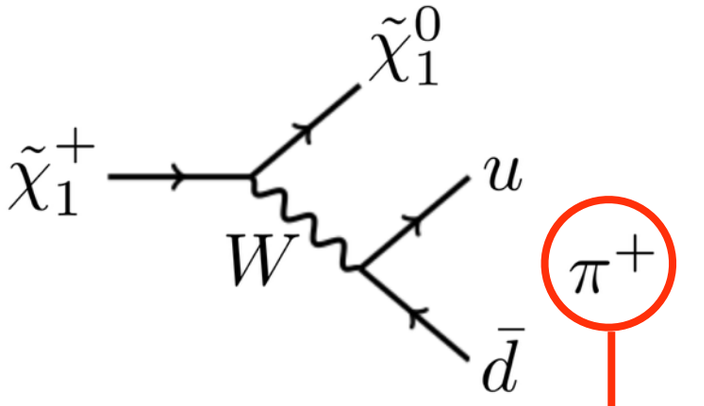
Search for disappearing tracks

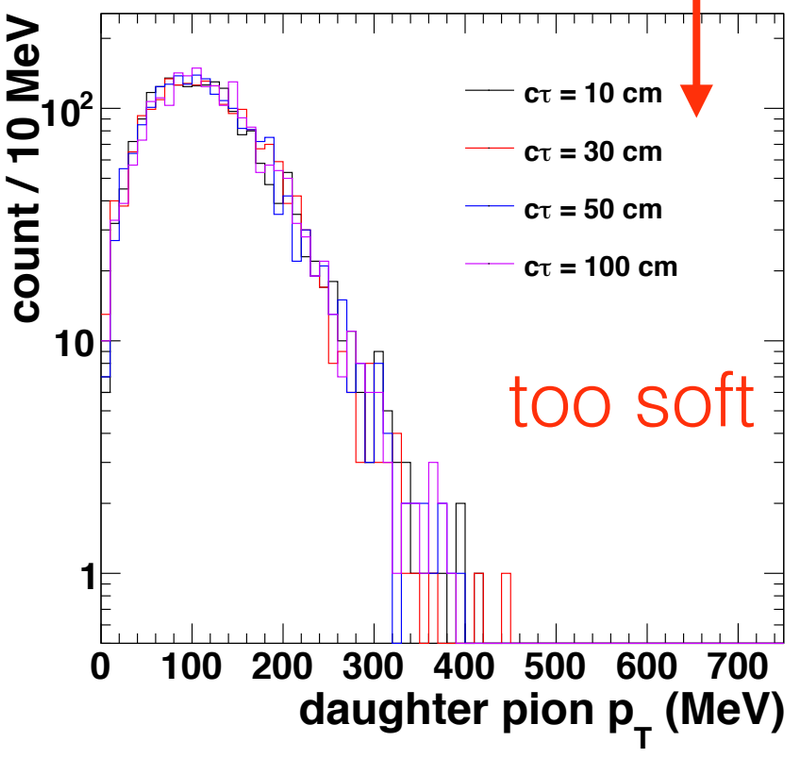
12 July 2018

Weekly SUSY analysis meeting

Viktor Kutzner

Search strategy





signature:

no associated **muon hits**

small/no energy deposition in the calorimeter

missing hits in the outer tracker

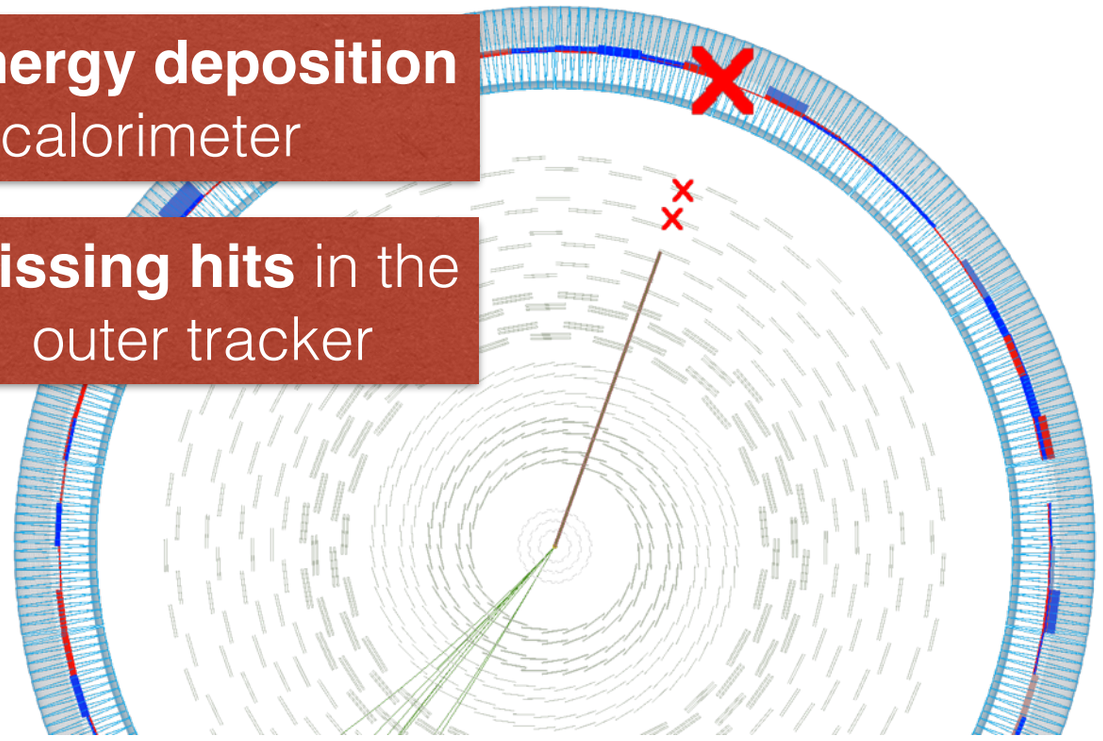


Illustration: Andrew Hart et al. (OSU)

mass splitting: $\Delta m = m(\tilde{\chi}_1^{\pm}) - m(\tilde{\chi}_1^0)$

- $m_\pi < \Delta m \lessapprox 200$ MeV: **disappearing track visible in tracker**
- $\Delta m \gtrapprox 200$ MeV: decay before first tracking layer

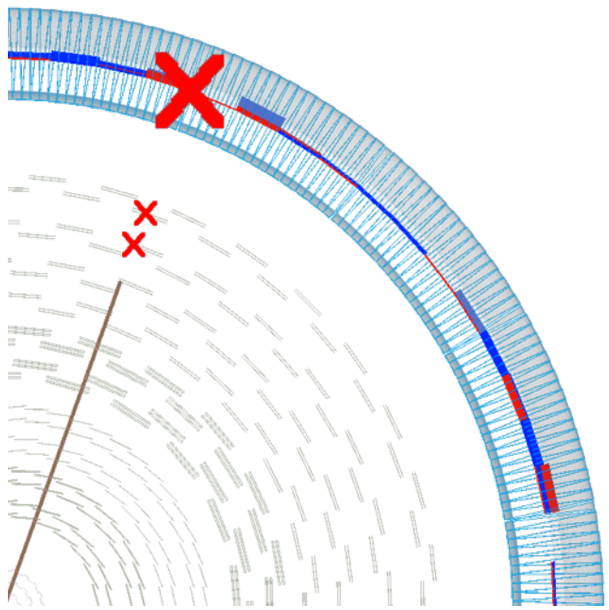
need to suppress background from

- fake tracks
- tracks from failed lepton reconstruction

Tagging disappearing tracks

relevant track properties:

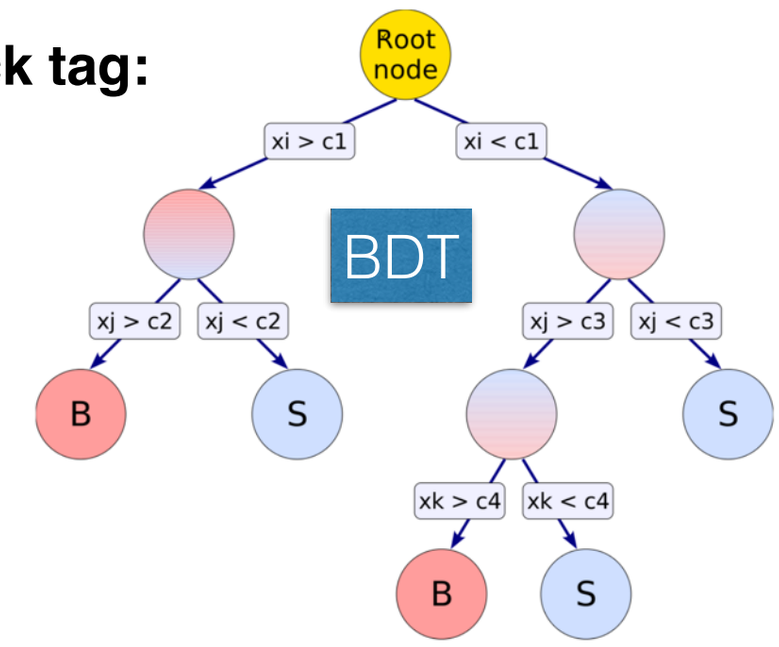
- number of pixel / tracker hits
- missing inner / middle / outer hits
- distance to primary vertex (d_{xy}, d_z)
- χ^2 / ndof
- Δp_T / p_T^2
- high purity track quality



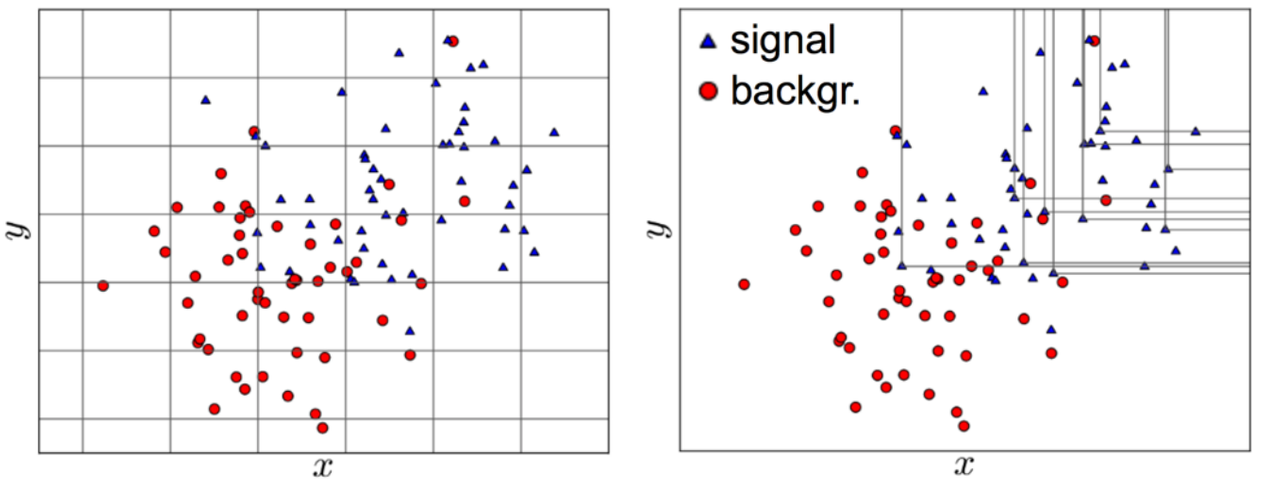
avoid **model dependence** by too tight cuts on p_T, η, or isolation

- deposited energy in calorimeter within cone of $\Delta R < 0.5$

optimize track tag:



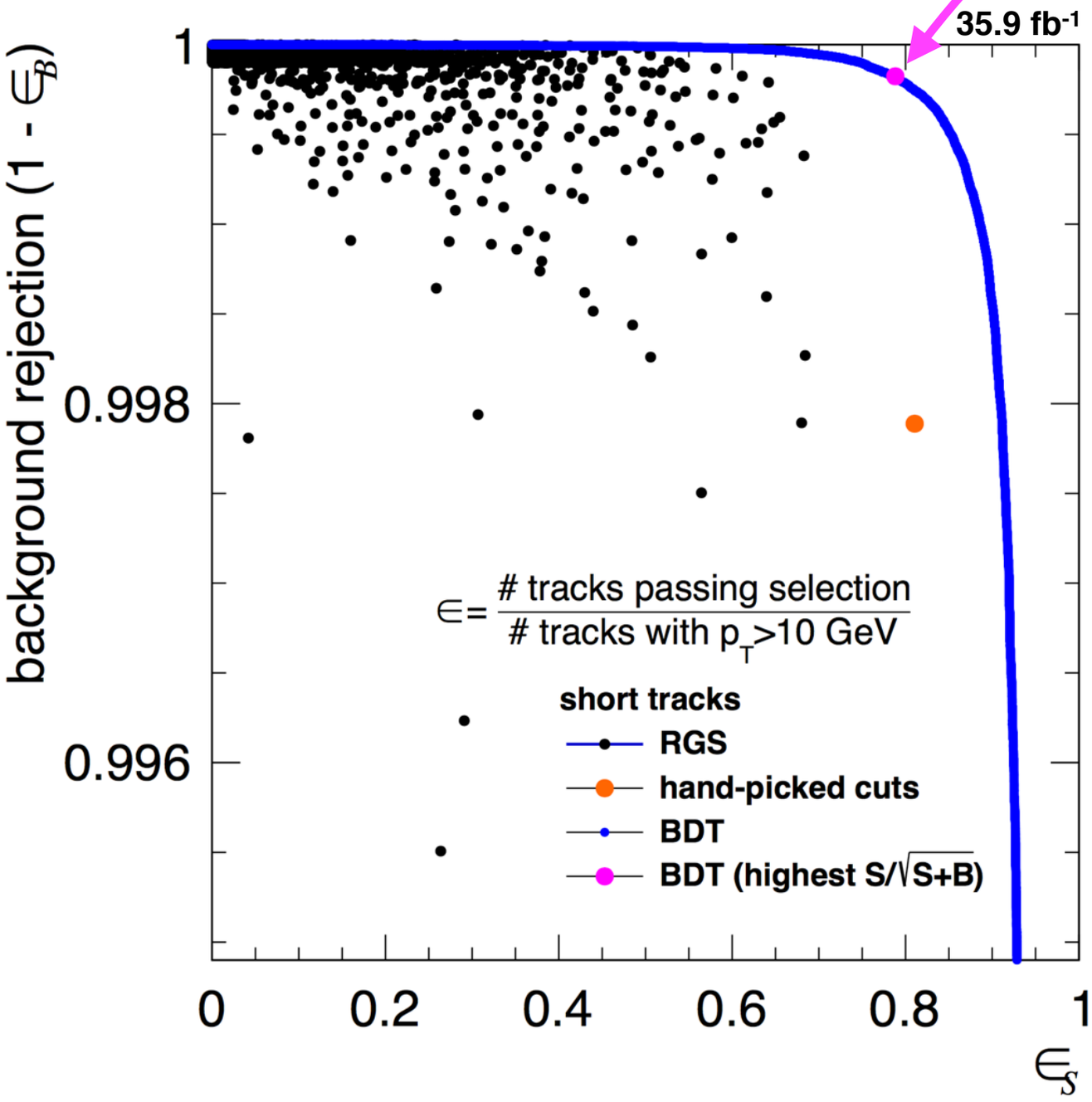
Random Grid Search



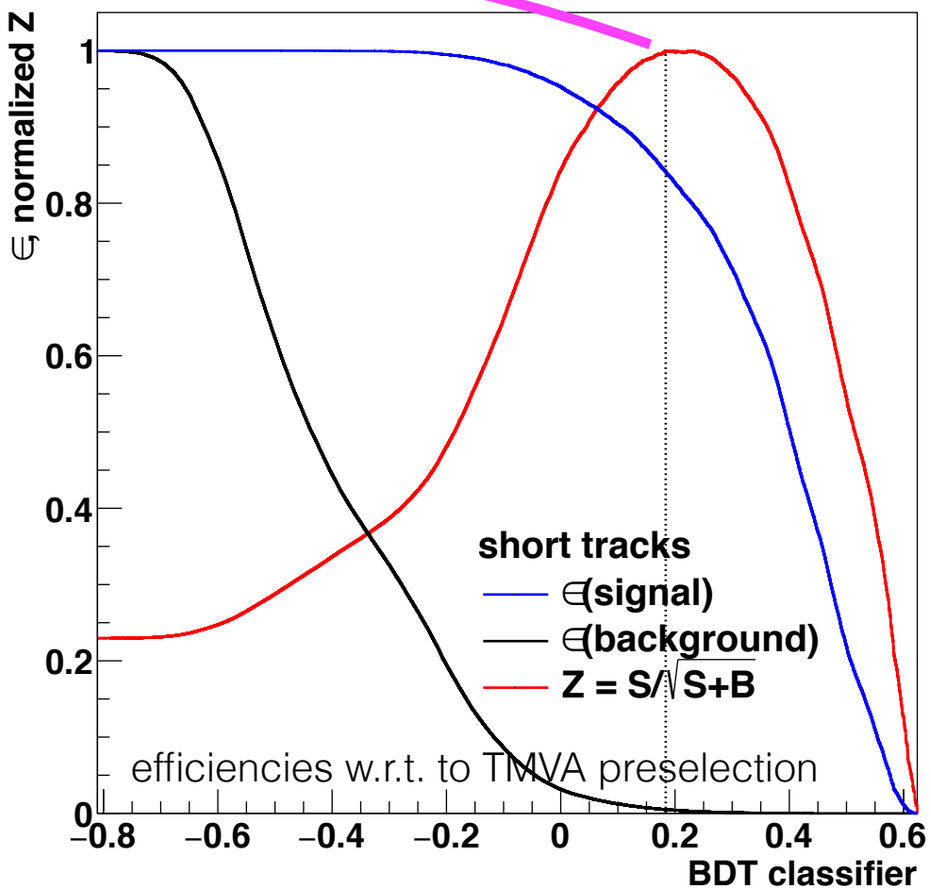
arxiv: 1706.09907

Optimization methods

for pixel-only tracks:
ROC plot for RGS, BDT and hand-picked cuts for reference



largest significance



variables used for BDT training:

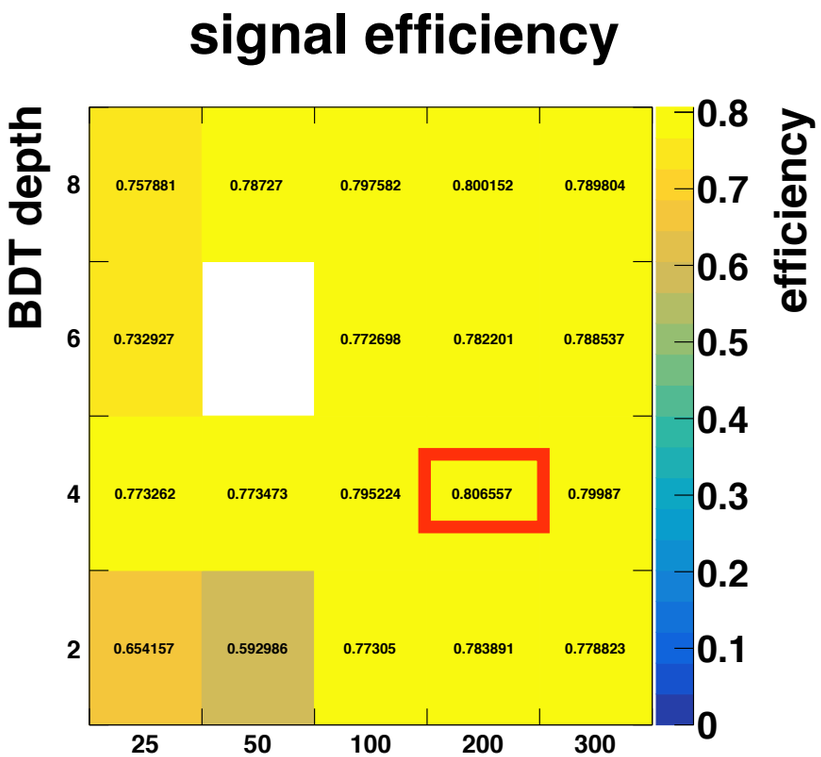
- pixel & tracker hits, dxyVtx, dzVtx, nMissingOuterHits, trkRelIso, matchedCaloEnergy, ptErrOverPt2

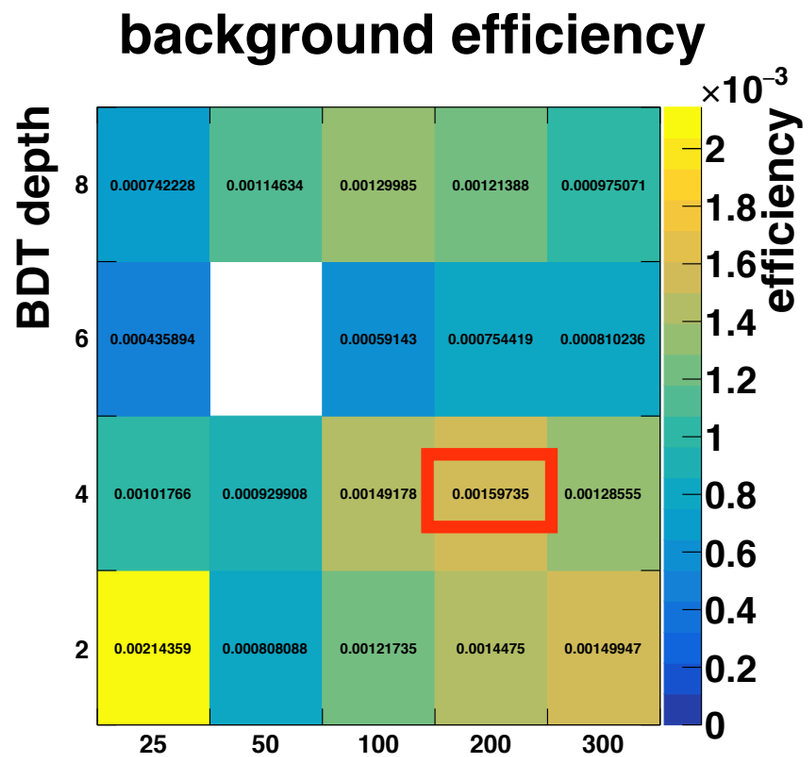
variables used for RGS:

- tracker layers, dxyVtx, dzVtx, neutralPtSum, chargedPtSum, trkRelIso, nMissingOuterHits, ptErrOverPt2

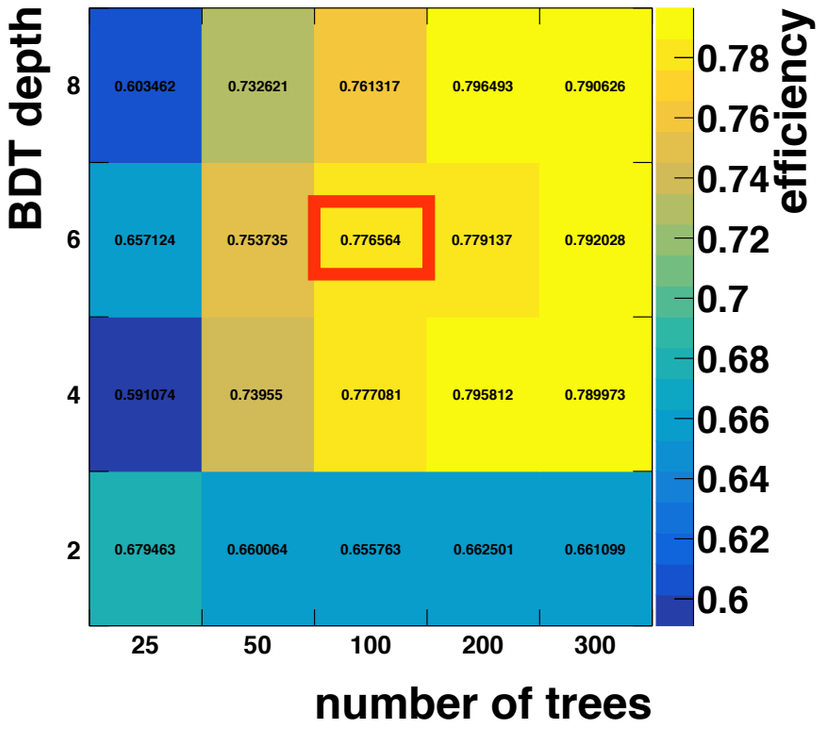
BDT configuration scan

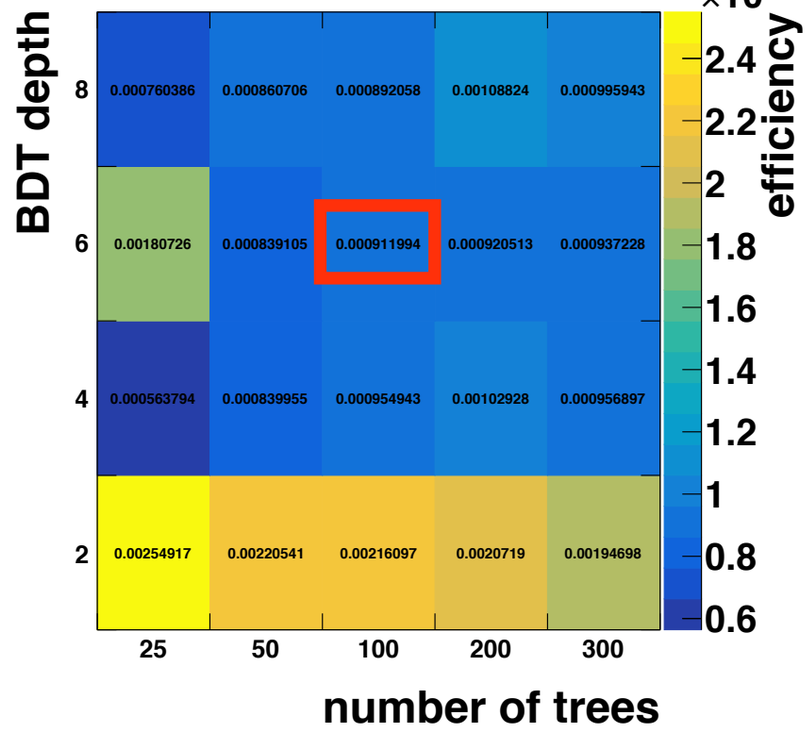
pixel-only tracks





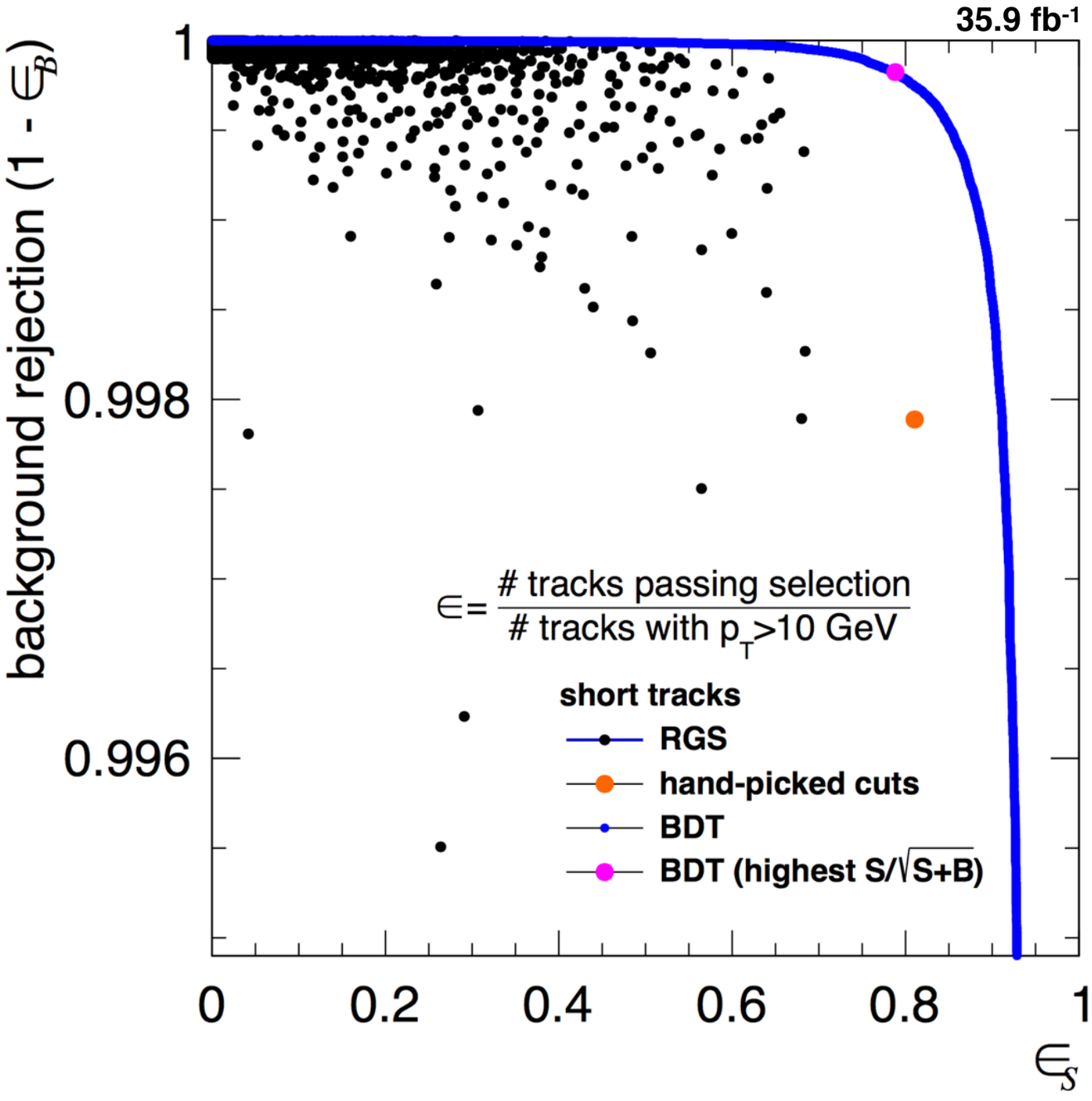
tracker tracks < 7 layers





Optimization methods

for pixel-only tracks:
ROC plot for RGS, BDT and hand-picked cuts for reference



current plan:

use both approaches:

- train BDT using track variables only
- use RGS for E_{calo} and nMissHits (possibly also BDT classifier)

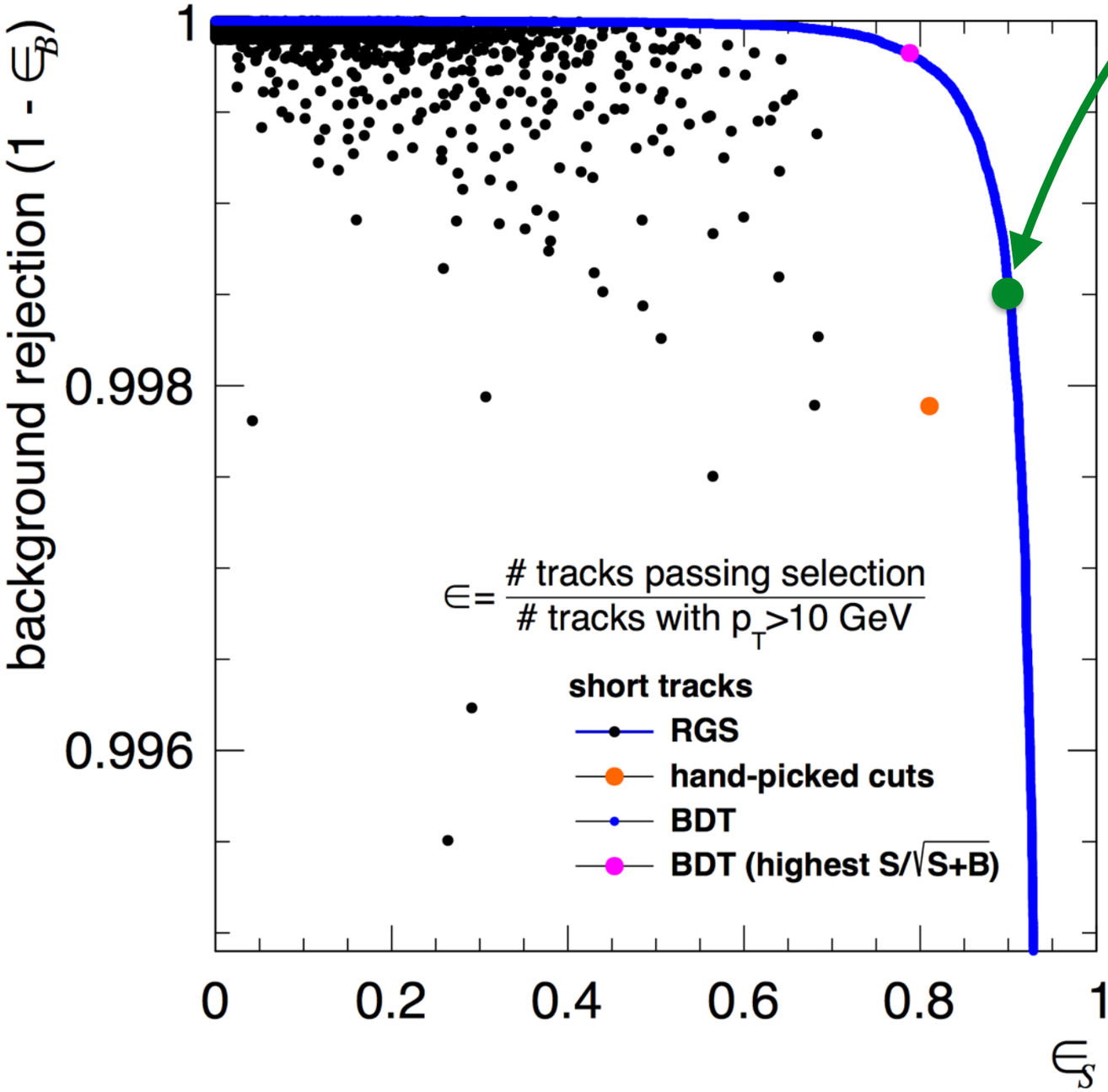
background estimation:

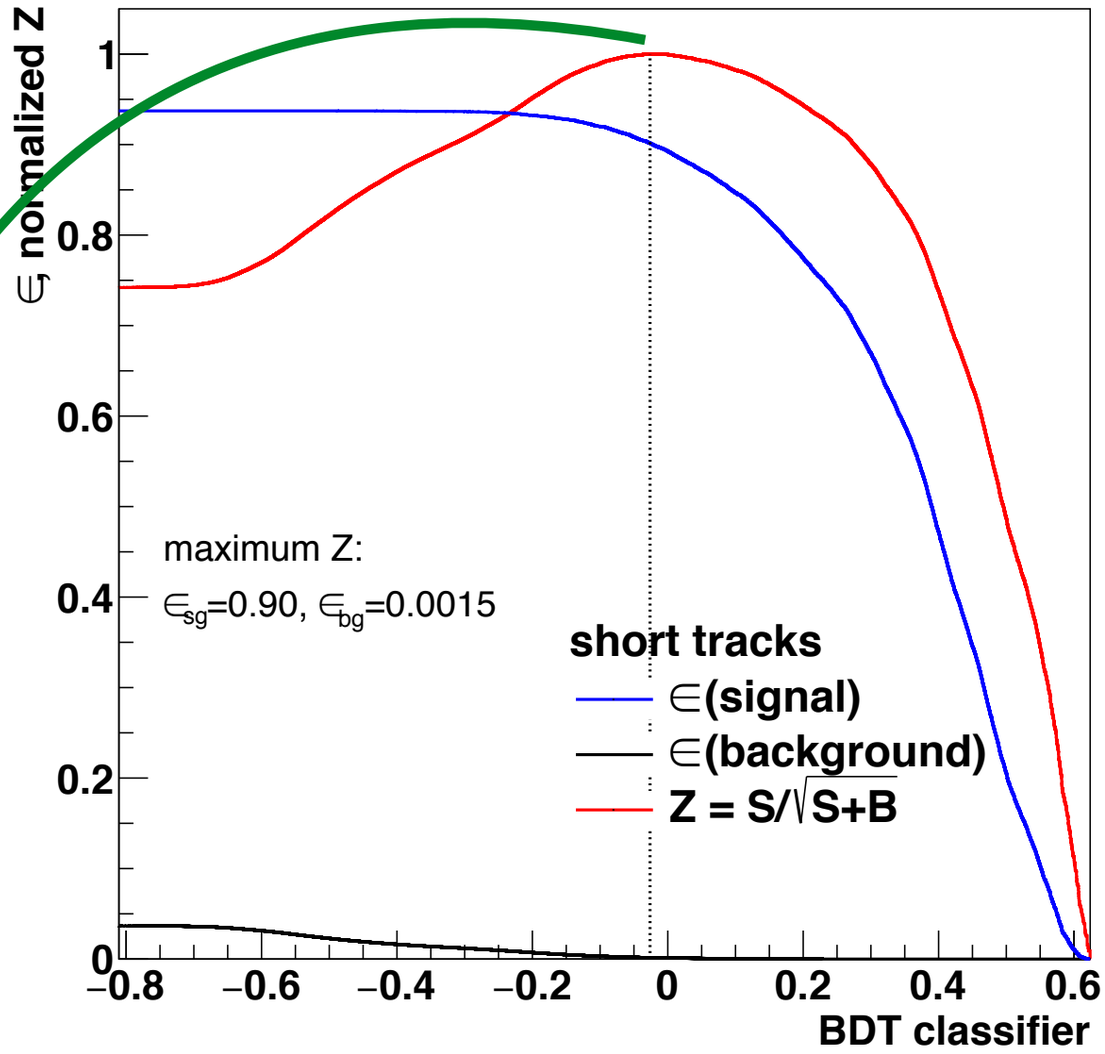
- currently including BDT weights for skimming ntuples
- => derive κ factors using improved track tag

Backup

Optimization methods

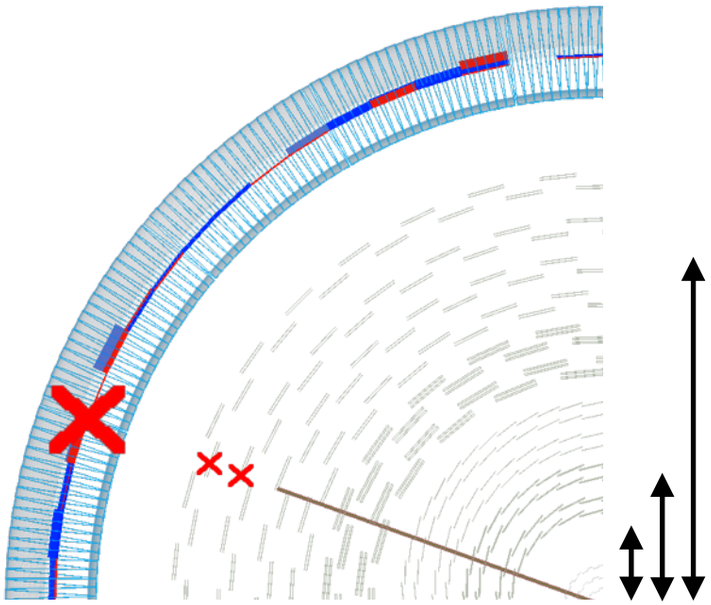
for reference: Z calculated from efficiencies w.r.t to tracks with $p_T > 10$ GeV





won't use for working point selection

Disappearing track categorization



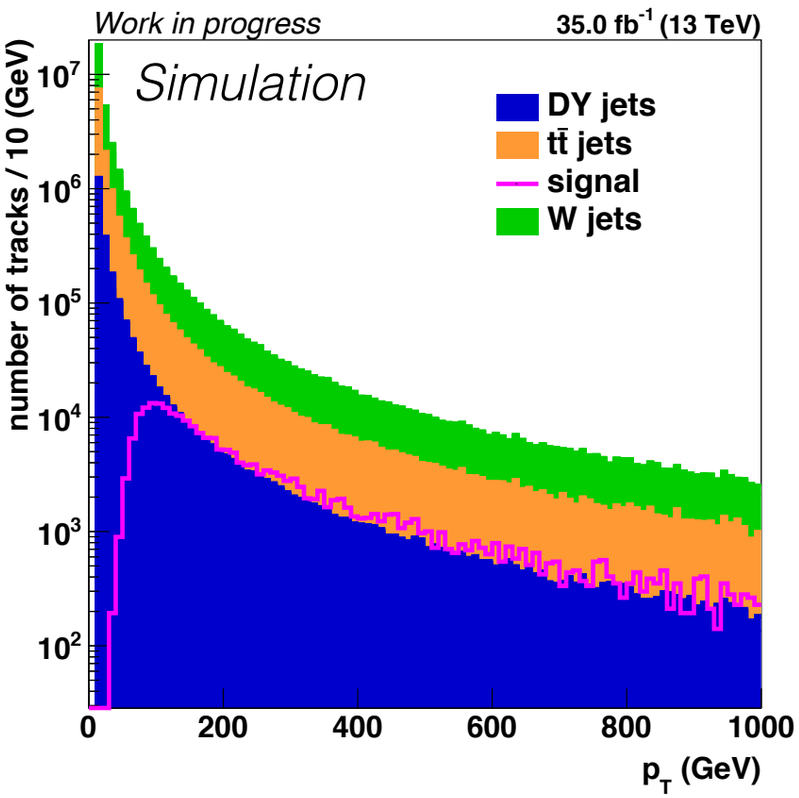
define track categories:

- **short tracks**: pixel detector only
- **medium tracks**: up to 6 layers
- **long tacks**: ≥ 7 layers

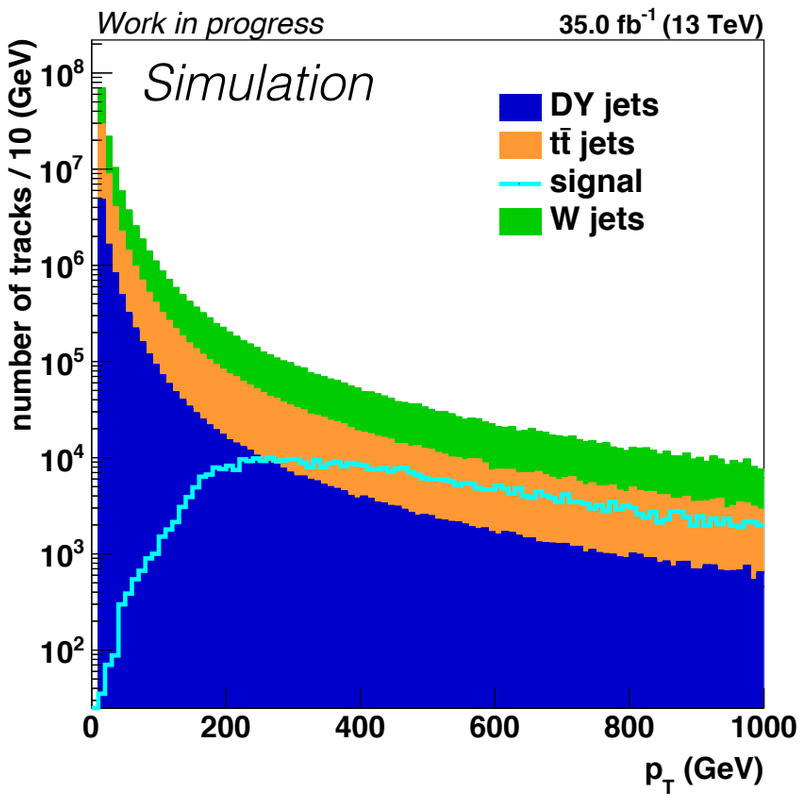
preselection:
p_T > 10 GeV

signal scaled to 100 pb

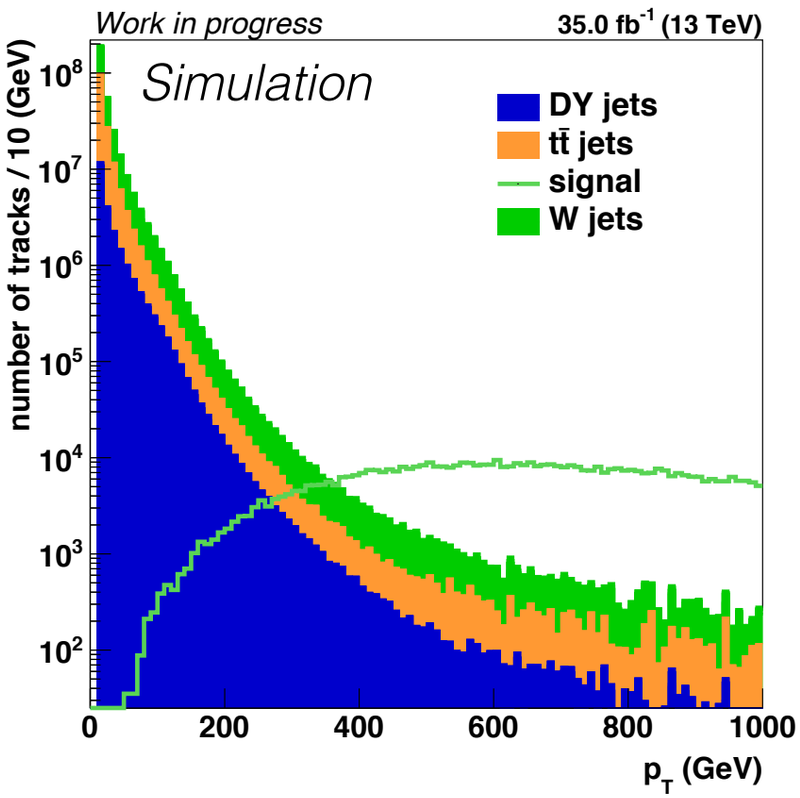
short tracks



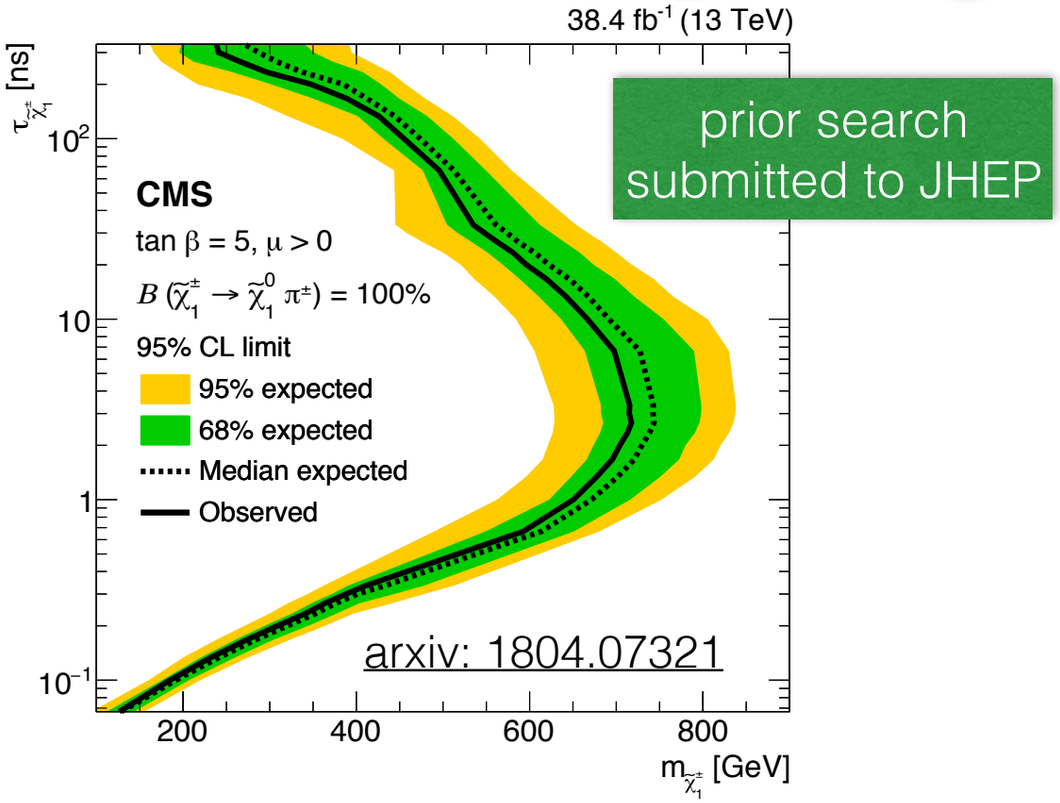
medium tracks



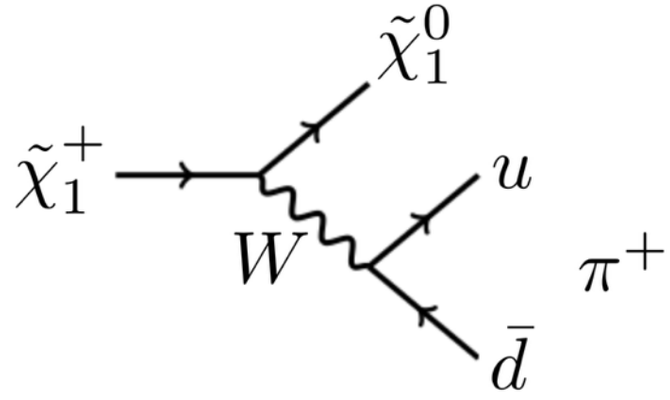
long tracks



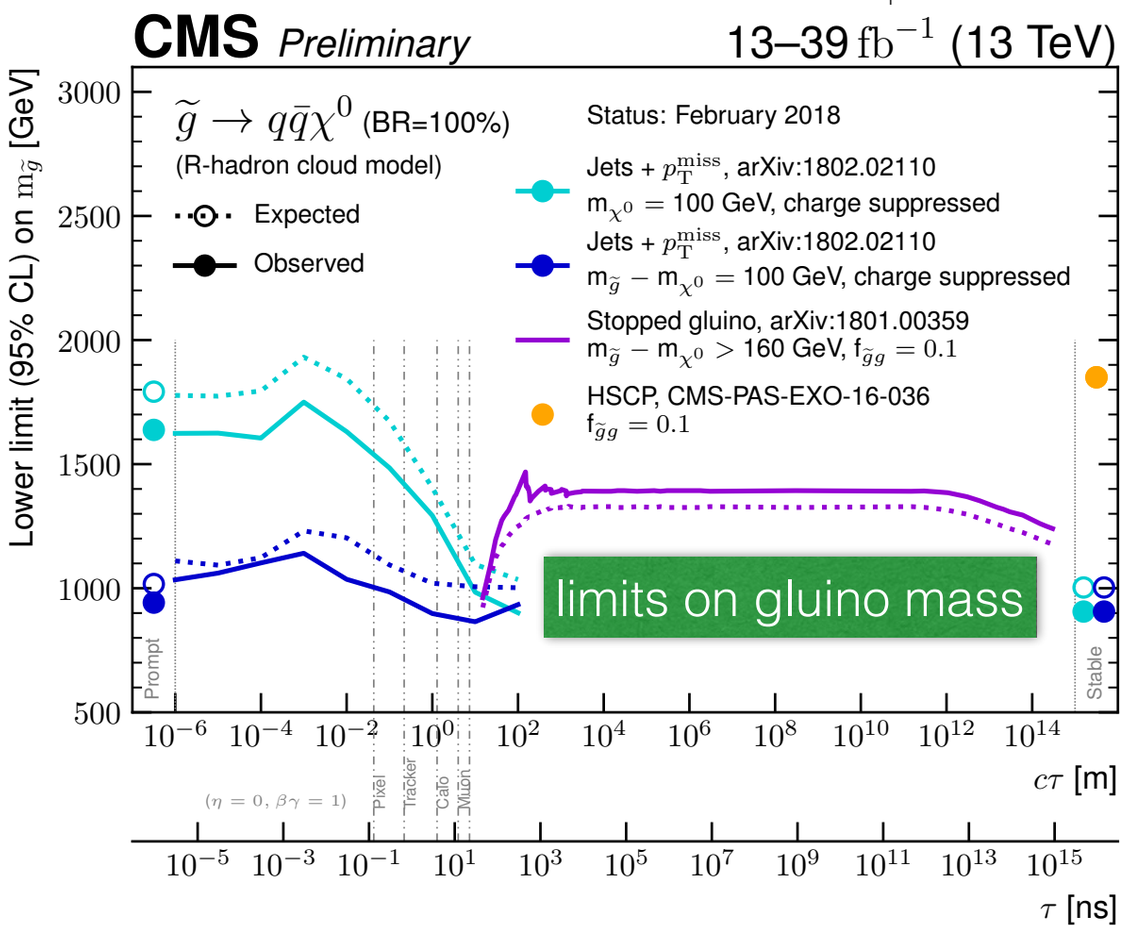
Signal generation



prior search submitted to JHEP



signal generation with Pythia8:
strong chargino production through
$gg \rightarrow \tilde{g}\tilde{g}$



limits on gluino mass

- m($\tilde{g}$) = 1800 GeV
- m(chargino) = 1400 GeV
- Δm = 180 MeV
- cτ = 10, 30, 50, 100 cm

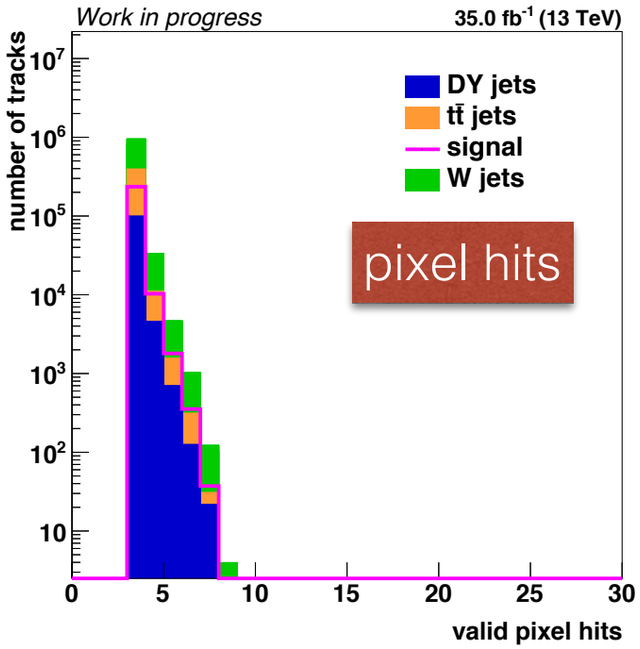
include models from pMSSM scan for event selection

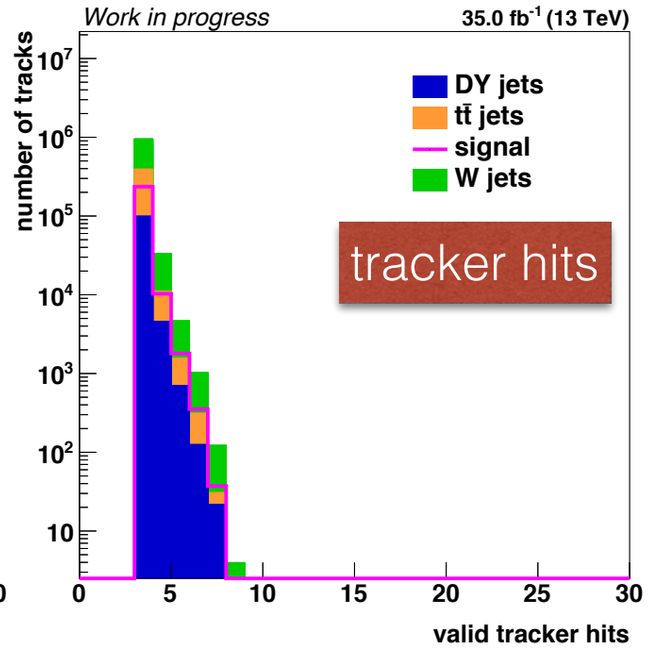
Short tracks: input variables

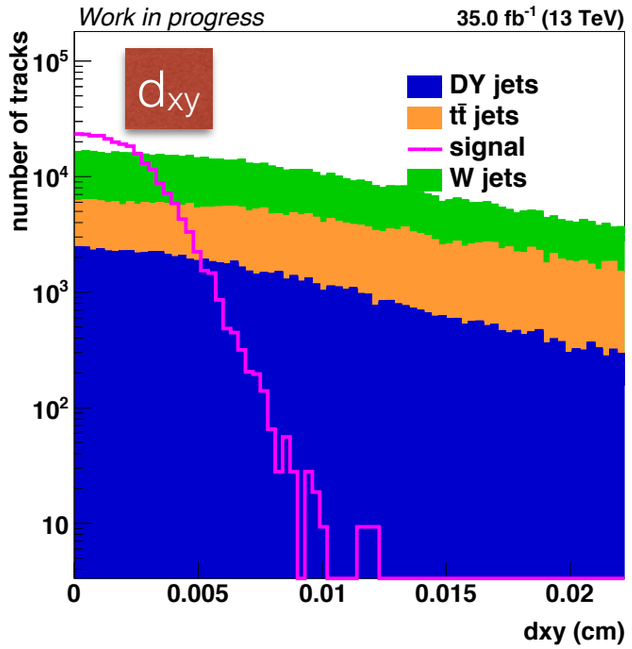
short tracks

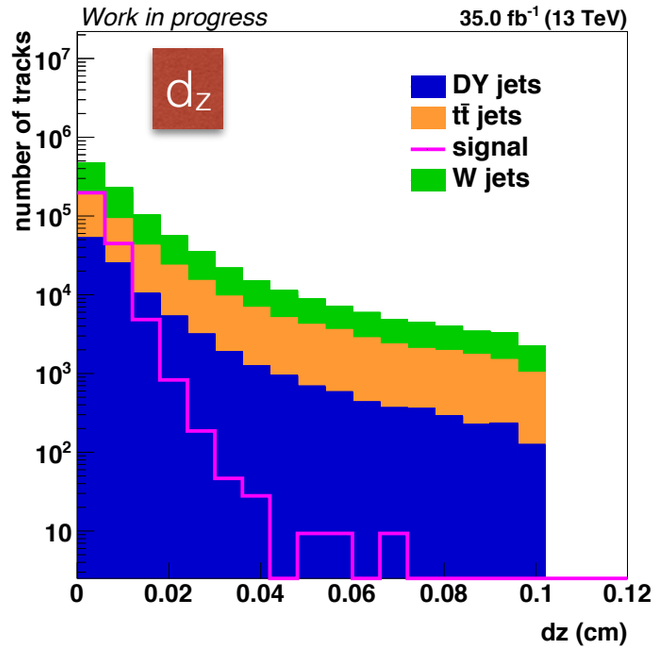
track variables after applying a basic preselection:

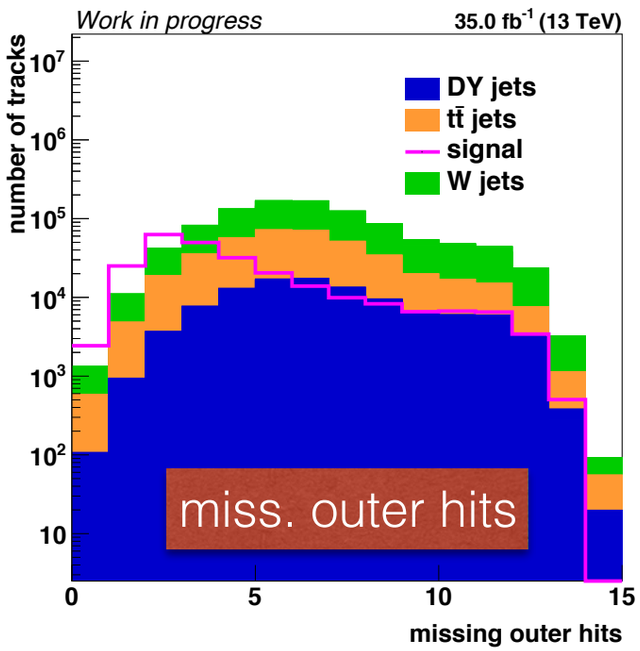
$p_T > 15$ GeV, $|\eta| < 2.4$, rel. isolation < 0.2, $d_{xy} < 0.2$, $d_z < 0.1$,
$\Delta p_T/p_T^2 < 10$ 1/GeV, **PF lepton veto & no missing inner hits**

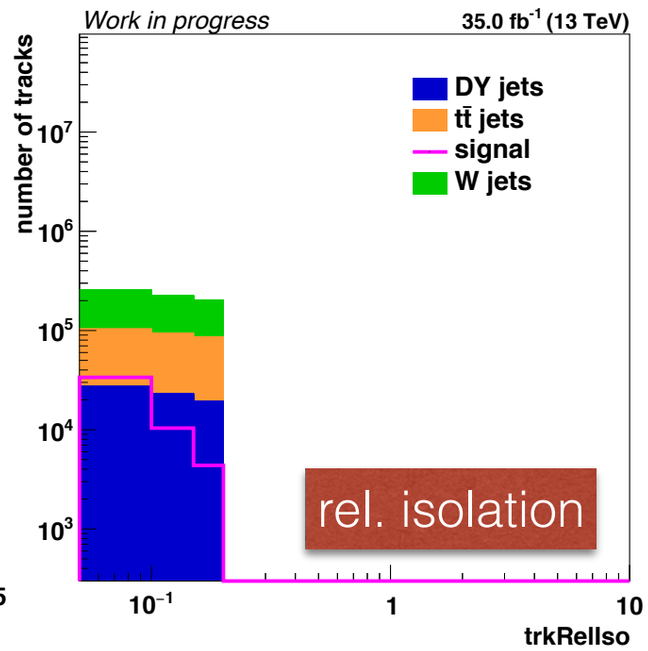


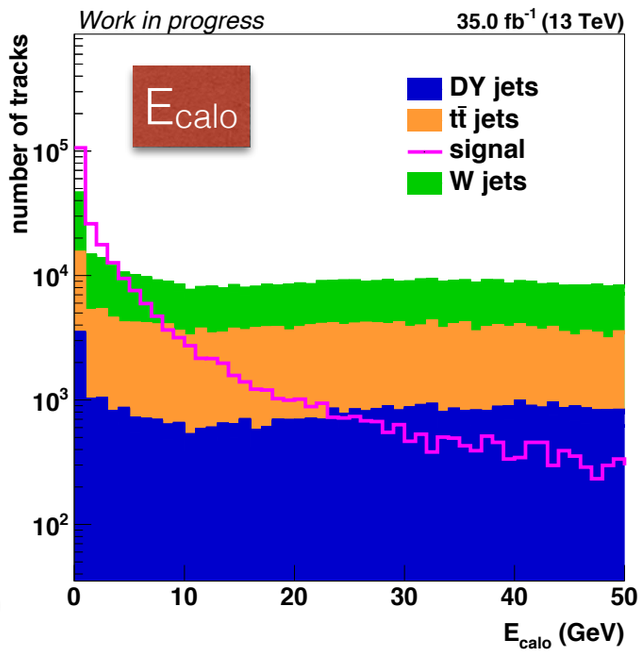


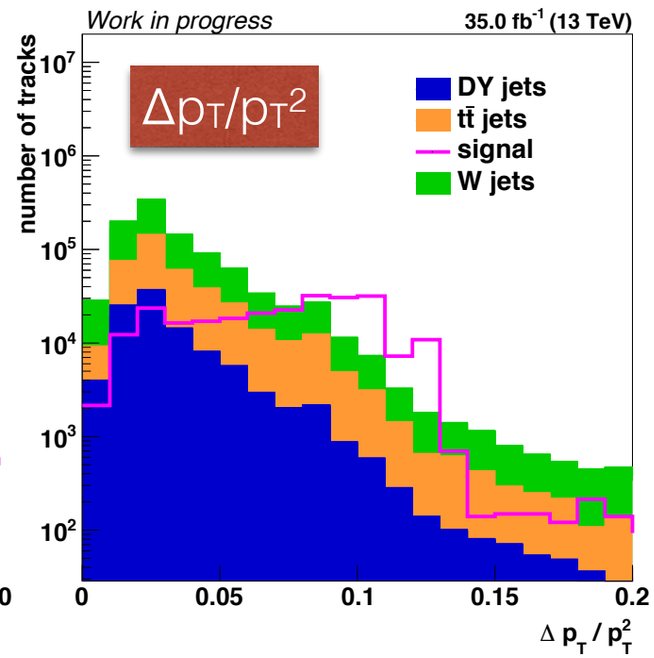












Input variables

medium tracks

track variables after applying a basic preselection:

$p_T > 15$ GeV, $|\eta| < 2.4$, rel. isolation < 0.2, $d_{xy} < 0.2$, $d_z < 0.1$,
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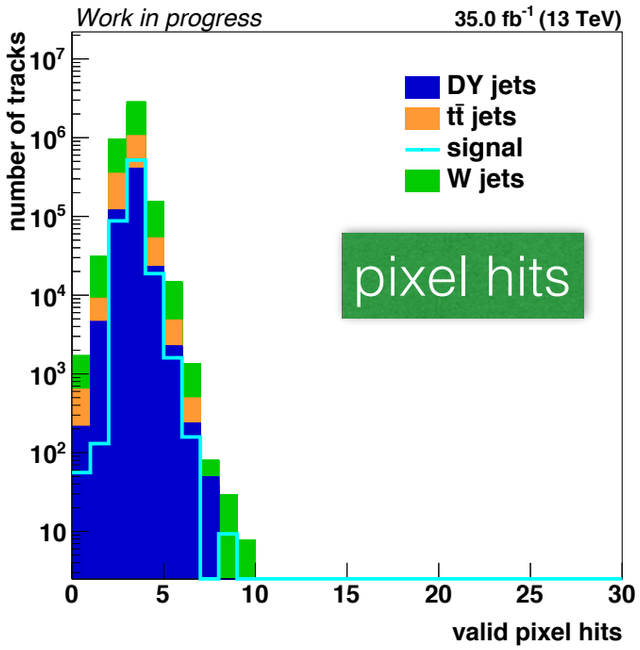

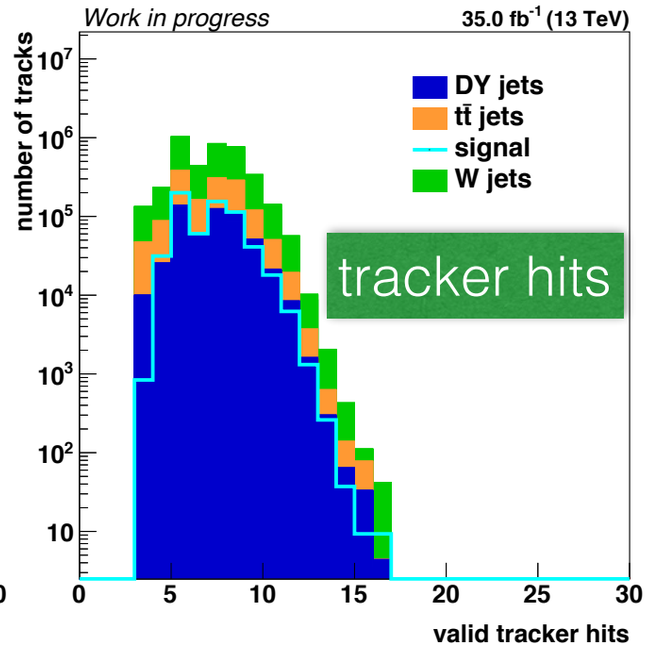

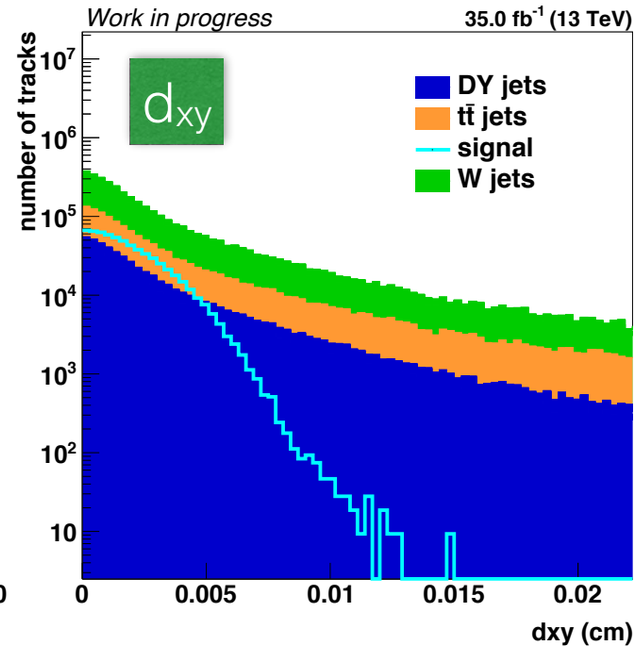

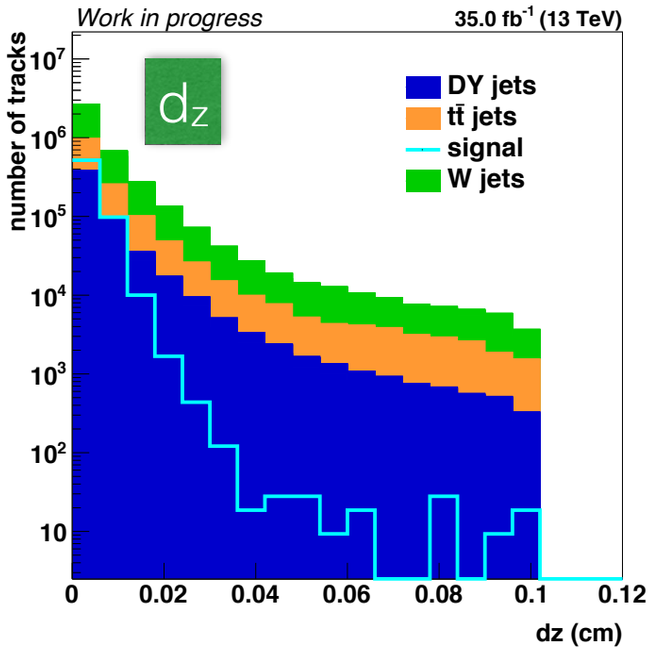

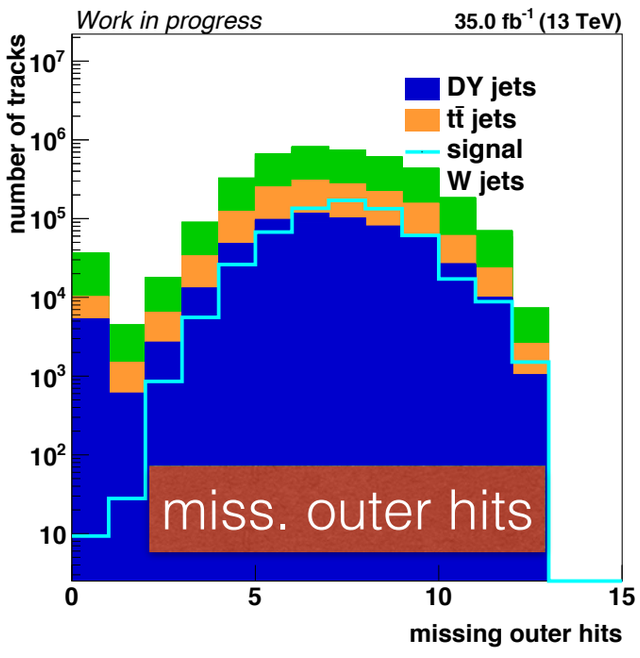

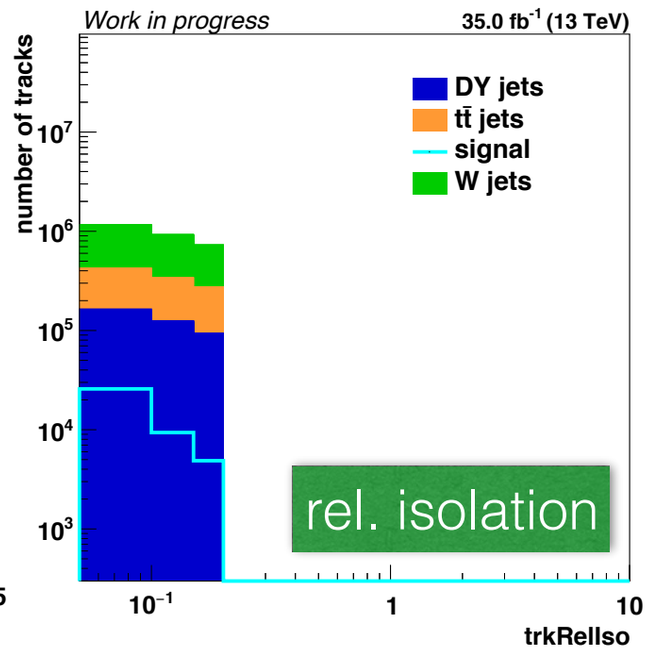

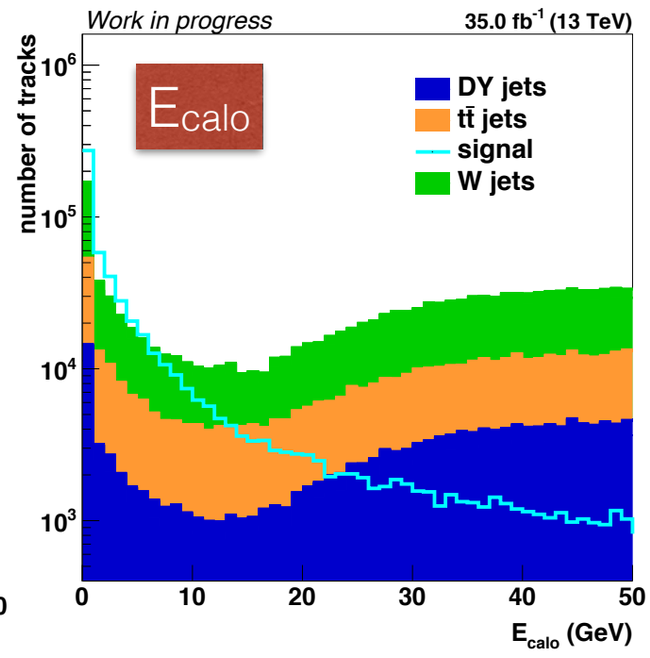

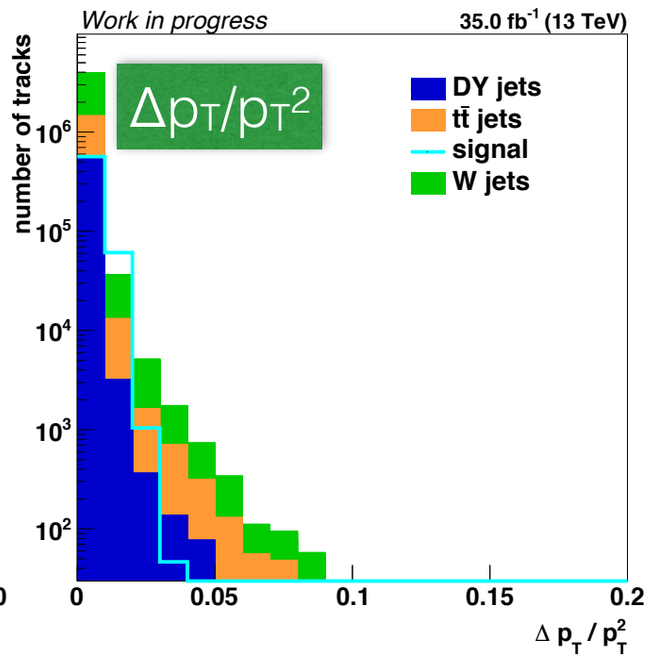

Long tracks: input variables

long tracks

track variables after applying a basic preselection:

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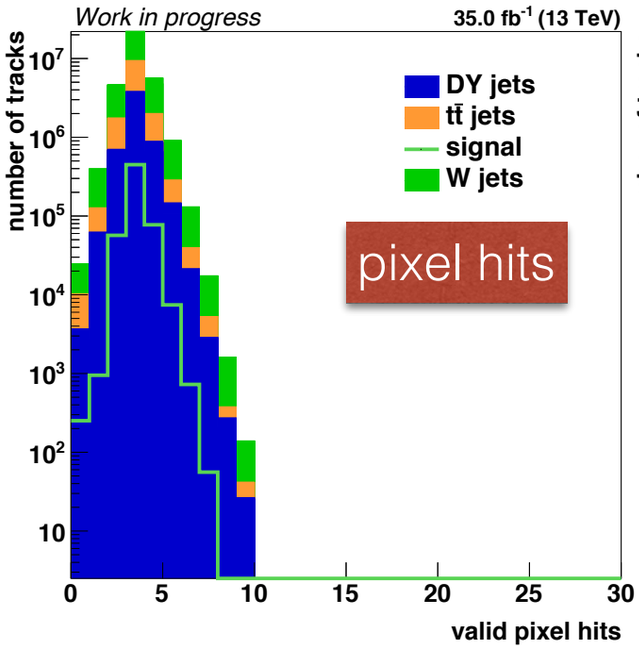
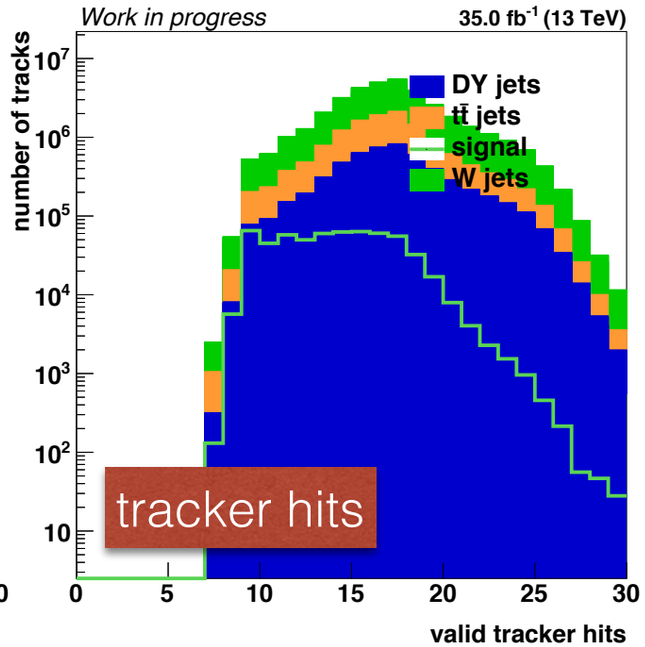
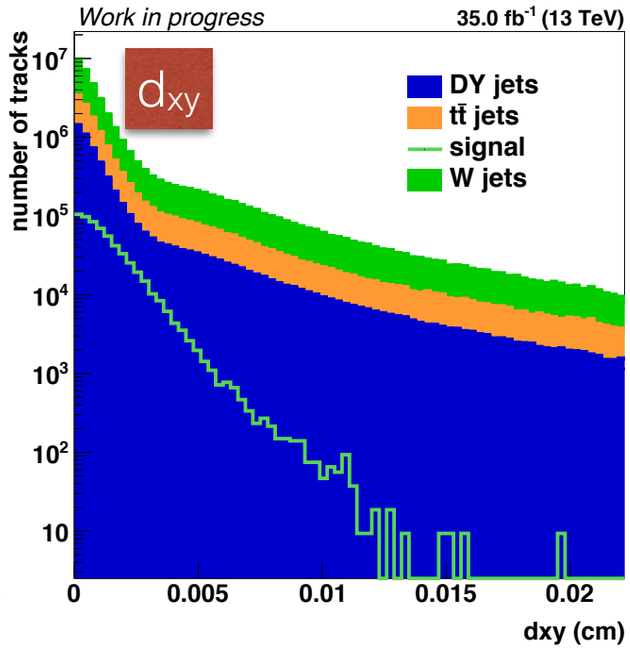
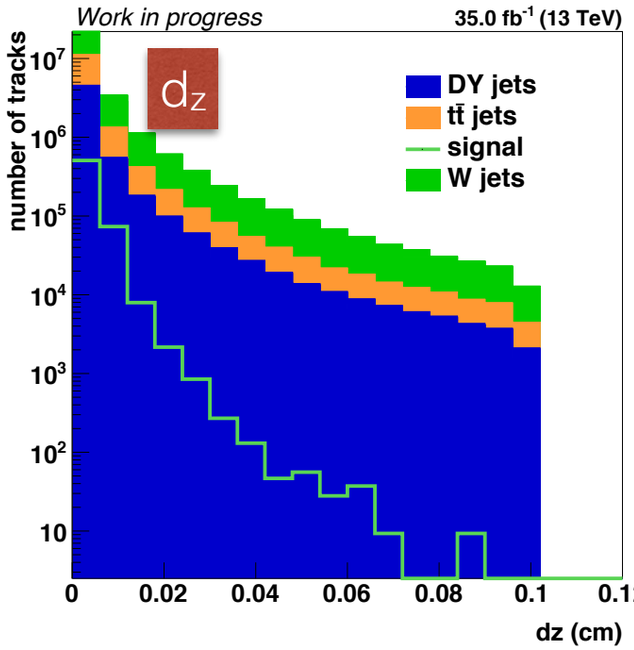
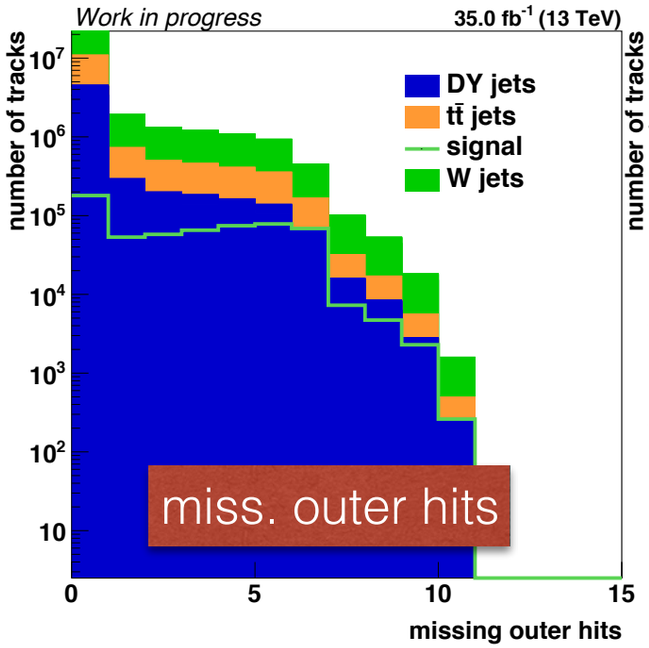
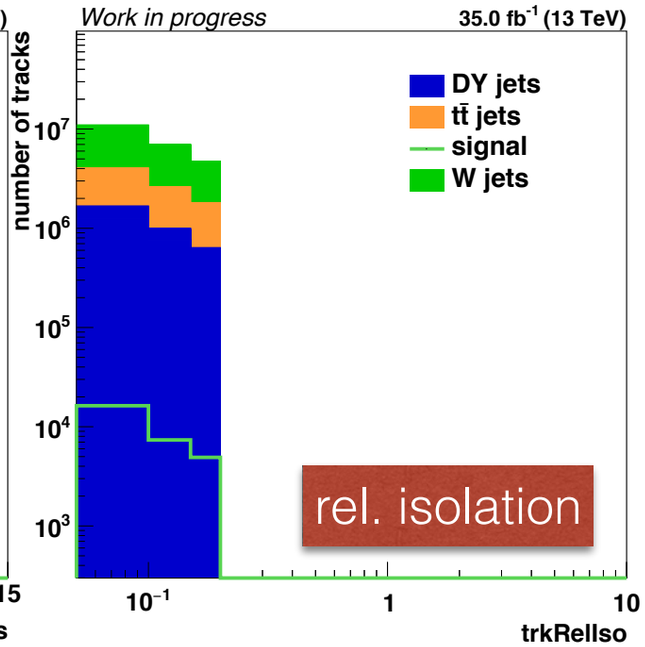


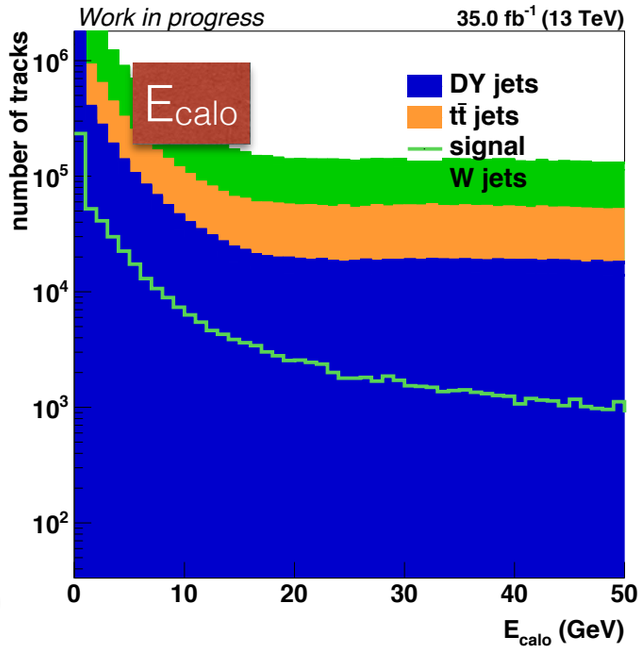


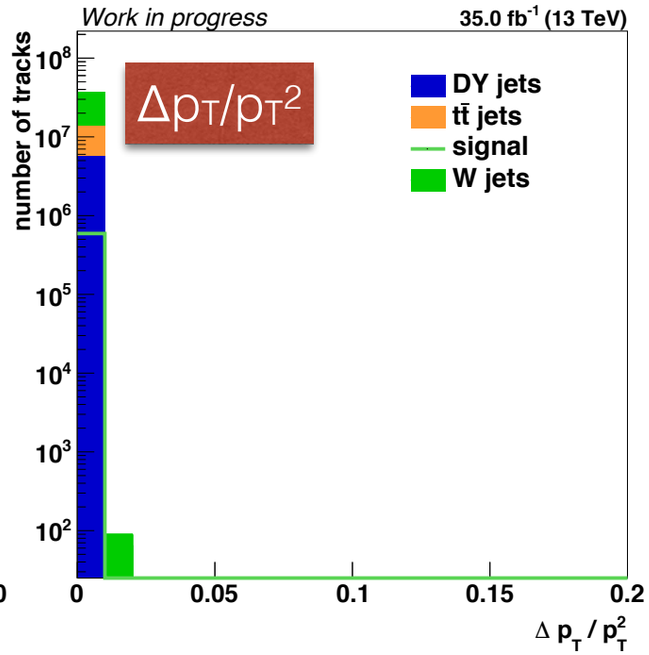








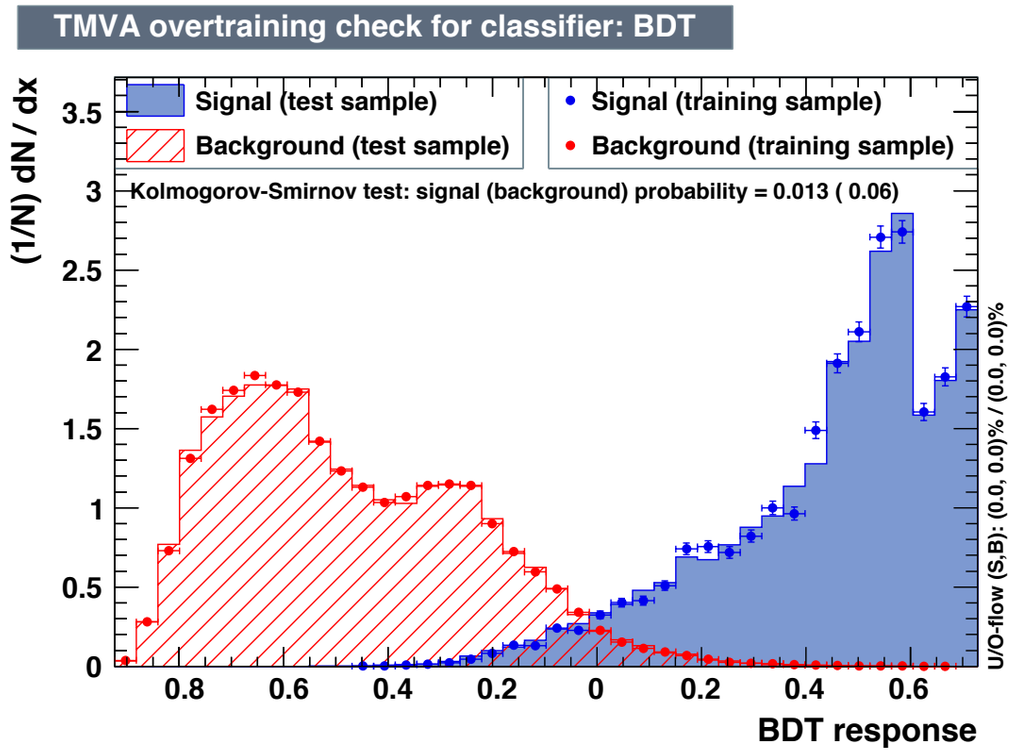


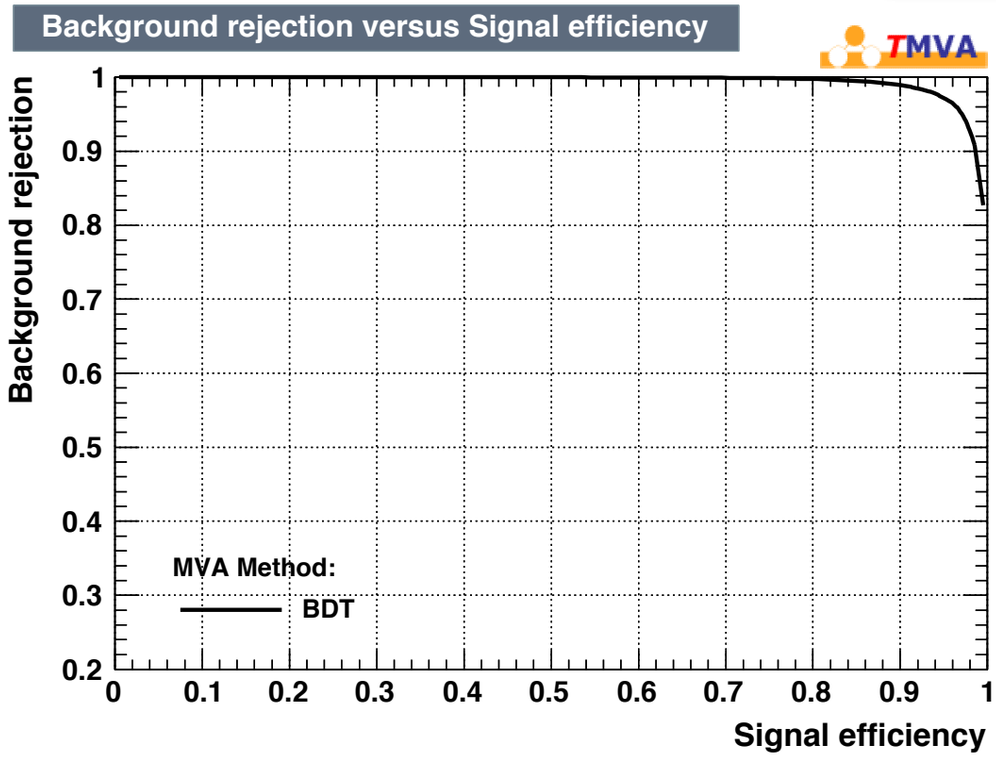


Short tracks: BDT training

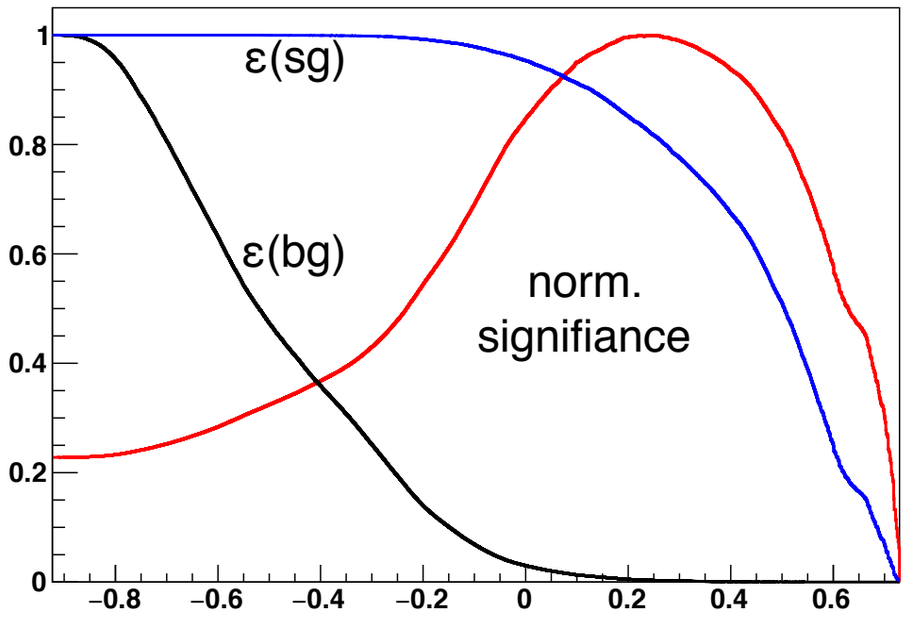
short tracks

BDT with 200 trees, depth = 4:



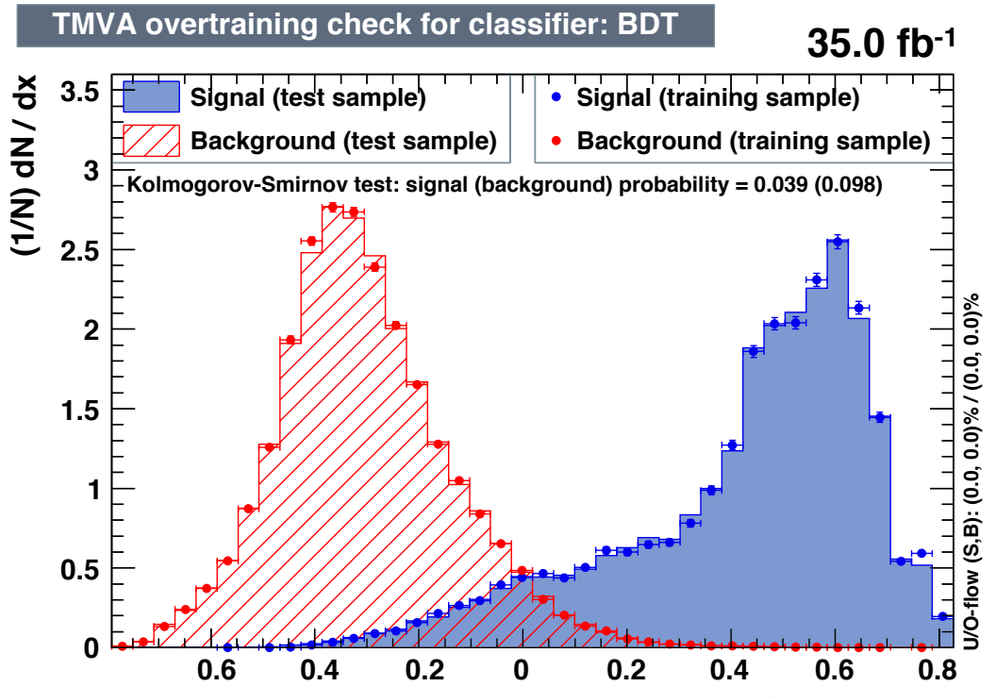


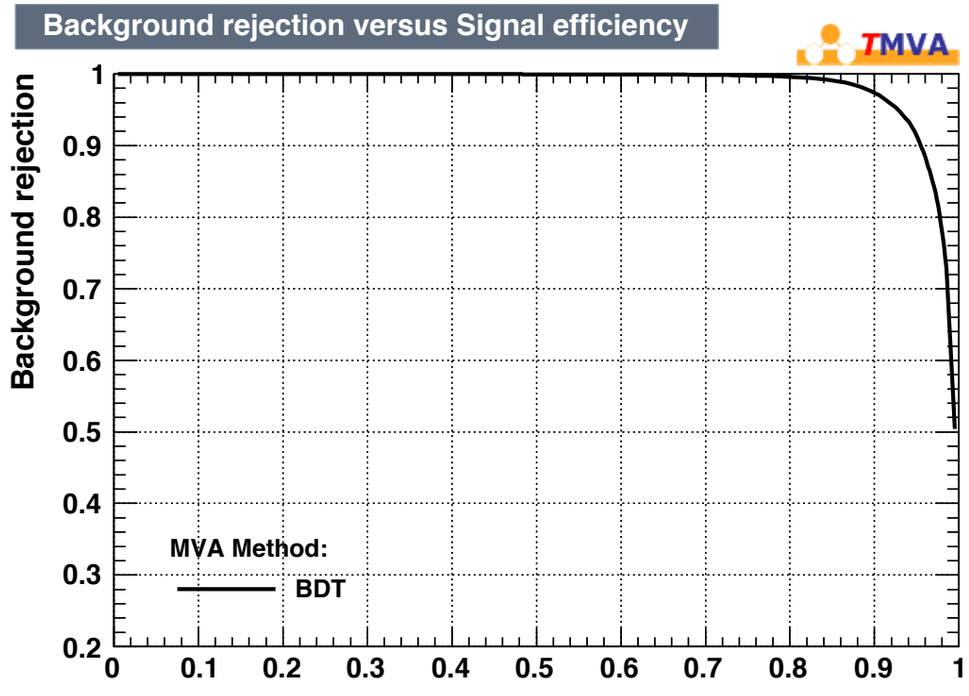
significance

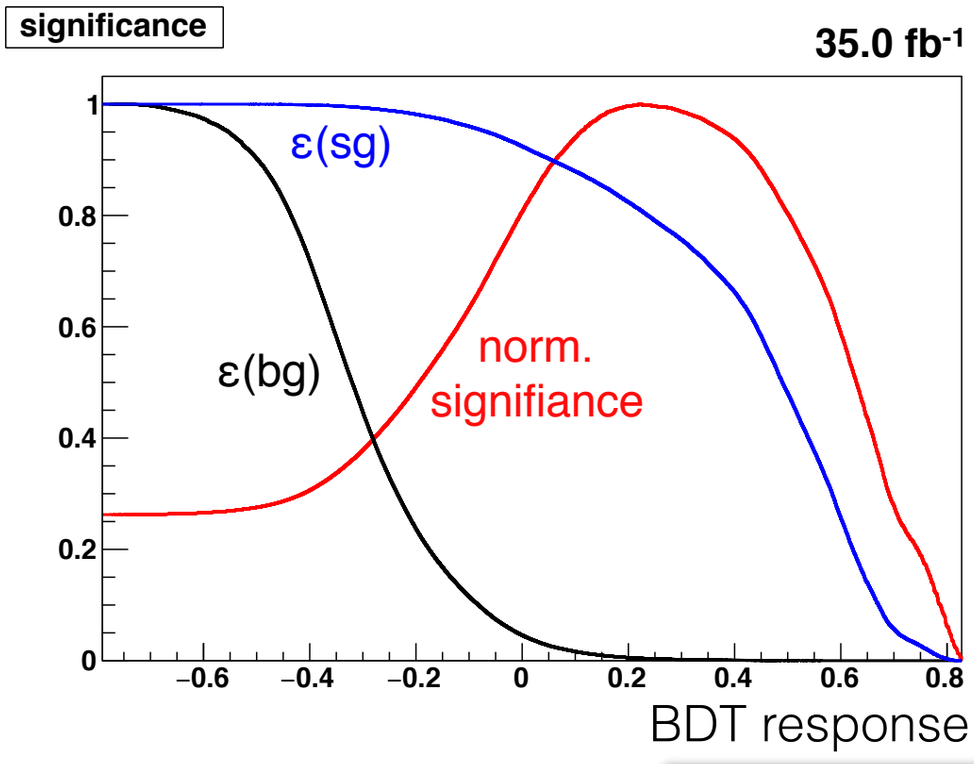


tracks	p_T > 10 GeV	basic presel.	BDT
signal	28414	26631	22470
background	22602396	540581	3708
weighted signal	7.31	6.85	5.78
	-	93 %	**79 %**
weighted background	33526972.71	994036.05	4881.73
	-	3 %	**1×10^{-4} %**

Disappearing track tag using BDT







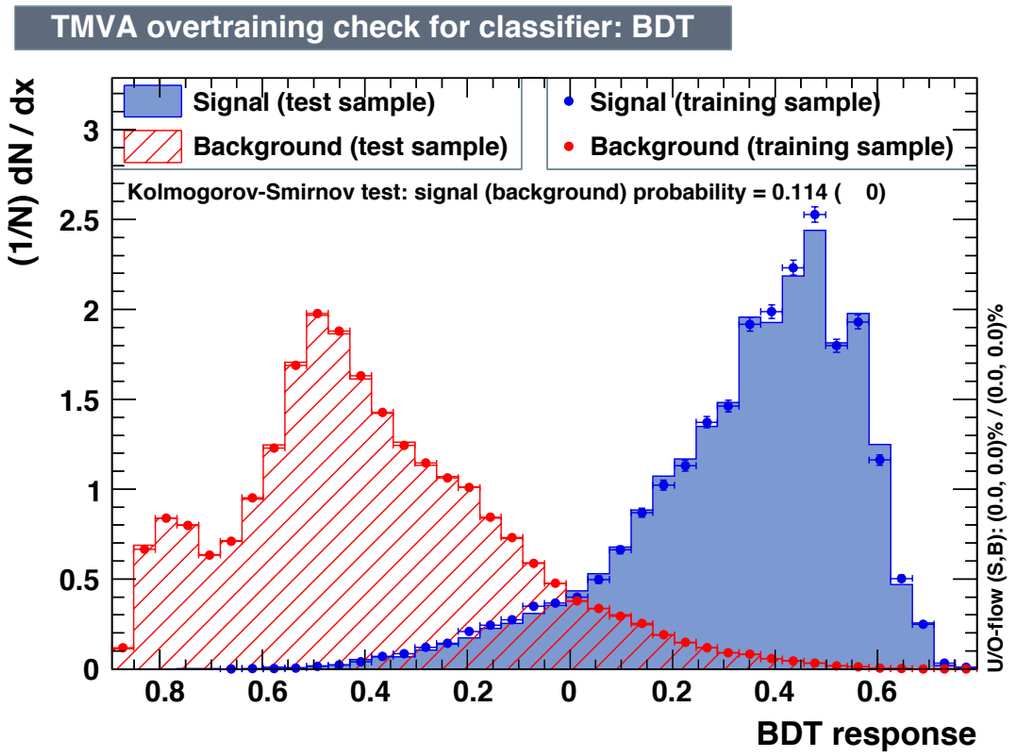
medium tracks	p_T > 10 GeV	basic presel.	presel. + BDT
signal	73483	67428	54579
SM background	58537393	1020968	5233
weighted sg.	18.90	17.34	14.04
ε(signal)	-	91 %	**74 %**
weighted bg.	127605814.04	4013965.45	18201.33
ε(background)	-	3 %	**1×10^{-4} %**

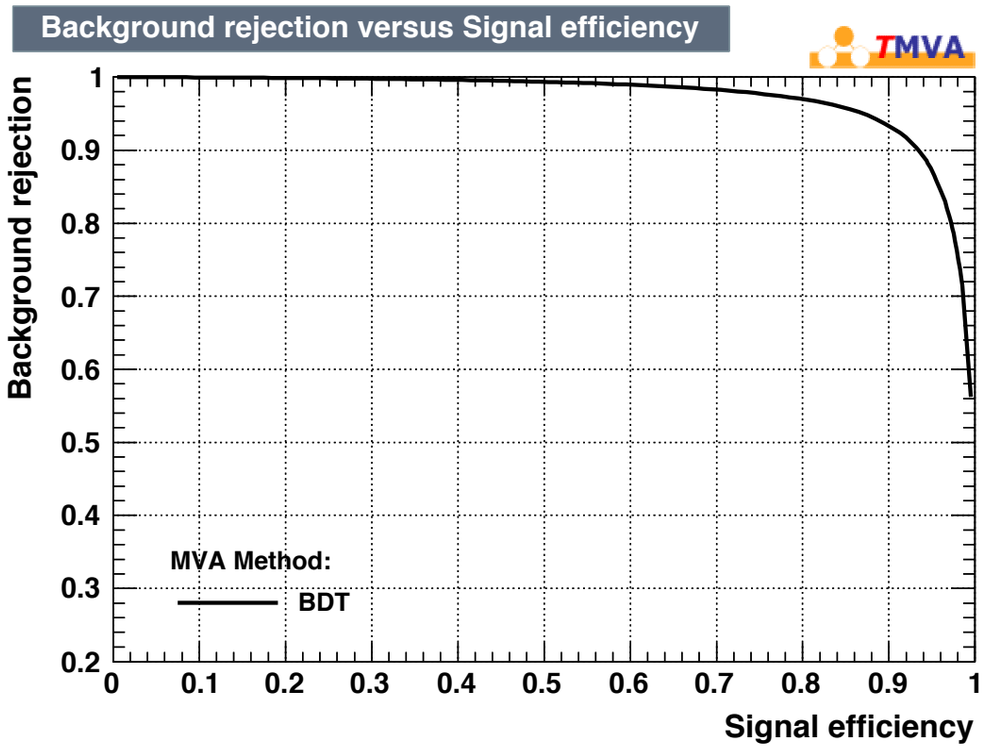
BDT outperforms other optimization methods

Long tracks: BDT training

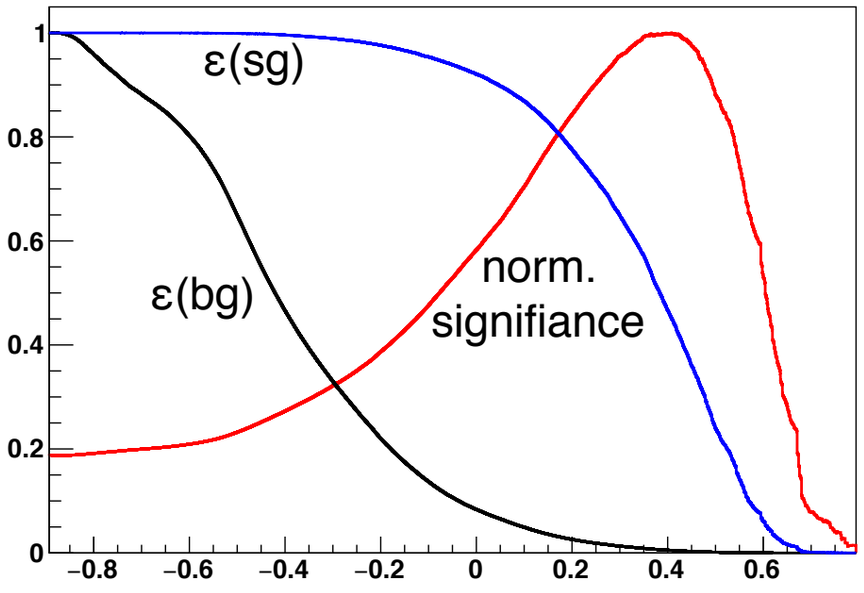
long tracks

BDT with 100 trees, depth = 6:





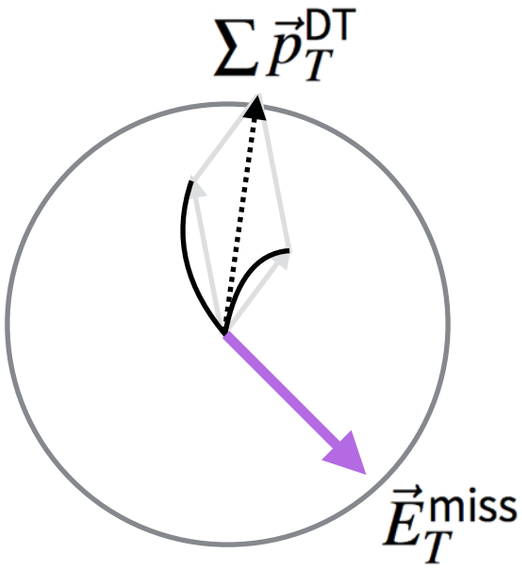
significance



tracks	p_T > 10 GeV	basic presel.	BDT
signal	68331	63590	31777
background	229399522	10325162	194875
weighted signal	17.58	16.36	8.17
		93 %	**46 %**
weighted background	322523449.45	36882968.74	358369.67
		11 %	**1×10^{-3} %**

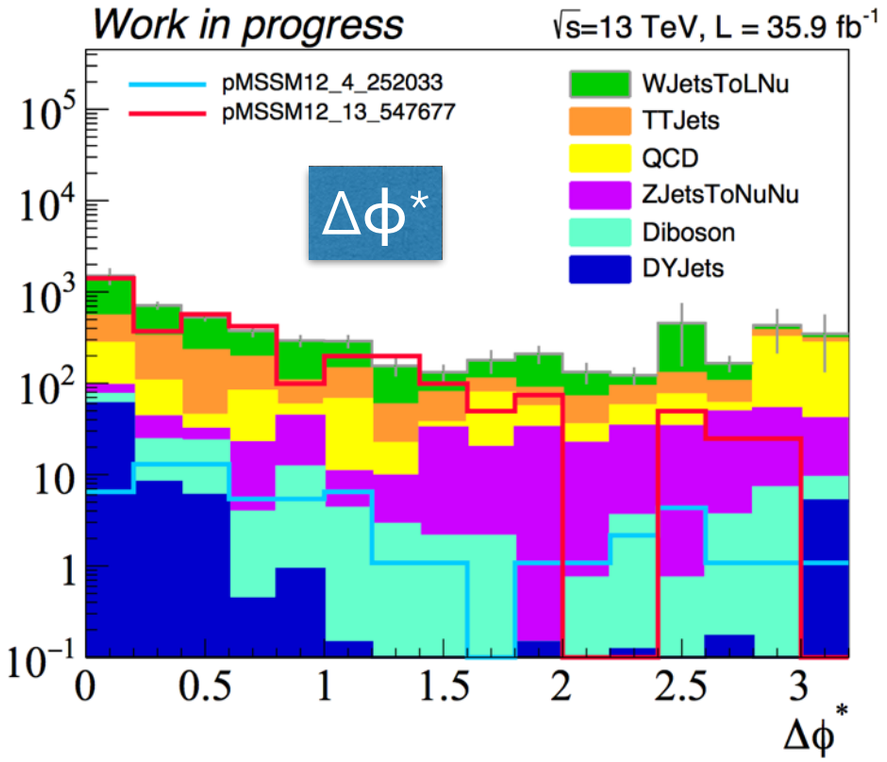
Event topology variables

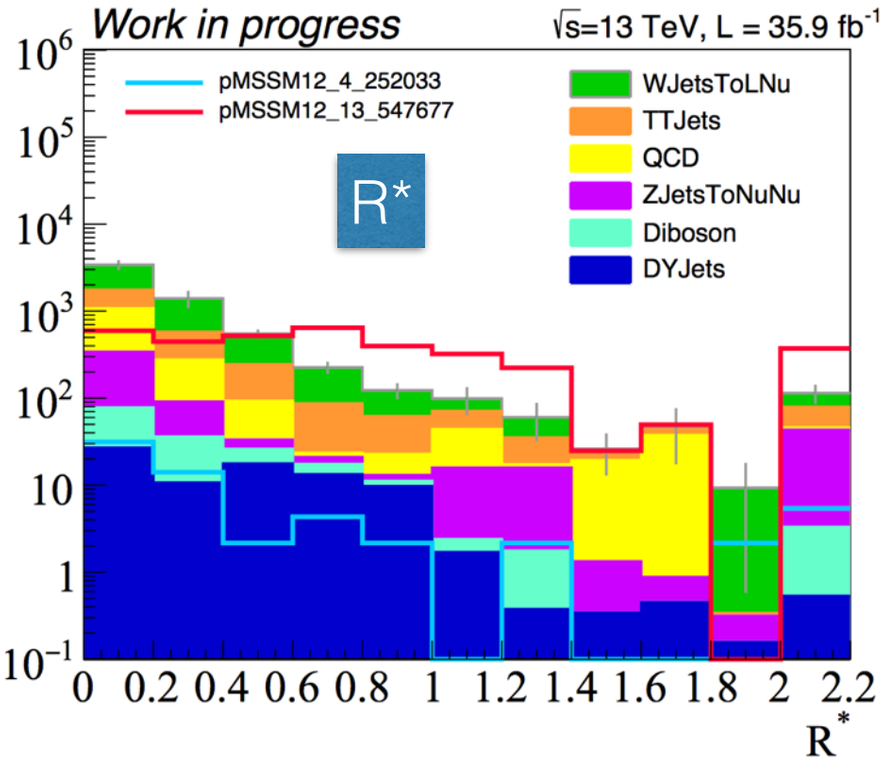
- select events with
  - **at least one disappearing track** (DT)
  - MET > 200 GeV
- consider benchmark signals from pMSSM scan to include different production mechanisms



$$\Delta\phi^* = \Delta\phi(\sum \vec{p}_T^{\,DT}, \vec{E}_T^{\,miss})$$

$$R^* = |\vec{p}_T^{\,DT}|/\vec{E}_T^{\,miss}$$





Event topology variables

- select events with
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  - MET > 200 GeV
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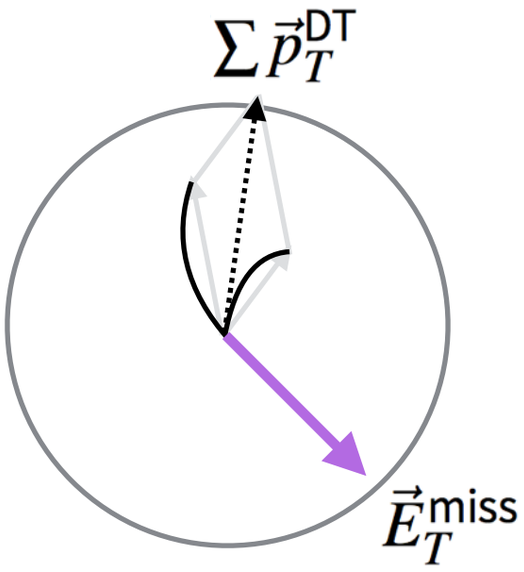


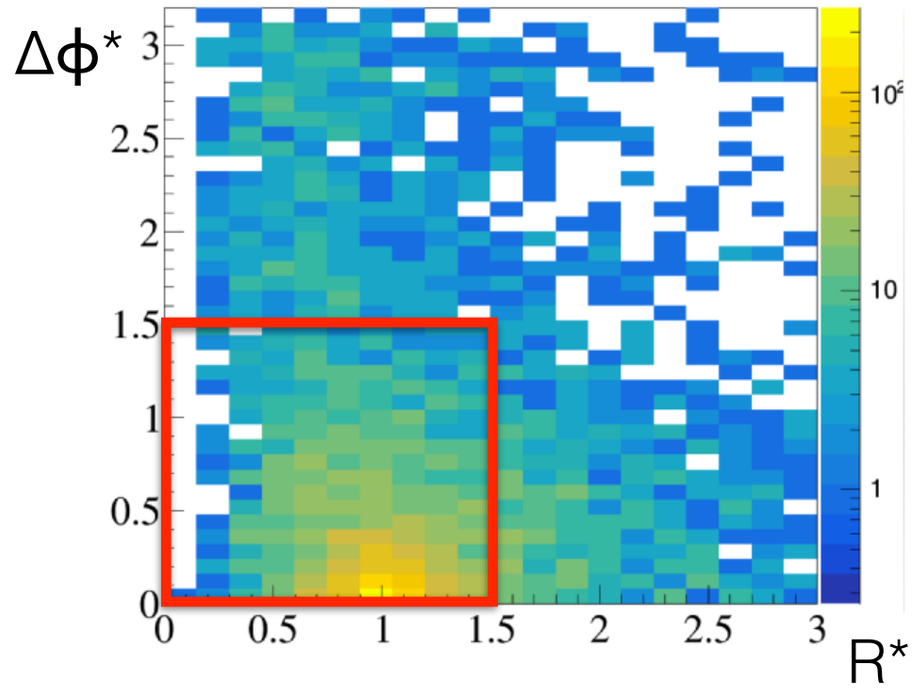
$$\Delta\phi^* = \Delta\phi(\textstyle\sum \vec{p}_T^{\,\mathrm{DT}}, \vec{E}_T^{\,\mathrm{miss}})$$

$$R^* = |\vec{p}_T^{\,\mathrm{DT}}|/\vec{E}_T^{\,\mathrm{miss}}$$

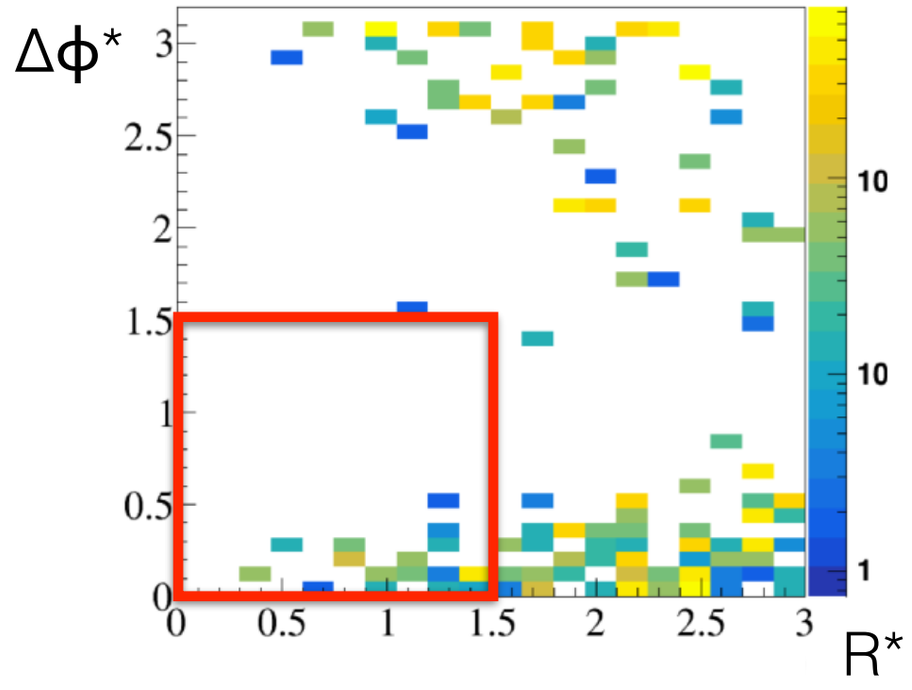
good handle for background reduction,

select event categories binned in MET and #jets

signal (cτ = 56 cm)



WJets background

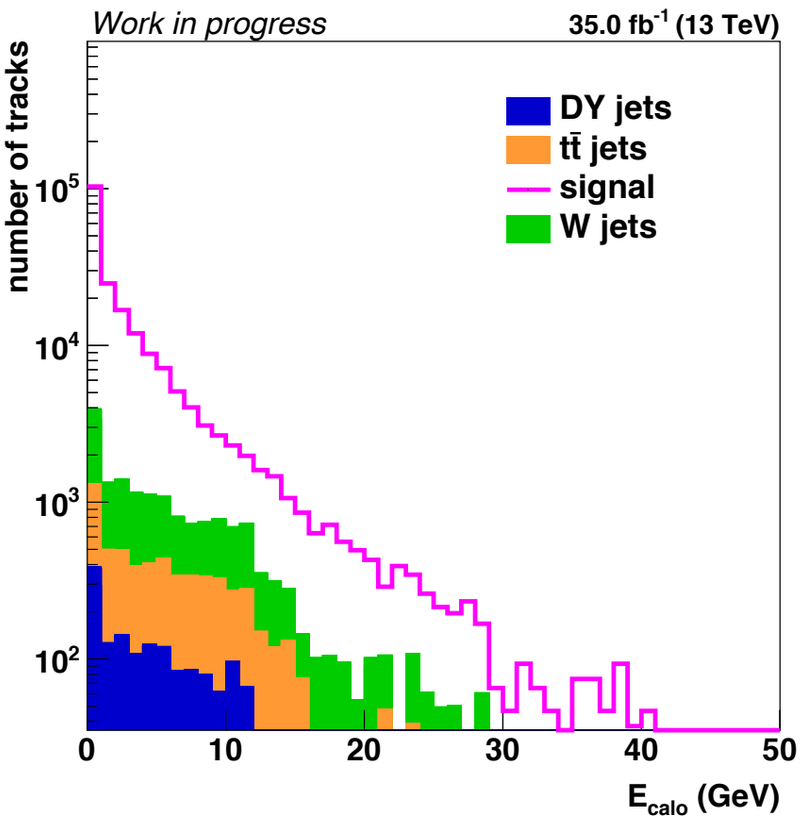


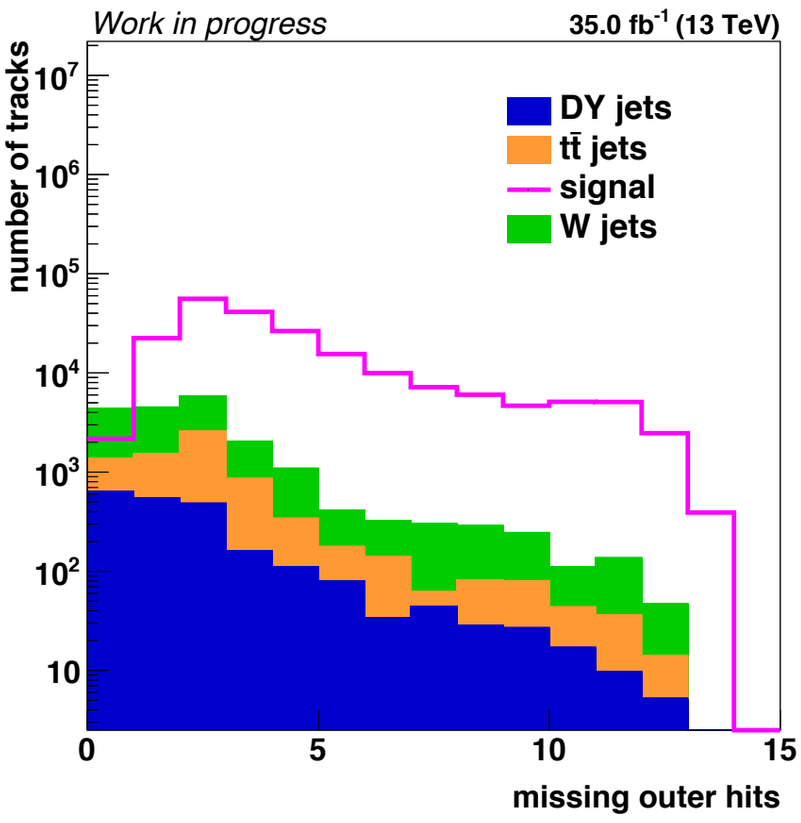
Short tracks: disapp. track tag

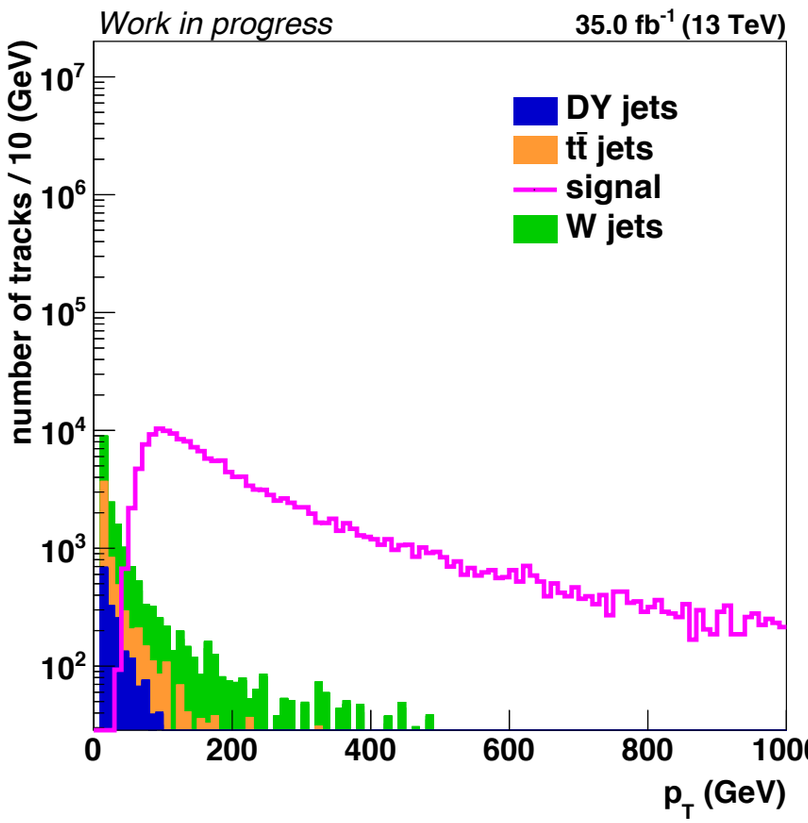
short tracks

track variables after applying basic preselection and BDT weights:

signal scaled to 100 pb





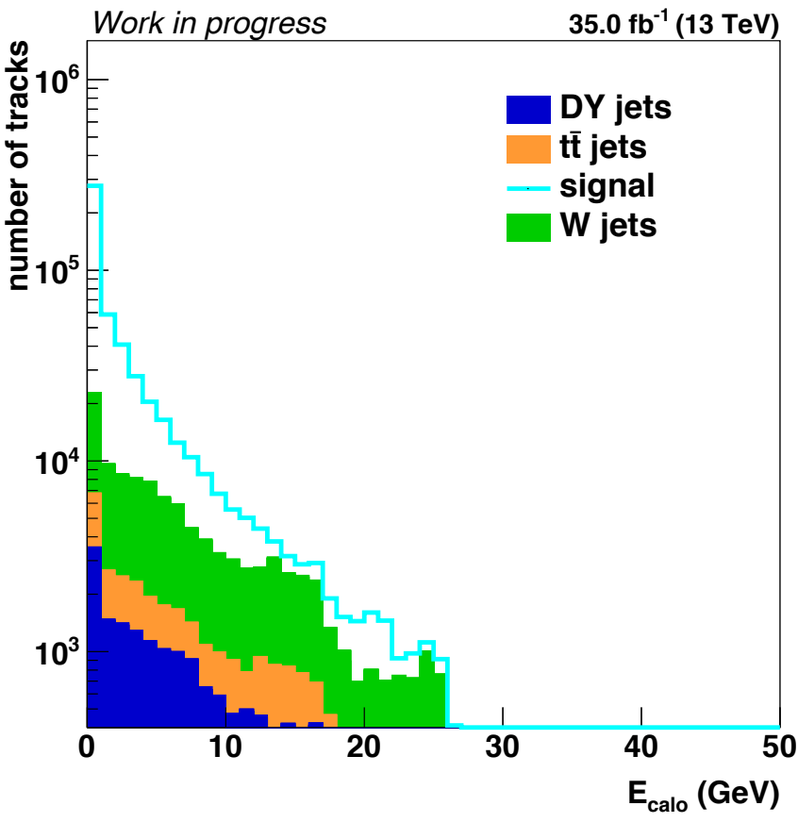


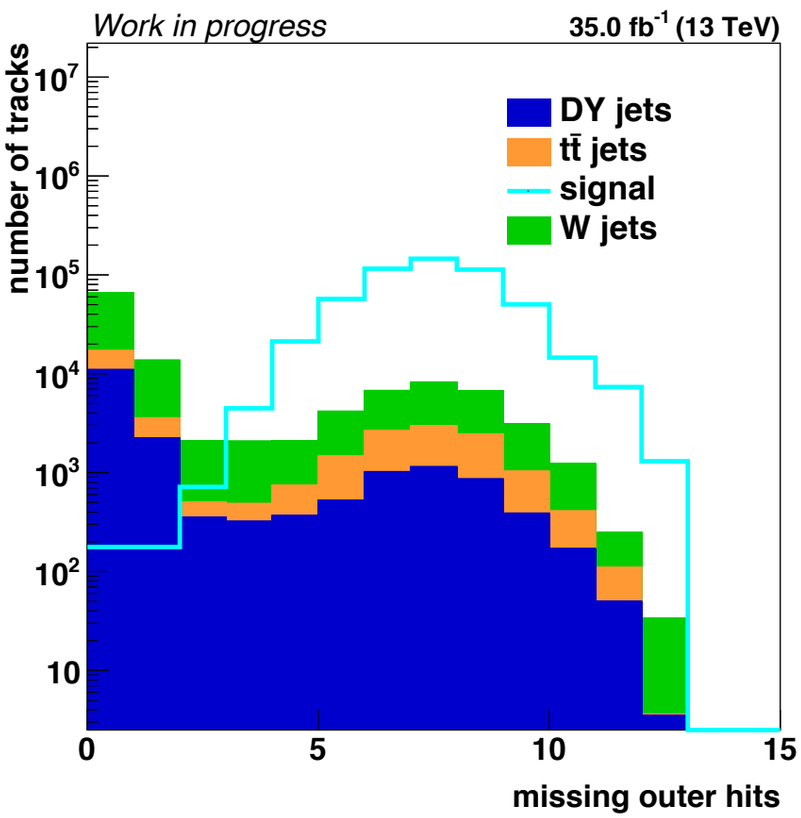
Medium tracks: disapp. track tag

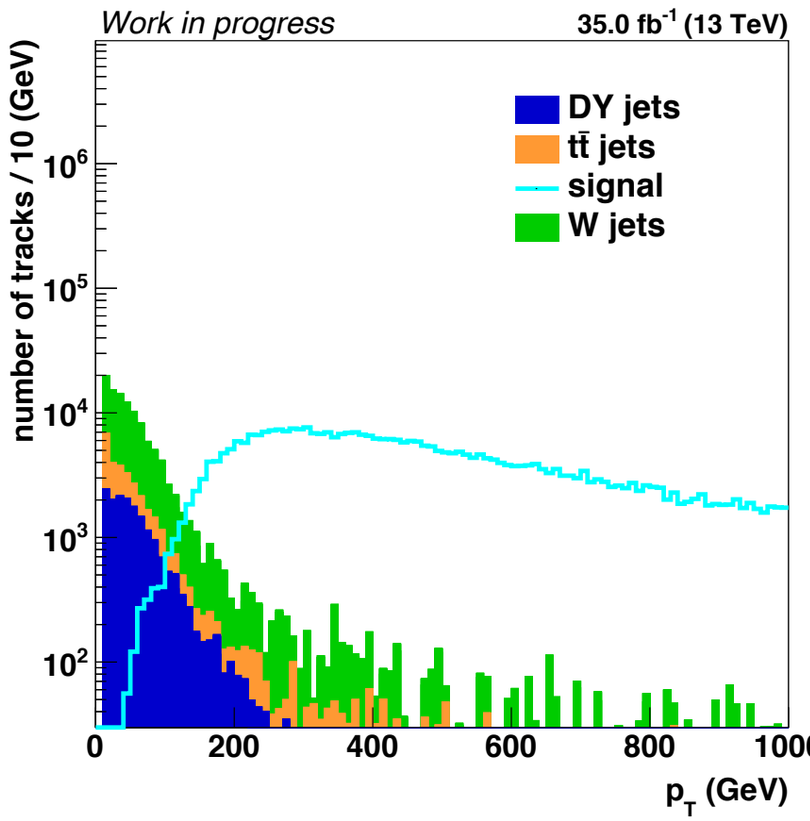
medium tracks

track variables after applying basic preselection and BDT weights:

signal scaled to 100 pb





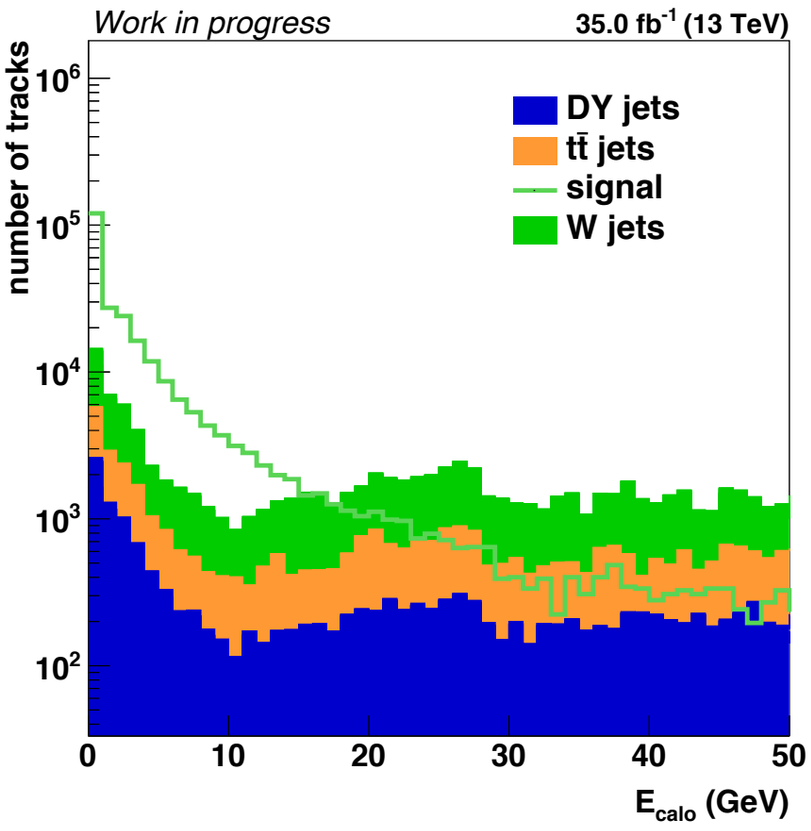


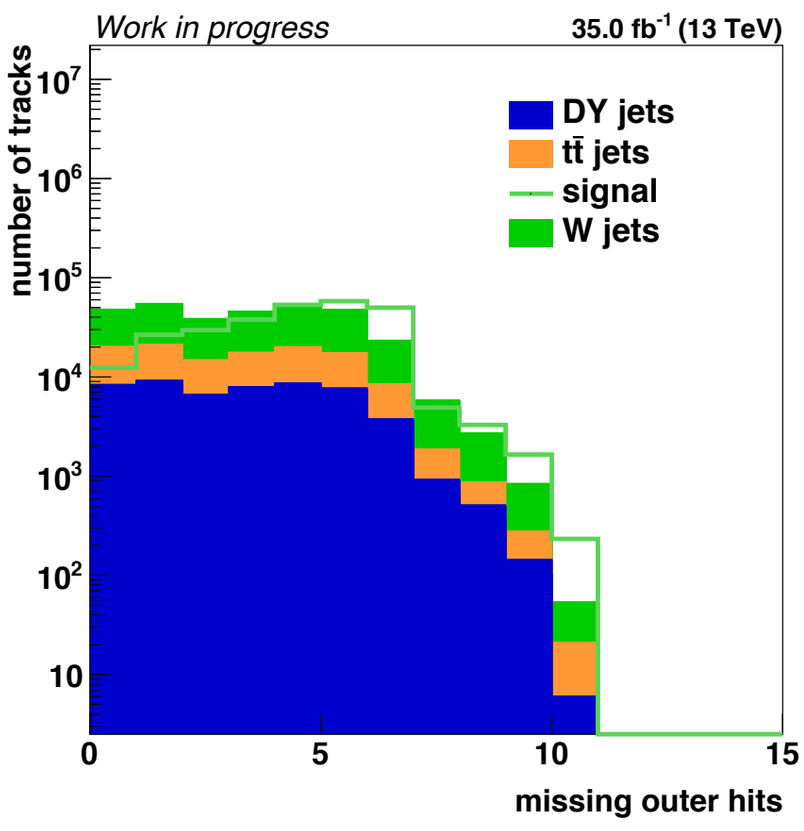
Long tracks: disapp. track tag

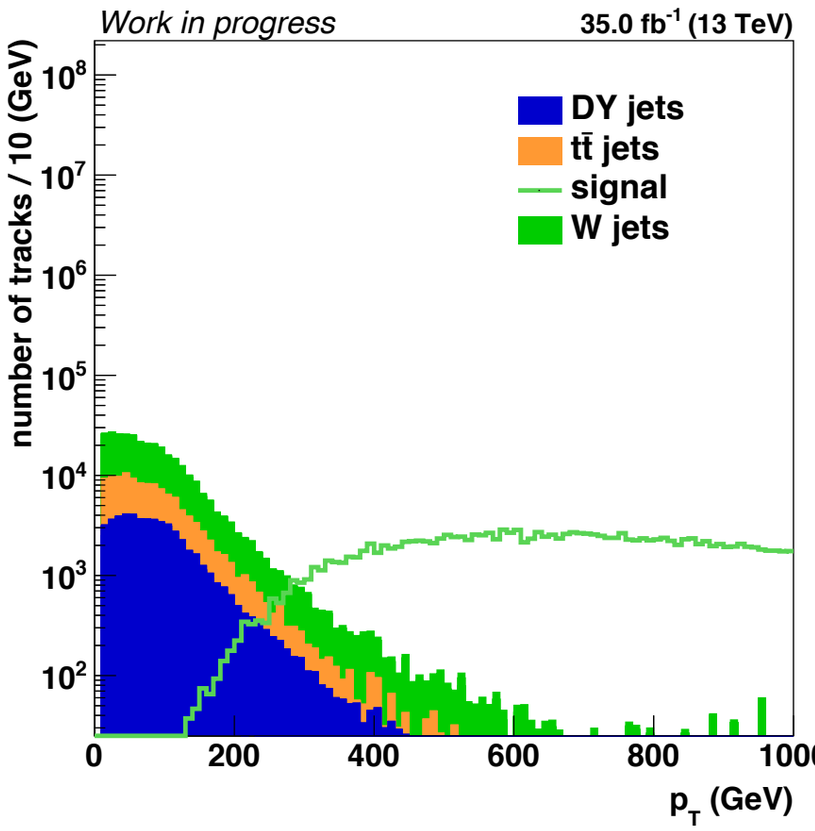
long tracks

track variables after applying basic preselection and BDT weights:

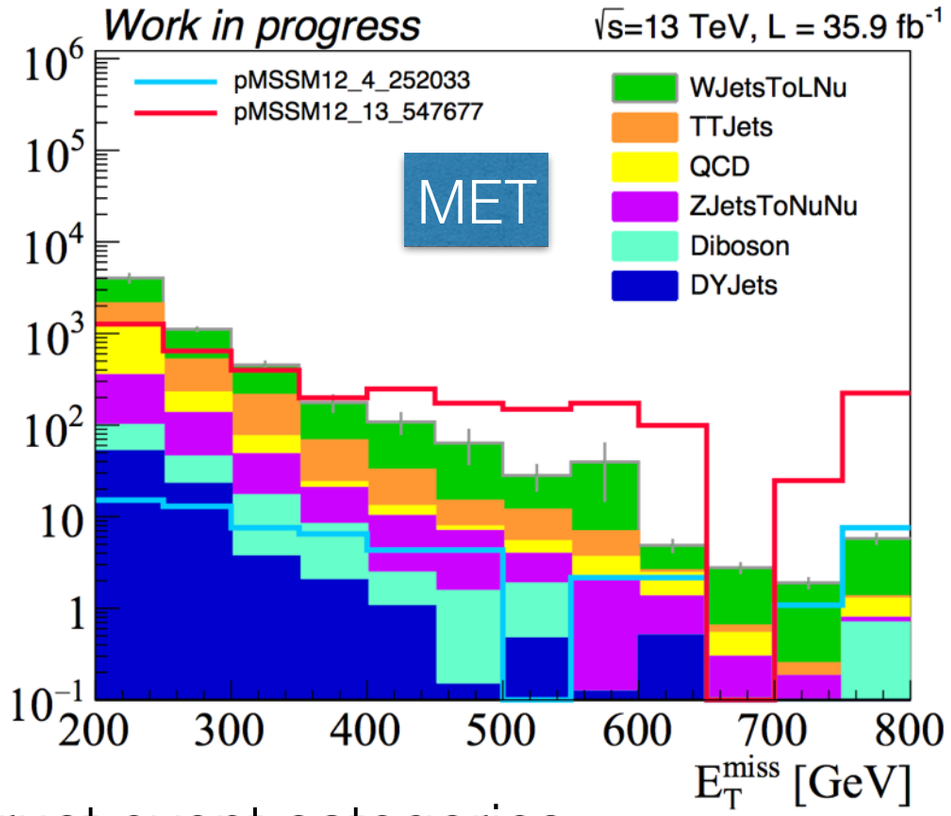
signal scaled to 100 pb

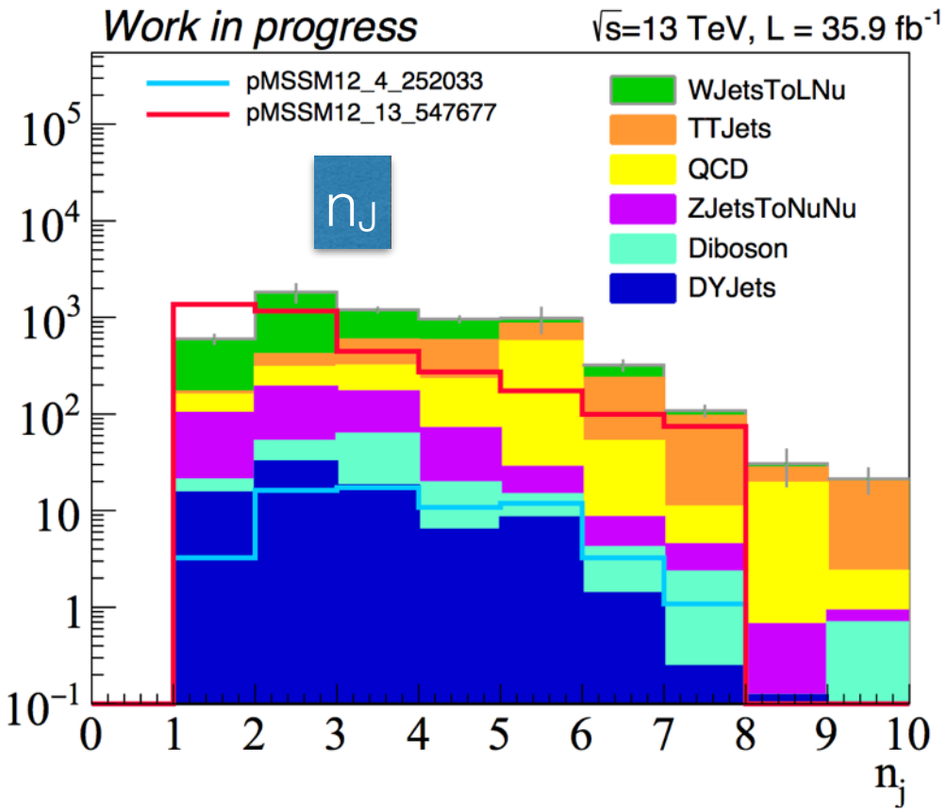




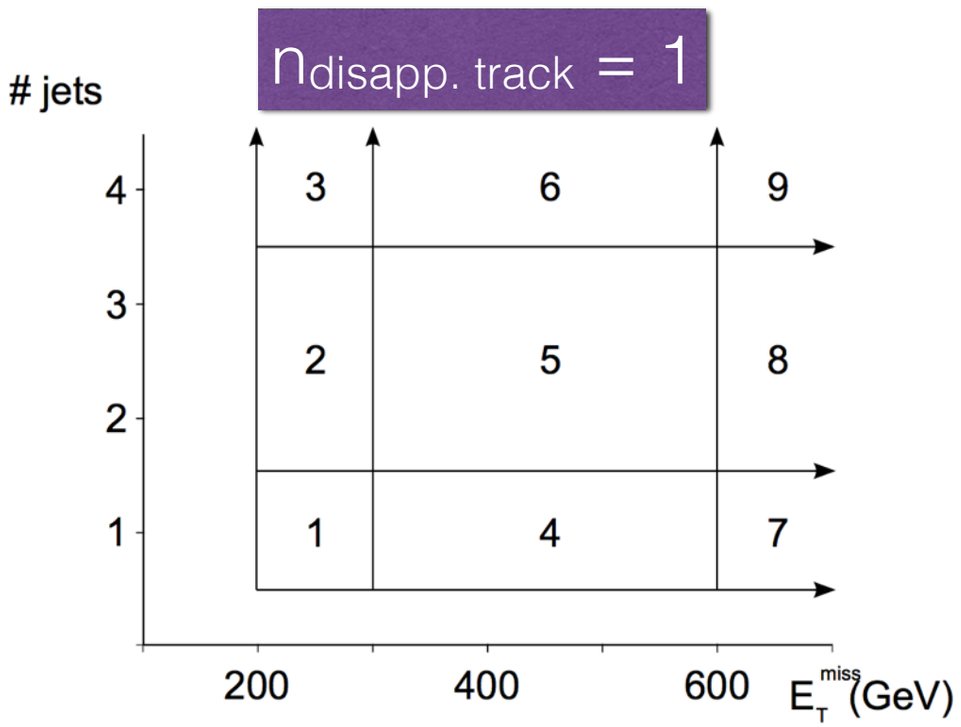


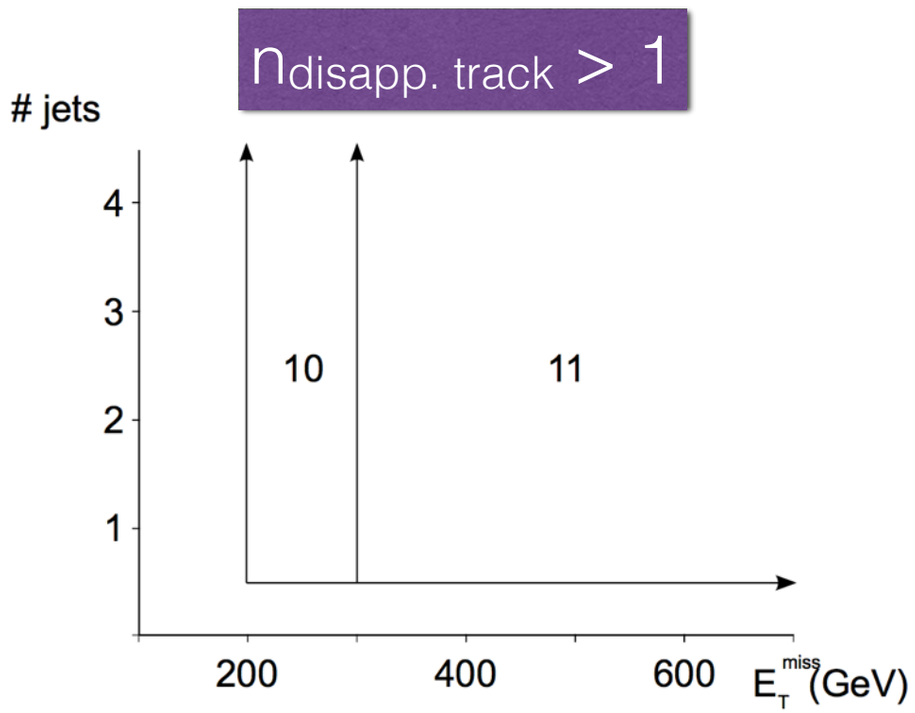
Event categories





- construct event categories:





Hand-picked cuts

Selection	Pixel only	< 7 layers	≥ 7 layers
p_T	>15 GeV	>15 GeV	>15 GeV
$\|\eta\|$	<2.4	<2.4	<2.4
d(xy)	<**0.02**	<**0.01**	<**0.01**
d(z)	<0.05	<0.05	<0.05
Neut. PF sum ($\Delta R<0.05$)	<10 GeV & <10%	<10 GeV & <10%	<10 GeV & <10%
Ch. PF sum ($\Delta R<0.01$)	<10 GeV & <10%	<10 GeV & <10%	<10 GeV & <10%
PF lepton removal	YES	YES	YES
PF rellso	<0.2	<0.2	<0.2
PF abslso	< 10.0	< 10.0	< 10.0
Min. #hits, #layers	2	2	2
Lost inner hits	0	0	0
Lost outer hits	**ANY**	≥2	≥2
dp_T/p_T^2	<**0.2**	<**0.05**	<**0.005**
High purity	YES	YES	YES

Simulated MC background / signal

MC sample	cross section (pb)
signal (see slide 5)	0.00276133
Summer16.WJetsToLNu_HT-100To200_TuneCUETP8M1_13TeV-madgraphMLM-pythia8	1627
Summer16.WJetsToLNu_HT-200To400_TuneCUETP8M1_13TeV-madgraphMLM-pythia8	435.2
Summer16.WJetsToLNu_HT-400To600_TuneCUETP8M1_13TeV-madgraphMLM-pythia8	59.18
Summer16.WJetsToLNu_HT-600To800_TuneCUETP8M1_13TeV-madgraphMLM-pythia8	14.58
Summer16.WJetsToLNu_HT-800To1200_TuneCUETP8M1_13TeV-madgraphMLM-pythia8	6.66
Summer16.WJetsToLNu_HT-1200To2500_TuneCUETP8M1_13TeV-madgraphMLM-pythia8	1.608
Summer16.WJetsToLNu_HT-2500ToInf_TuneCUETP8M1_13TeV-madgraphMLM-pythia8	0.03891
Summer16.TTJets_TuneCUETP8M1_13TeV-madgraphMLM-pythia8	831.8
Summer16.TTJets_HT-600to800_TuneCUETP8M1_13TeV-madgraphMLM-pythia8_ext1	2.734
Summer16.TTJets_HT-800to1200_TuneCUETP8M1_13TeV-madgraphMLM-pythia8_ext1	1.121
Summer16.TTJets_HT-1200to2500_TuneCUETP8M1_13TeV-madgraphMLM-pythia8_ext1	0.1979
Summer16.TTJets_HT-2500toInf_TuneCUETP8M1_13TeV-madgraphMLM-pythia8_ext1	0.002368
Summer16.DYJetsToLL_M-50_TuneCUETP8M1_13TeV-madgraphMLM-pythia8_ext1	6025.0
Summer16.DYJetsToLL_M-50_HT-100to200_TuneCUETP8M1_13TeV-madgraphMLM-pythia8	181.3
Summer16.DYJetsToLL_M-50_HT-200to400_TuneCUETP8M1_13TeV-madgraphMLM-pythia8	50.42
Summer16.DYJetsToLL_M-50_HT-400to600_TuneCUETP8M1_13TeV-madgraphMLM-pythia8	6.984
Summer16.DYJetsToLL_M-50_HT-600to800_TuneCUETP8M1_13TeV-madgraphMLM-pythia8	1.681
Summer16.DYJetsToLL_M-50_HT-800to1200_TuneCUETP8M1_13TeV-madgraphMLM-pythia8	0.7754
Summer16.DYJetsToLL_M-50_HT-1200to2500_TuneCUETP8M1_13TeV-madgraphMLM-pythia8	0.1862
Summer16.DYJetsToLL_M-50_HT-2500toInf_TuneCUETP8M1_13TeV-madgraphMLM-pythia8	0.004385