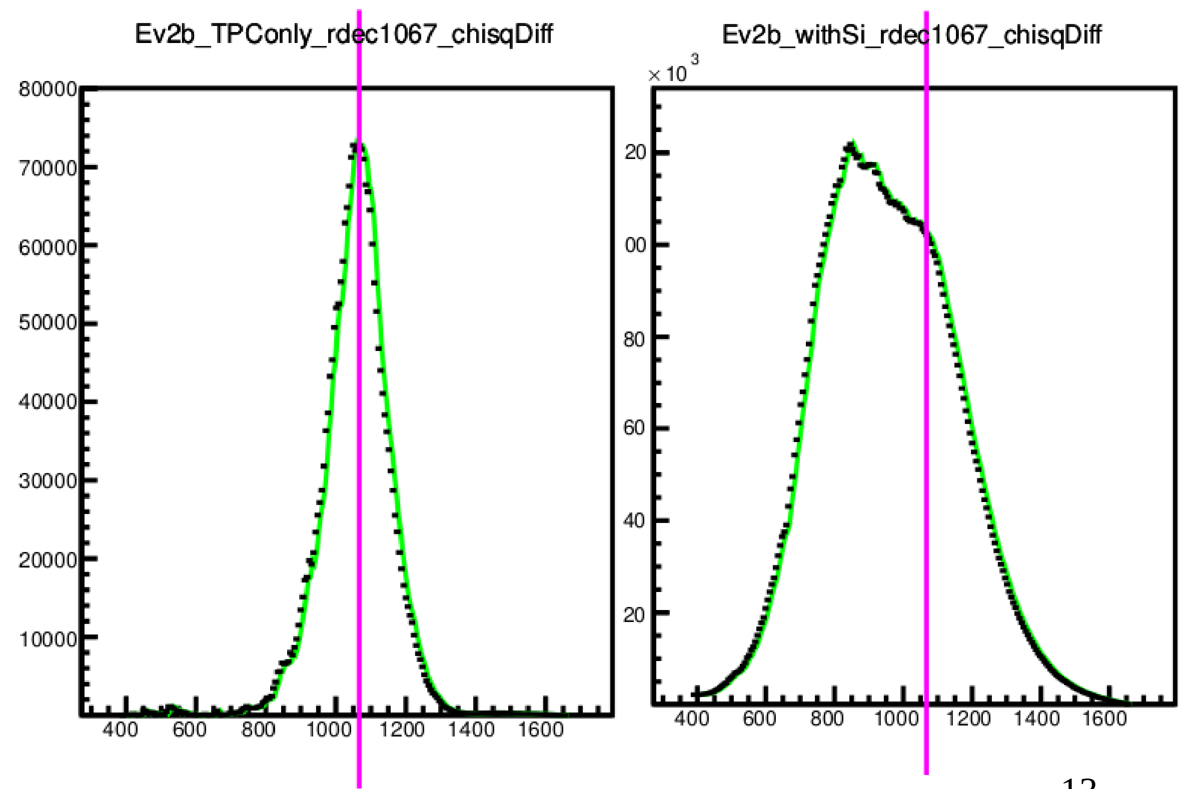


radius of cut-hit [mm]



at each TPC hit, have two tracks, with a common “cut-hit”

TPC only SiTrack + TPC



radius of cut-hit [mm]

compare the 2 sets of track parameters at the cut-hit, using the covariance matrices

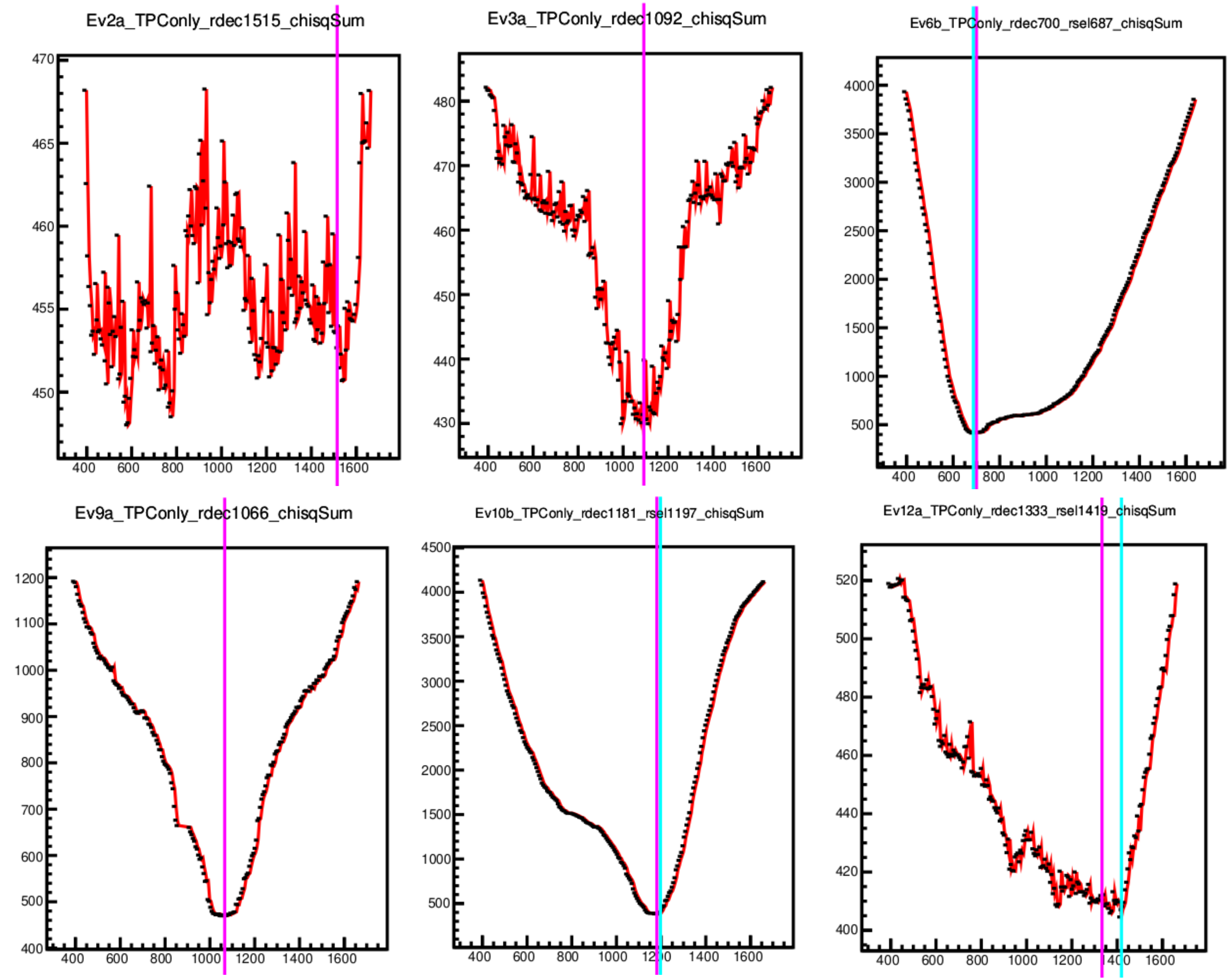
$$\mathrm{Chi}^2 = (\mathbf{P}_1-\mathbf{P}_2)^T\ (\mathrm{cov}_1+\mathrm{cov}_2)^{-1}\ (\mathbf{P}_1-\mathbf{P}_2)$$

small Chi2 = consistent parameters
large Chi2 = inconsistent

reconstructed kink point: minimum “chiSq-trk1 + chisq-trk2”

more examples

chiSq-trk1
+
chisq-trk2



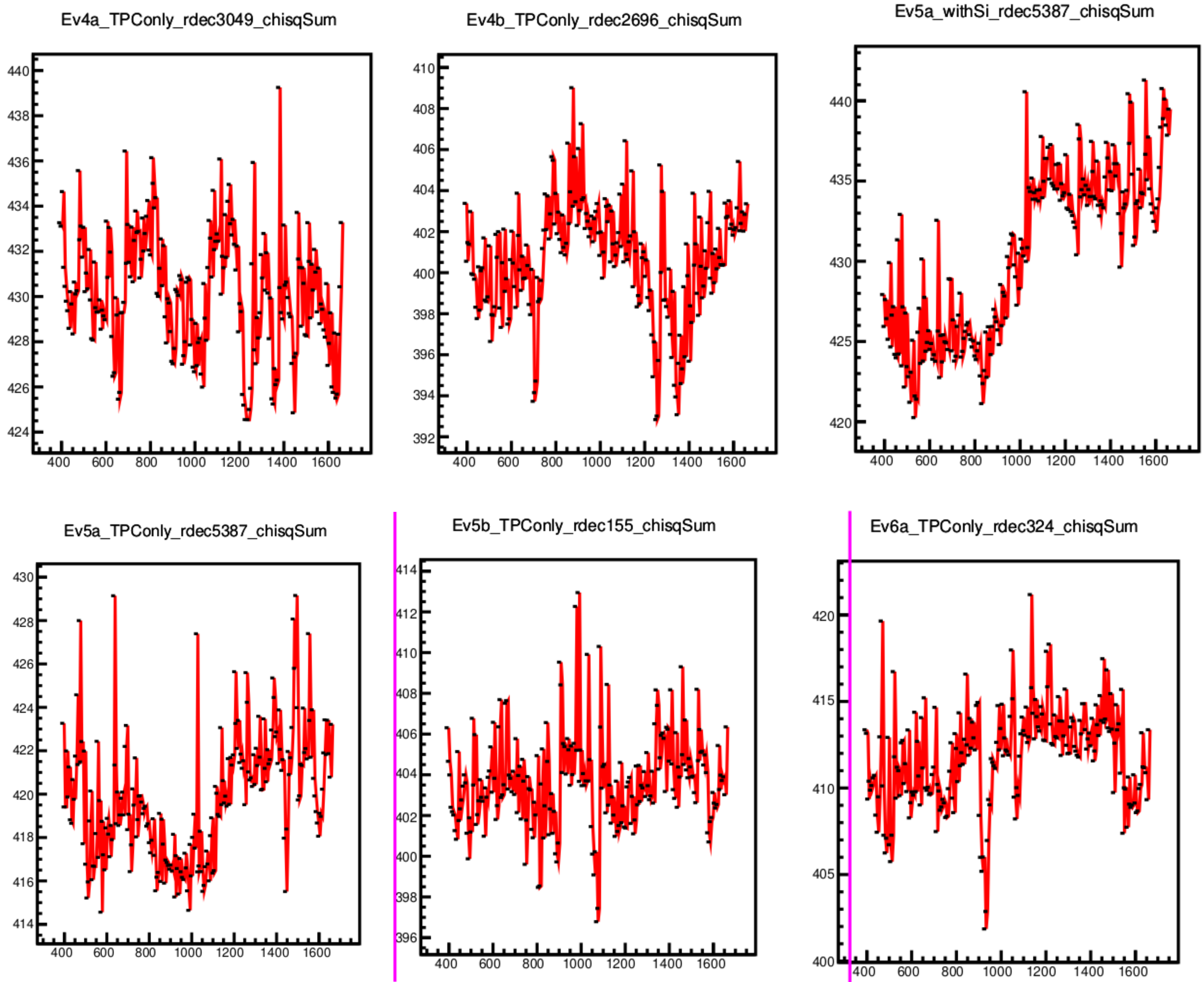
radius of “cut hit”

m2; m1 = 110 ; 109 GeV

examples with decay outside TPC

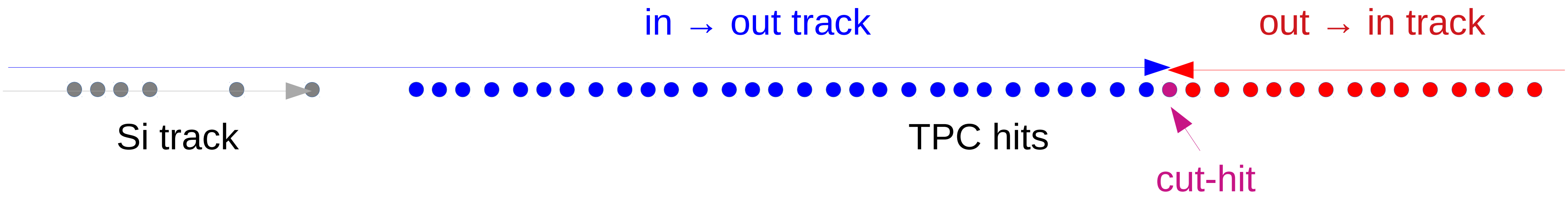
m2; m1 = 110 ; 109 GeV

chiSq-trk1
+
chisq-trk2



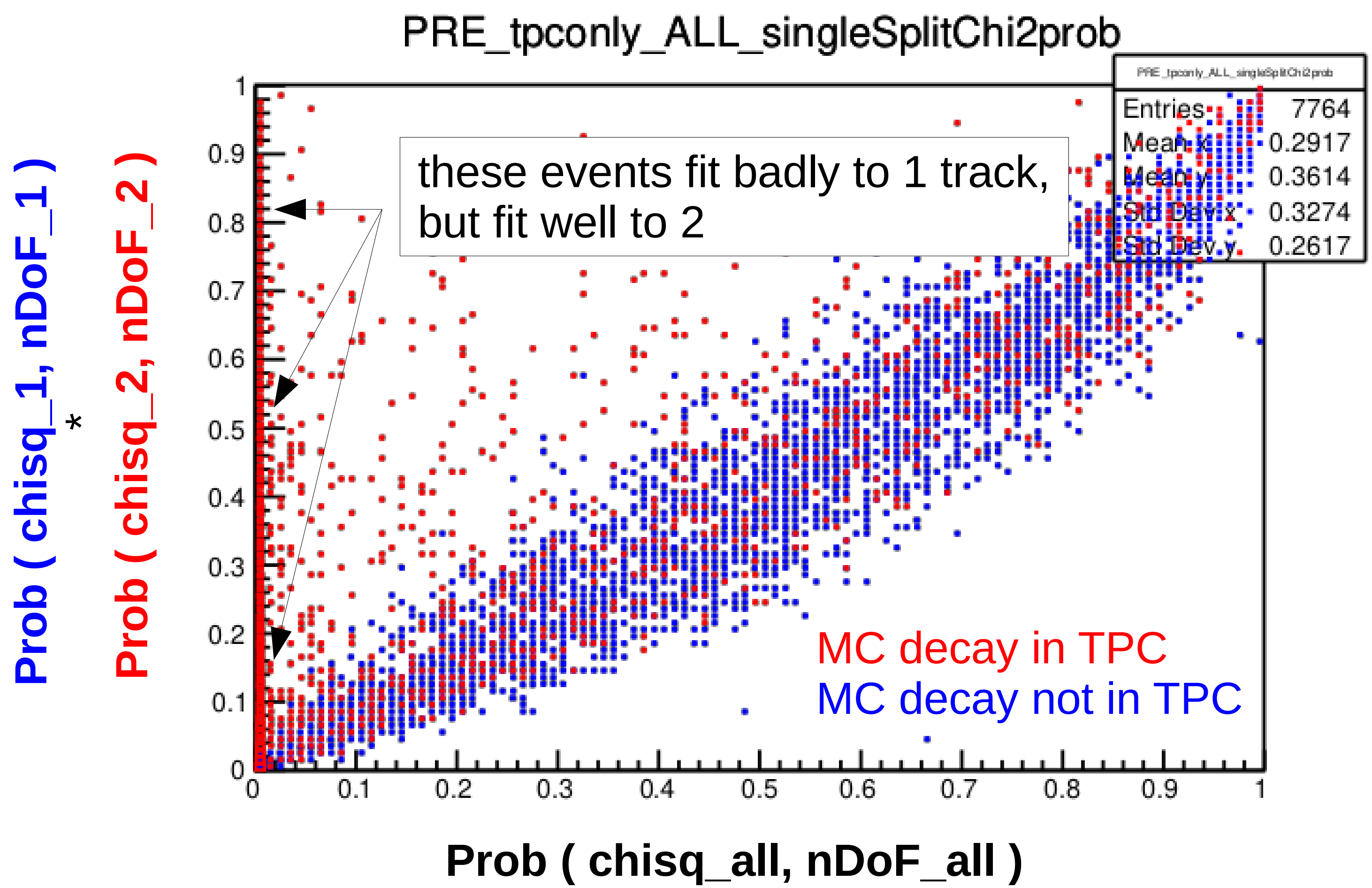
radius of "cut hit"

once we identify the cut-hit with minimum chisq,
how do we decide if it’s a real kink?

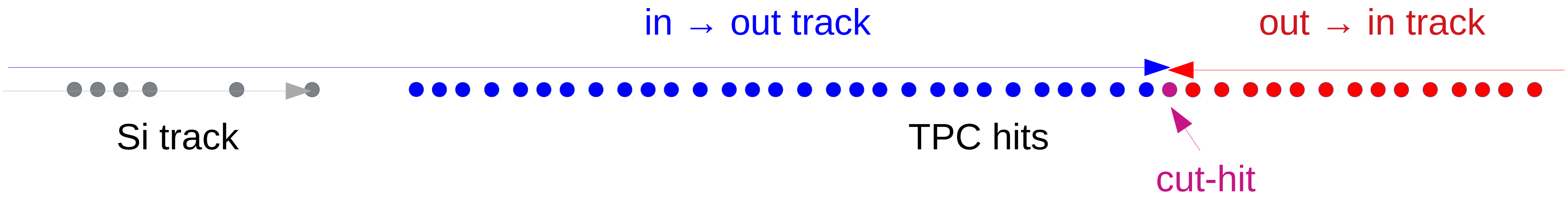


is an identified kink **significant** ?

compare **Prob (chisq_all, nDoF_all)** [track with all TPC hits]
with **Prob (chisq_1, nDoF_1) * Prob (chisq_2, nDoF_2)**

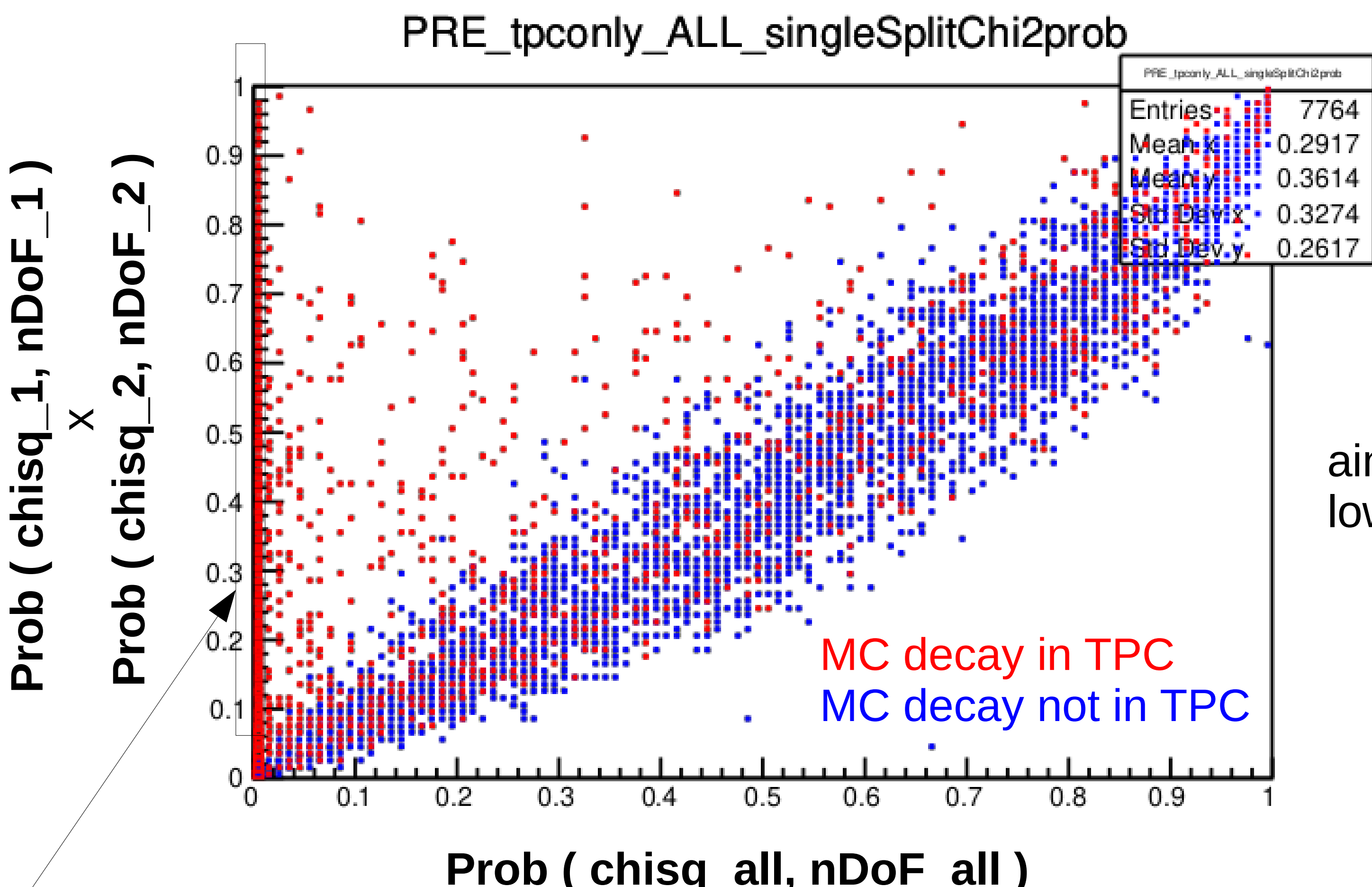


m2; m1 = 110 ; 109 GeV



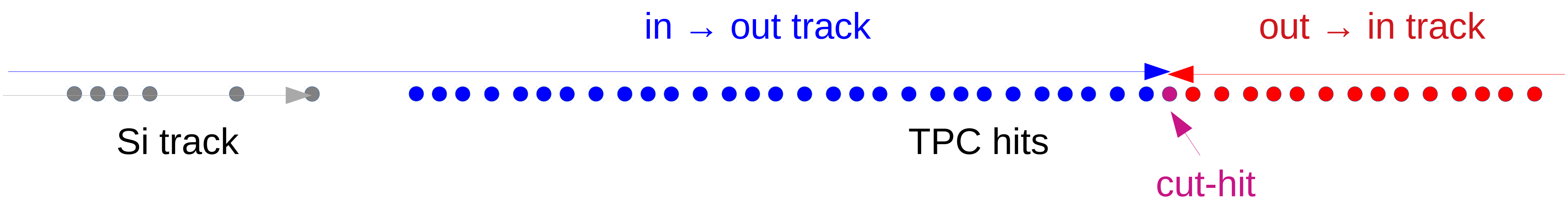
is an identified kink **significant** ?

compare **Prob (chisq_all, nDoF_all)** [track with all TPC hits]
with **Prob (chisq_1, nDoF_1)** x **Prob (chisq_2, nDoF_2)**



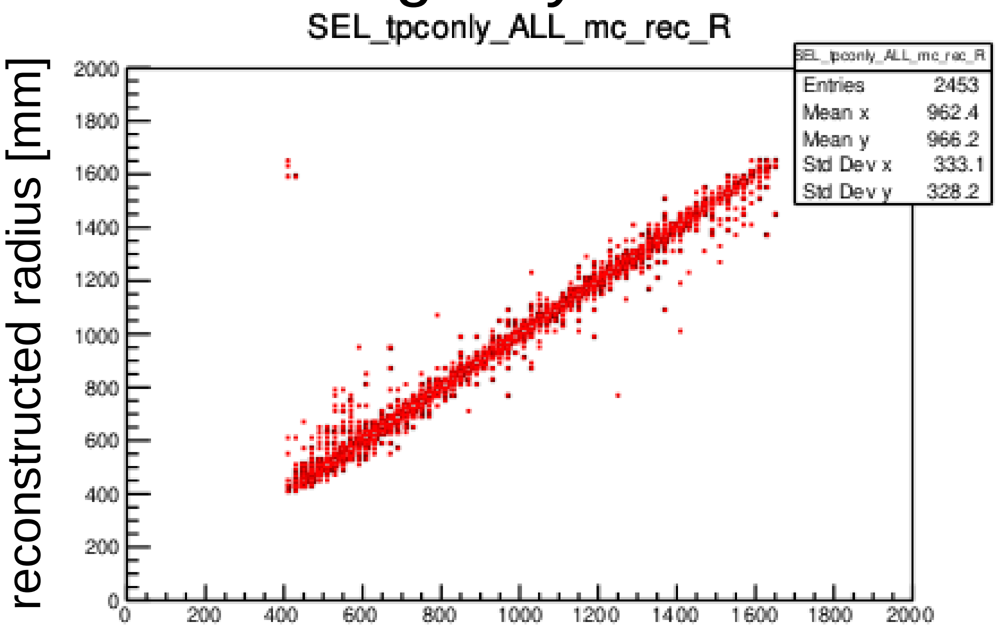
aiming for clean, low-bg selection

selected kinks: **Prob_all** < 1% && **Prob_1** * **Prob_2** > 5%

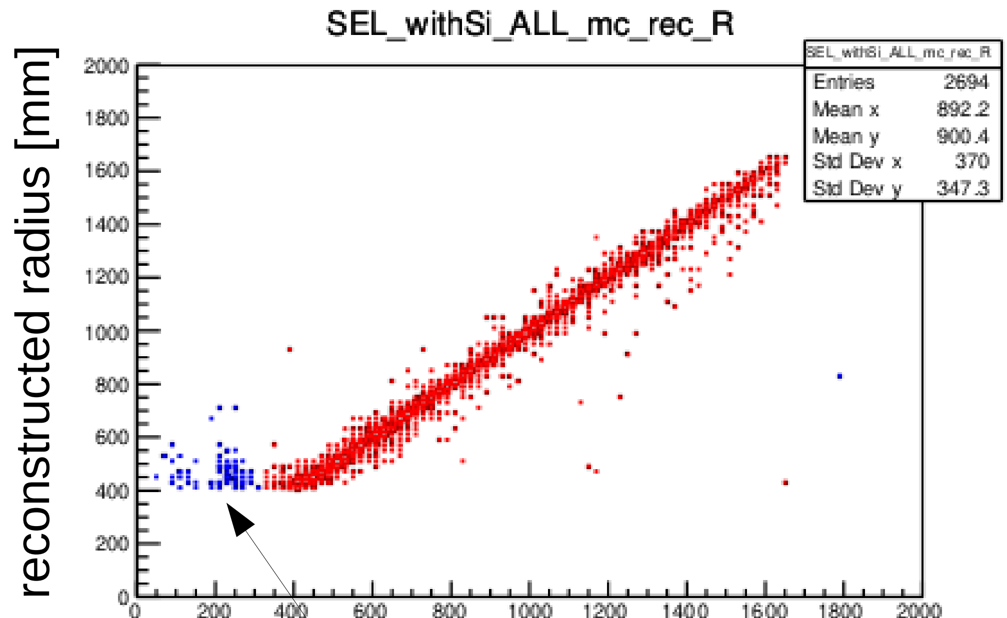


selected kink radius: reconstructed vs. MC

using only TPC hits



SiTrack + TPC hits



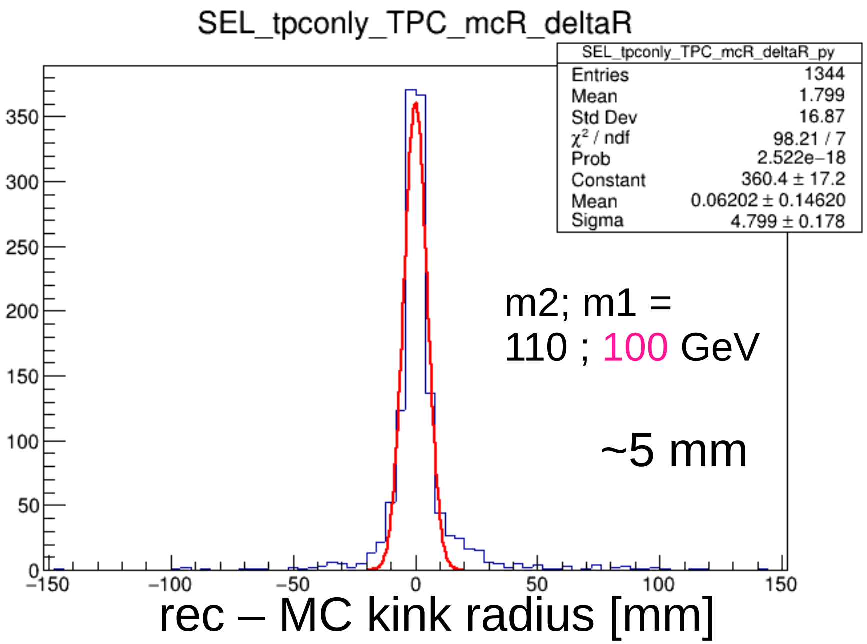
true (MC) decay radius [mm]

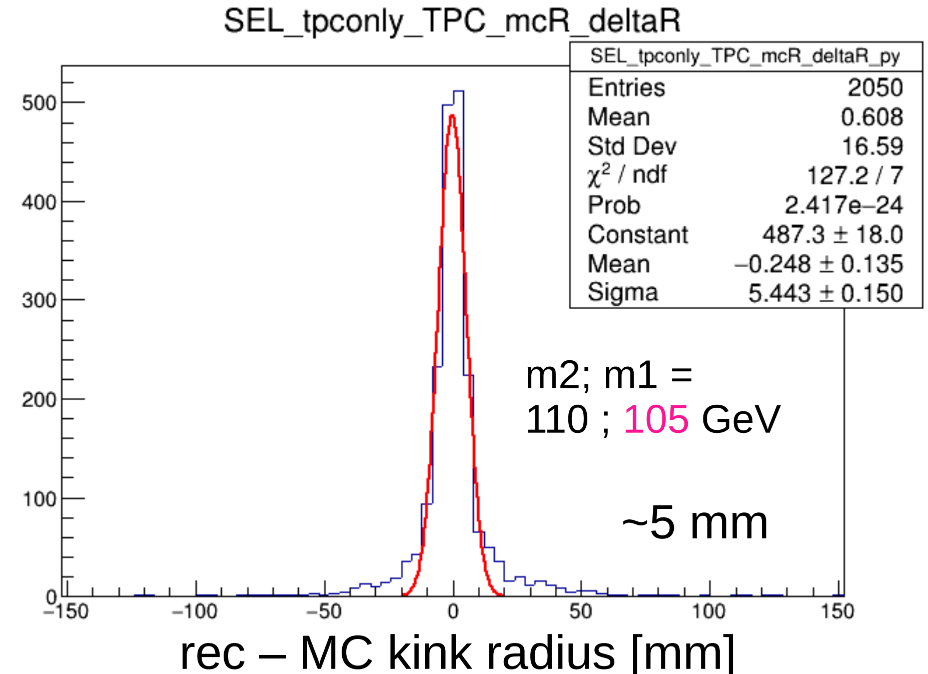
true kink in inner detector, but kink reconstructed in TPC

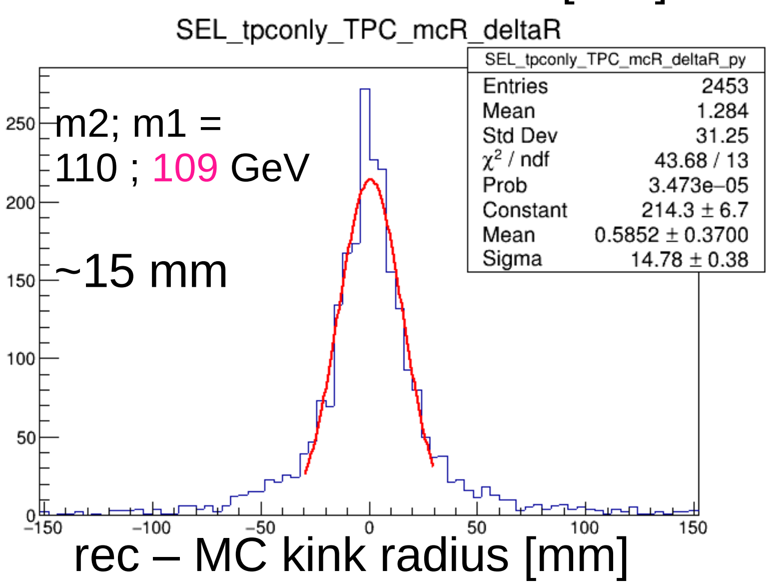
m2; m1 = 110 ; 109 GeV

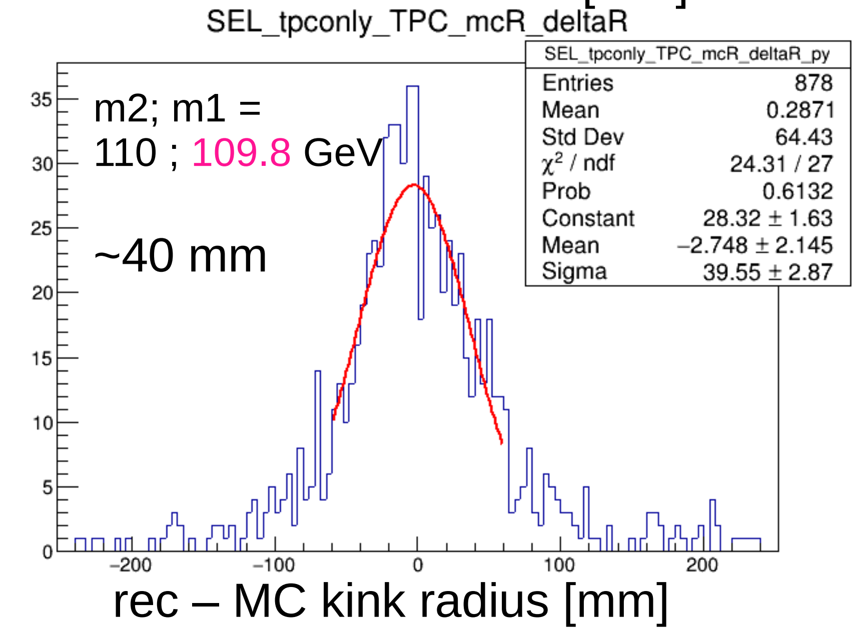
unified treatment of Si and TPC hits is needed → future plan
for now, use TPC-only

kink finding: position resolution





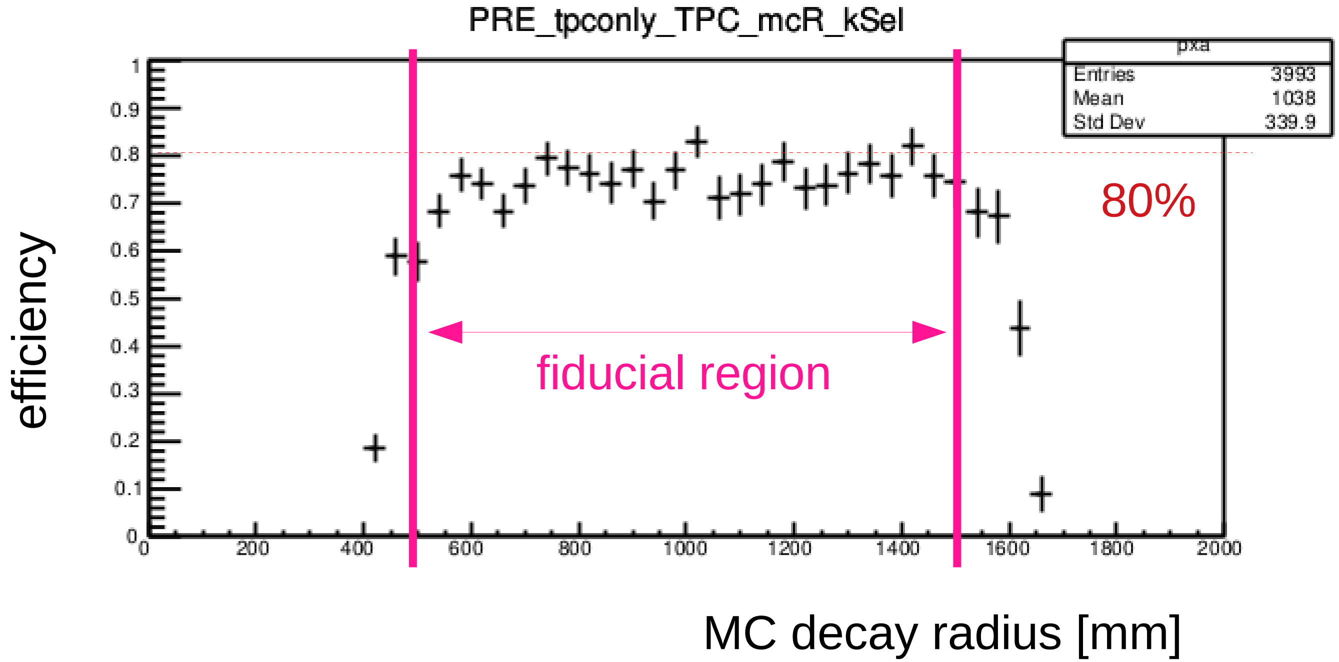




5~40 mm resolution in kink radius determination
0.06~3 mm bias in radius reconstruction
some non-Gaussian tails

kink finding efficiency

(TPC only; fraction of in-TPC decays for which we find a kink
n.b. no quality cut yet: e.g. consistent kink radius)

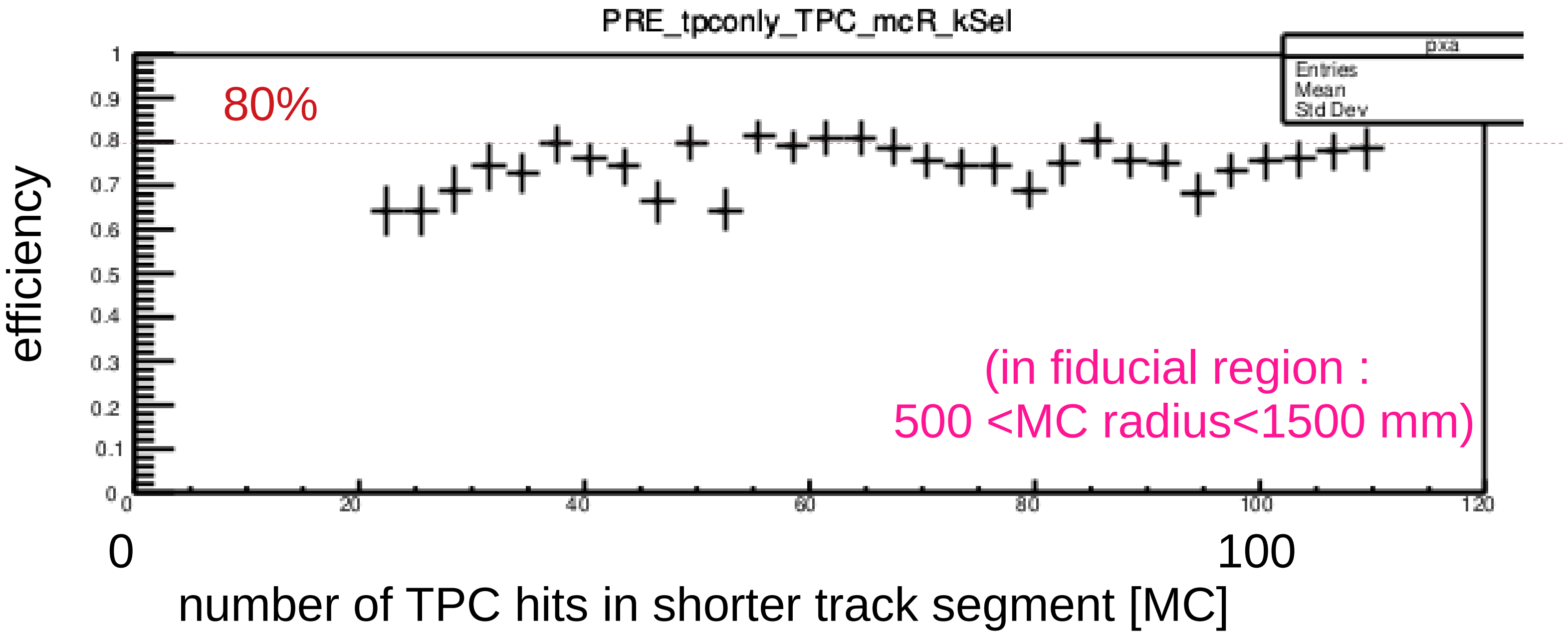


less efficient if decay is near inner/outer TPC surface

m2; m1 = 110 ; 109 GeV

kink finding efficiency

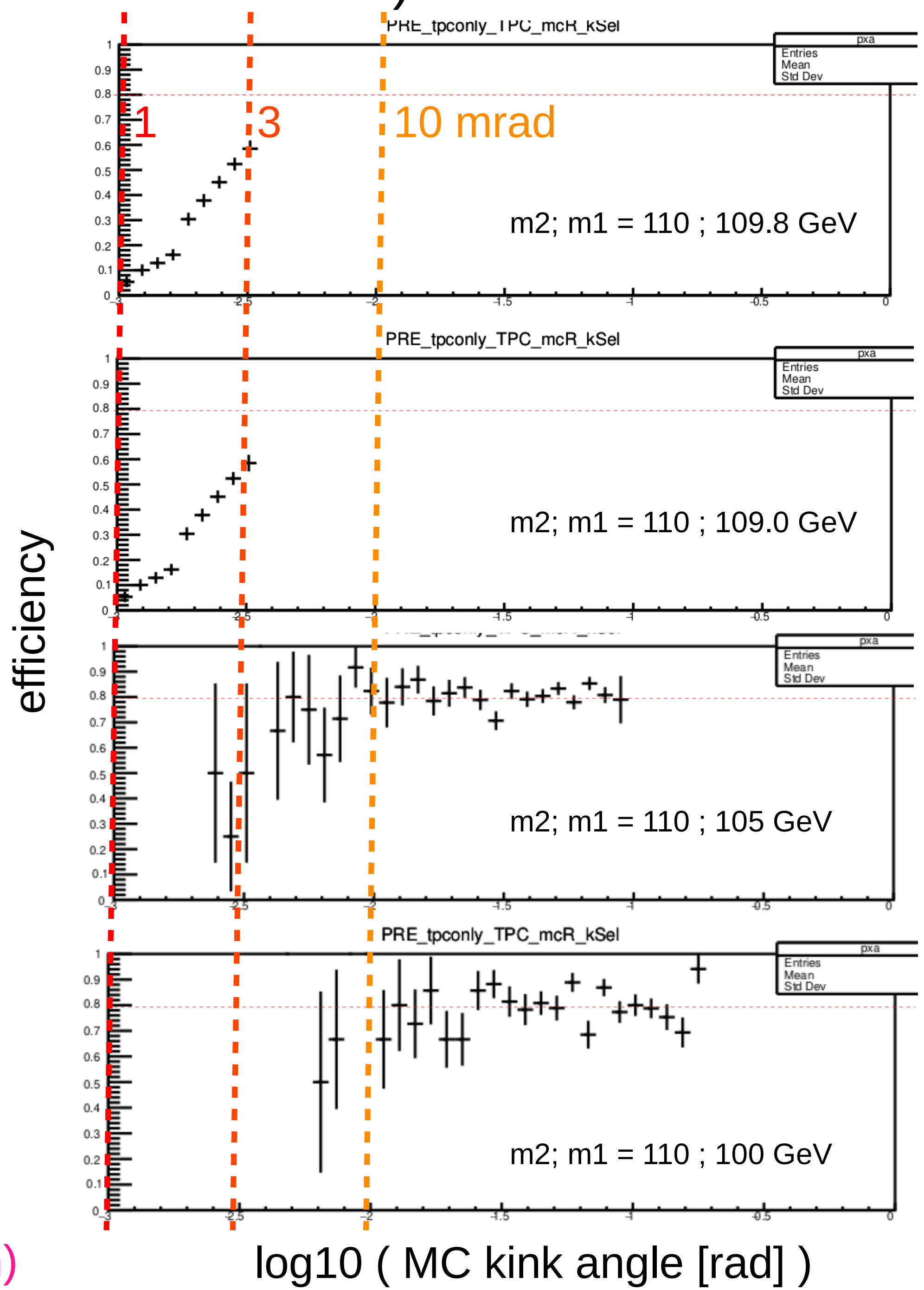
(TPC only; no quality cut yet: eg consistent kink radius)



m2; m1 = 110 ; 109 GeV

kink finding efficiency

(TPC only; no quality cut yet: eg consistent kink radius)



look at 3d angle between mother-daughter at decay point: “MC kink angle”

distribution depends strongly on mass difference

efficiency

for decays with >200 TPC hits &

decay radius in range 500-1500 mm

~80% above ~6 mrad (0.3 deg)

~55% at 3 mrad

~5% at 1 mrad

(in fiducial region :
500 <MC radius<1500 mm)

summary

kinked tracks can be a signature of BSM physics

looking at kink-finding in TPC

using only TPC information,
good efficiency for kinks >3~5 mrad

future plans

backgrounds / fake kinks / real decays in flight / bremstrahlung

adding silicon hits

apply to some BSM models