

NanoAODs production packages comparison for $B^0 \rightarrow K^{*0} \mu^+ \mu^-$ decay channel

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BPHNano

- CMS framework designed for the production of custom NanoAODs for B-physics analyses
- Developed to avoid each analysis reinventing the same reconstruction code
- Supports multiple decay channels simultaneously, all within the same output file
- New channels and variables can be added with minimal code changes
- Produces NanoAODs that contain standard NanoAOD content + BPH additional branches

Validation

- Our objective is to check whether BPHNano-produced NTuples (**BPH**) are equivalent to the standard private NTuple production in CMSSW (**Nano**)
- Since both methods of production apply pre-selection cuts in order to generate the NanoAOD outputs, we need to:
 - Identify, through both package codes, the equivalent branch names of NanoAOD outputs
 - Use them to apply the same cuts to both outputs
 - Compare plots of different physical variables after the cuts are equalized

Identification

- Embedded pre-selections, applied during generation, that cannot be removed (e.g. `isLooseMuon`)
- Not all variables from one package have a direct equivalent in the other (e.g. `mumuDCA`, `svip2d`).
 - Some of these are also used as pre-selection criteria for the final outputs.
- Some branches represent the same physical concept, but are derived differently (e.g., `muon pT`).
- This means we can't fully equalize all pre-selections using only cuts on the available output branches, so some differences are expected.

Dataset

Dataset: [/ParkingDoubleMuonLowMass0/Run2024C-PromptReco-v1/MINIAOD](#)

Dataset size: 4156631421735 (4.2TB) Number of blocks: 38 Number of events: 75262728 Number of files: 1288 Creation time: 2024-04-16 20:14:39

[Release](#), [Blocks](#), [Files](#), [Runs](#), [Configs](#), [Parents](#), [Children](#), [Sites](#), [Physics Groups](#) [XSDB](#) Sources: [dbs3](#) [show](#)

BPH cuts

$4.5 < \text{"B_chosen_mass"} < 6.5$	$\text{BToTrkTrkMuMu_fit_trk1_pt, trk2_pt} > 0.72$
$\text{BPHMuon_pt1, pt2} > 3.96$	$0.99 < \text{BToTrkTrkMuMu_mll_fullfit} < 4.848$
$ \text{BPHMuon_eta1} , \text{BPHMuon_eta2} < 2.4$	$\text{MuMu_svprob} > 0.1$
$\text{Track_DCASig} > 0.8$	$\text{MuMu_l_xy} / \text{MuMu_l_xy_unc} > 3.0$
$\text{MuMu_pt} > 6.831$	$\text{MuMu_fit_cos2D} > 0.9$

Nano cuts

$4.5 < \text{"B_chosen_mass"} < 6.5$	$\text{mumuCosAlphaBS} > 0.9$
$ \text{rawkstTrkmEta} , \text{rawkstTrkpEta} < 2.4$	$ \text{rawmumEta} , \text{rawmupEta} < 2.4$

Dataset

0,1,...,7

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nfill	nrun	nls	ncms	totdelivered(/fb)	totrecorded(/fb)
26	42	24254	24254	7.590384497	7.251968024

Dataset integrated luminosity $\approx 0.9 \text{ fb}^{-1}$

- CMSSW version: CMSSW_15_o_13_patch2
- CMSSW Private [github](#)
- BPHNano [github](#)

Methodology

- Generation of the .root files from the mentioned frameworks (without modifications)
- Merging into two single compressed .root files, selecting only the relevant NTuples for our decay channel
- Processing via Python and uproot:
 - Application of cuts on physical variables in order to equalize the different cuts originating from the generation
 - Application of loose cuts for background rejection (e.g., $5.22 < m_B \text{ (GeV/c}^2\text{)} < 5.35$)
 - Direct comparison of the physical variables

Cuts

BPH cuts

$4.5 < \text{"B_chosen_mass"} < 6.5$	$\text{BToTrkTrkMuMu_fit_trk1_pt, trk2_pt} > 0.72$
$\text{BPHMuon_pt1, pt2} > 3.96$	$0.99 < \text{BToTrkTrkMuMu_mll_fullfit} < 4.848$
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$\text{MuMu_pt} > 6.831$	$\text{MuMu_fit_cos2D} > 0.9$

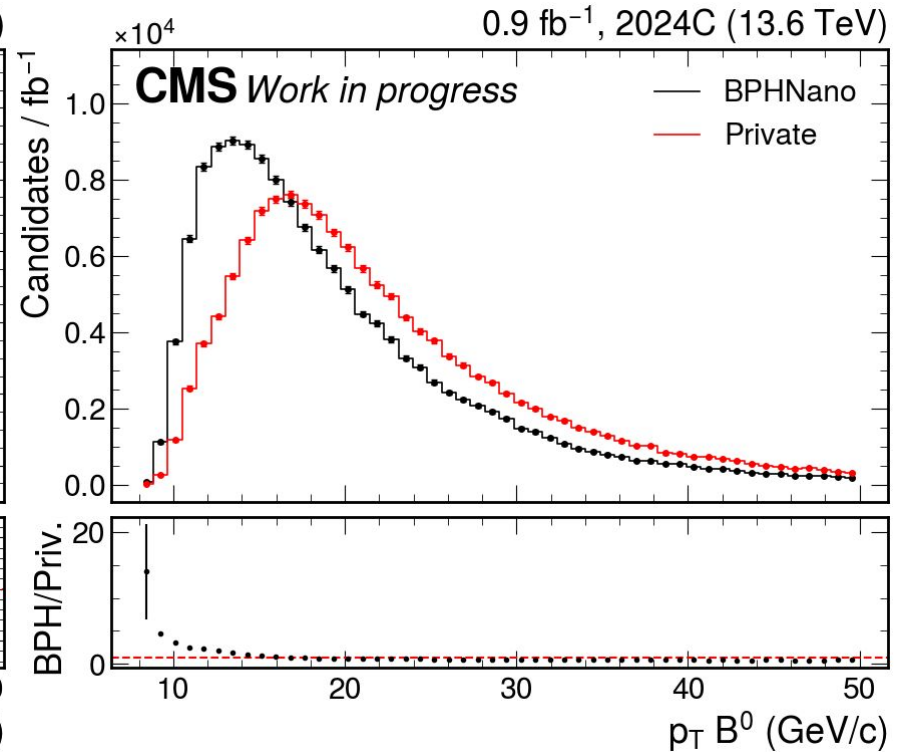
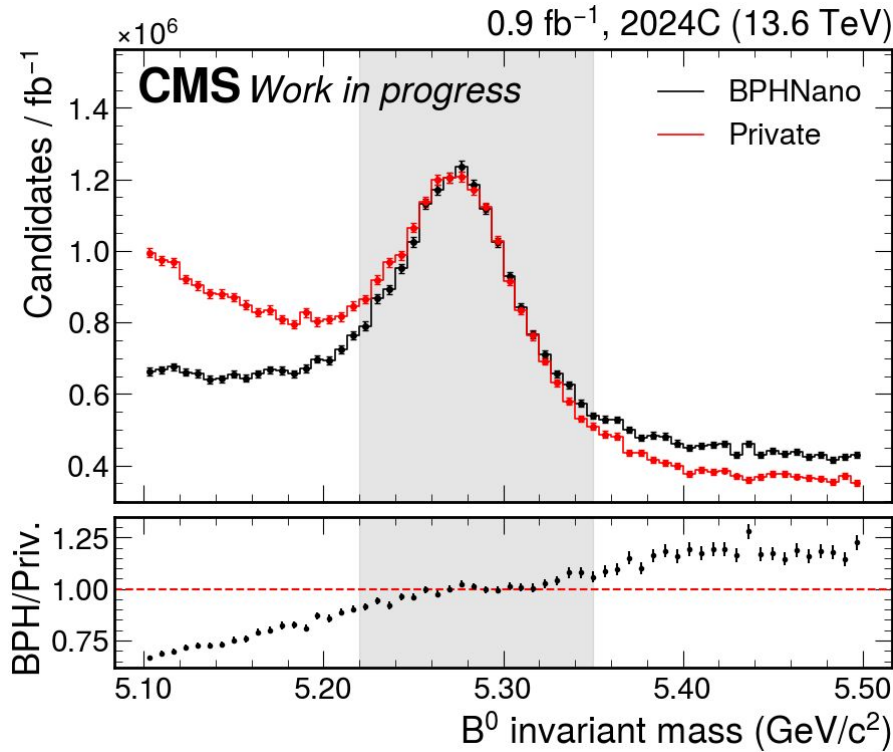
Nano cuts

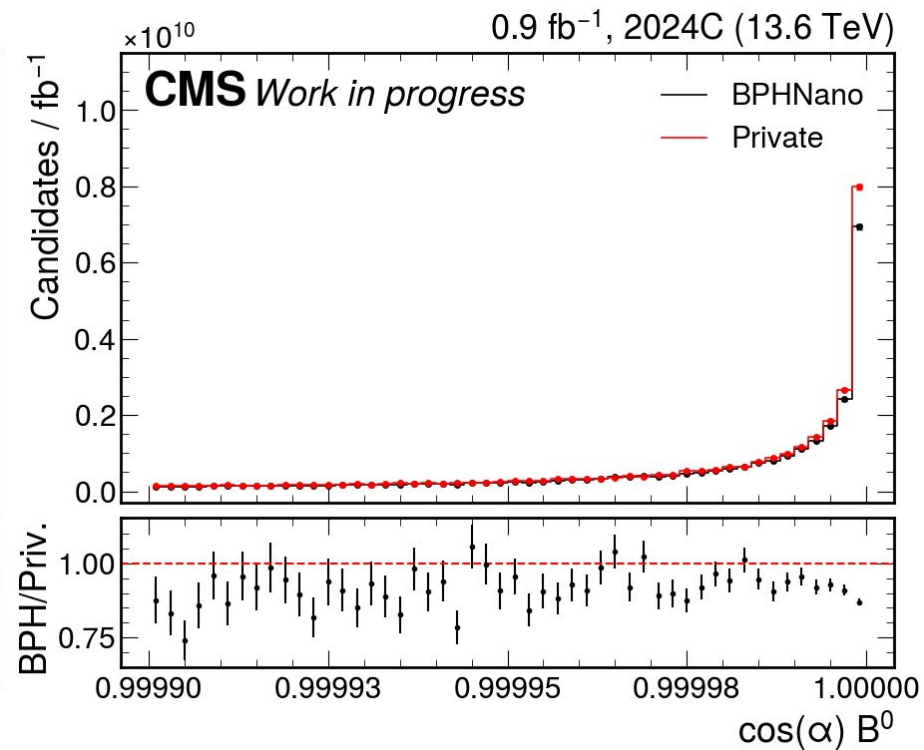
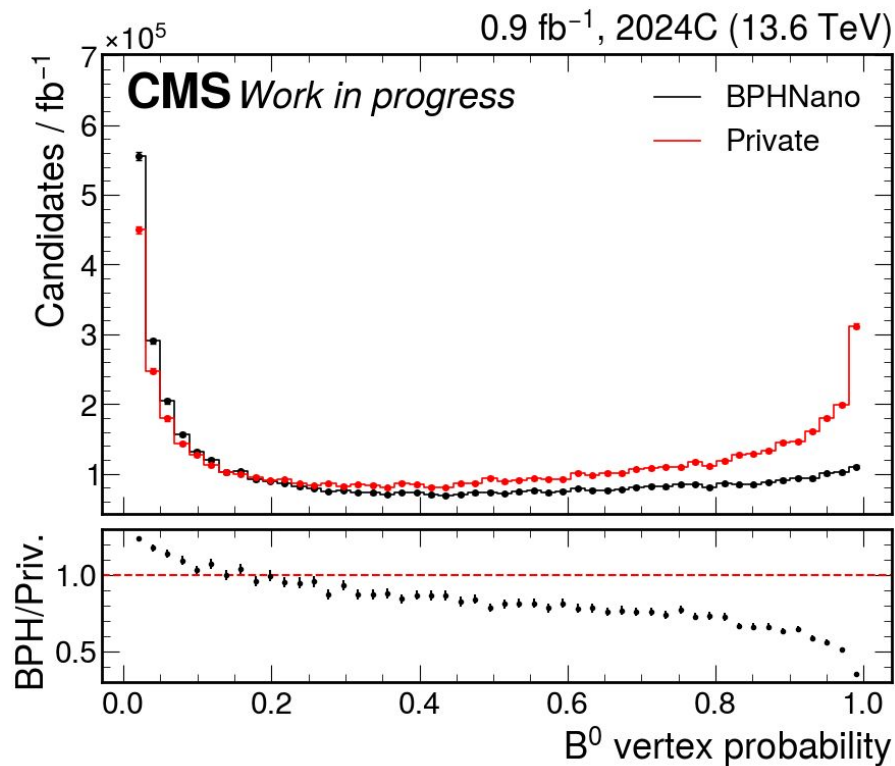
$4.5 < \text{"B_chosen_mass"} < 6.5$	$\text{mumuCosAlphaBS} > 0.9$
$ \text{rawkstTrkmEta} , \text{rawkstTrkpEta} < 2.4$	$ \text{rawmumEta} , \text{rawmupEta} < 2.4$

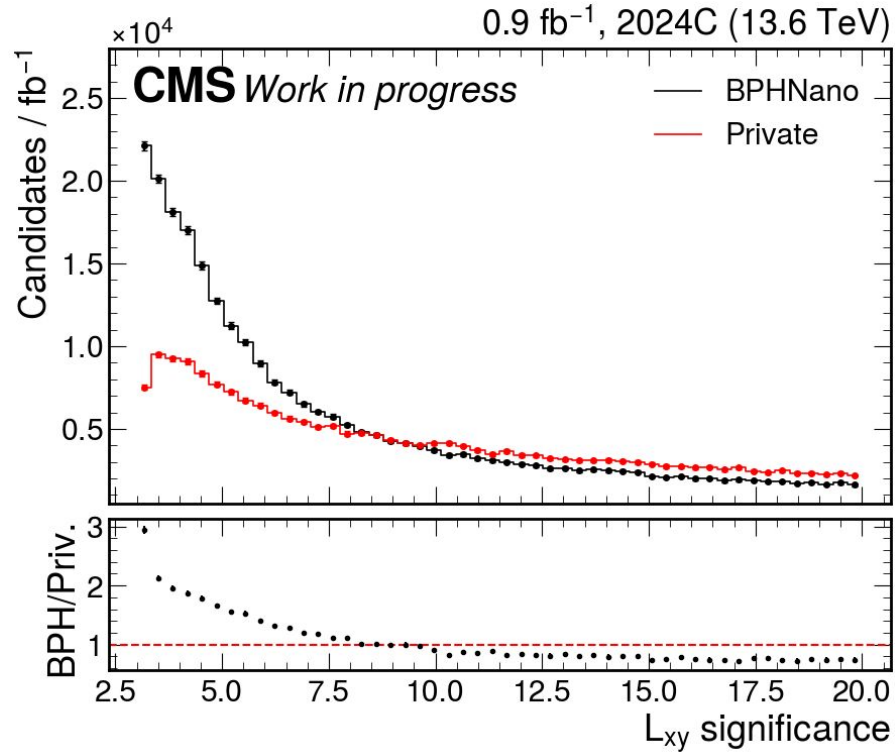
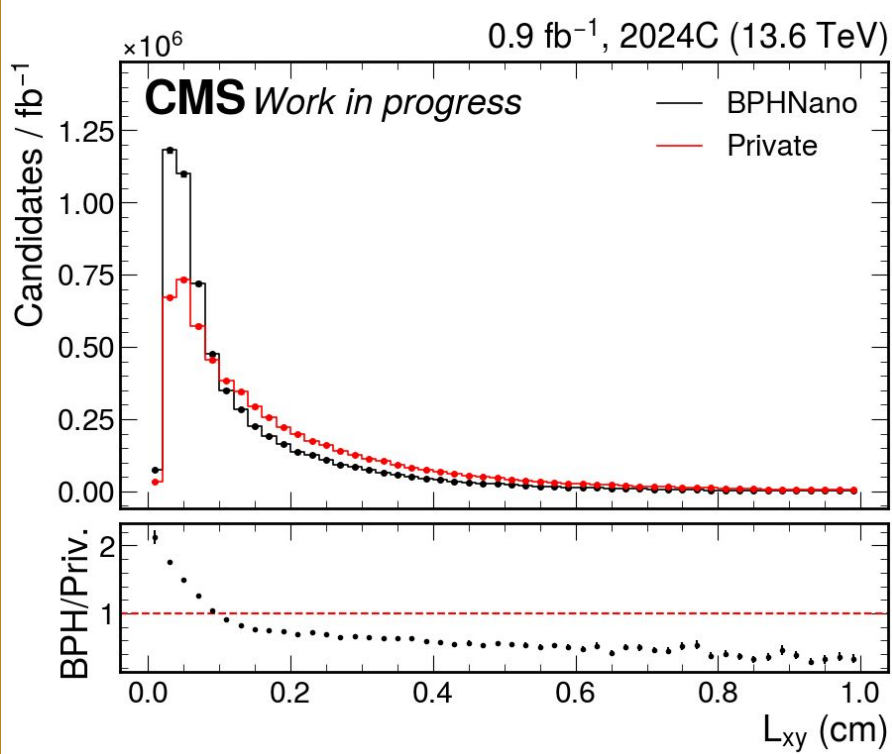
BPH: 31.083.532 candidates (295.3 GB) $\rightarrow$ 942.827 after cuts (3.03% efficiency), 49.1 GB
 Private: 1.910.666 candidates (12.1 GB) $\rightarrow$ 1.662.114 after cuts (86.99% efficiency), 11.3 GB

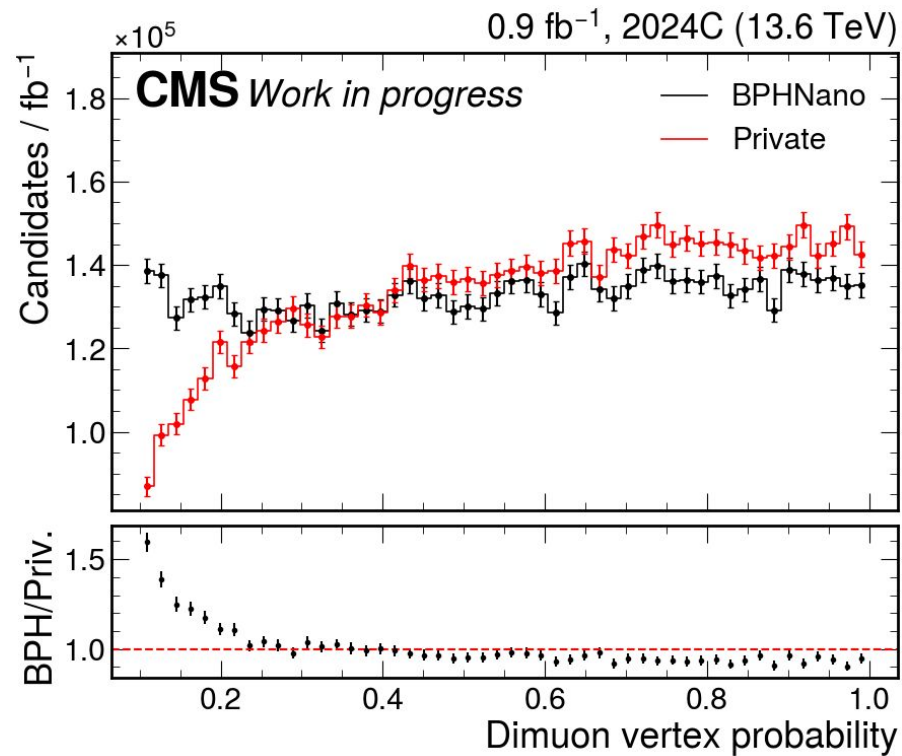
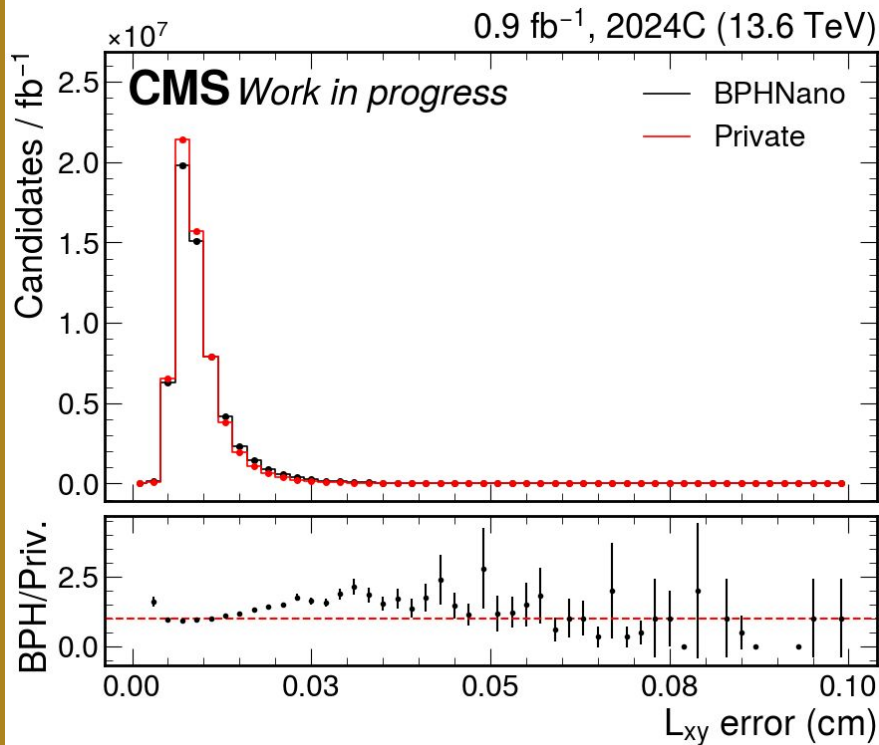
Plots

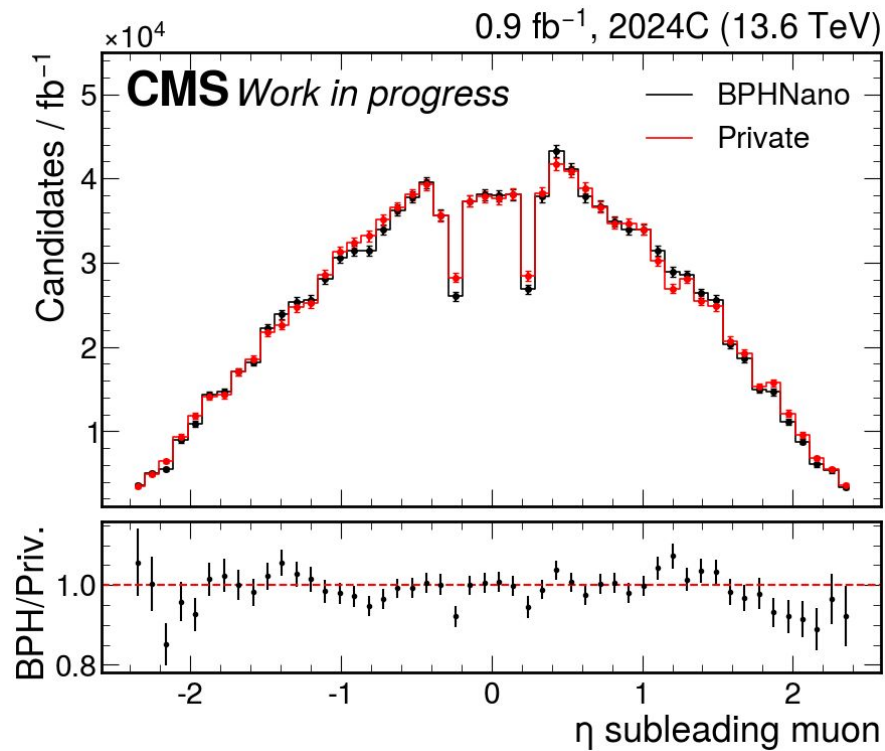
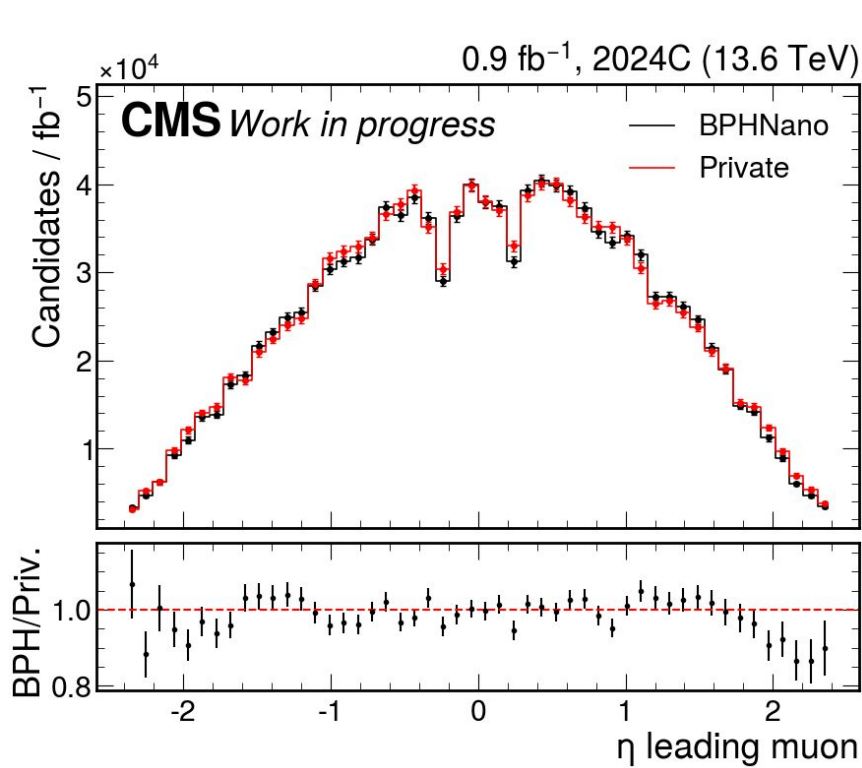
- * All normalized by integrated luminosity
- * No resonances removed

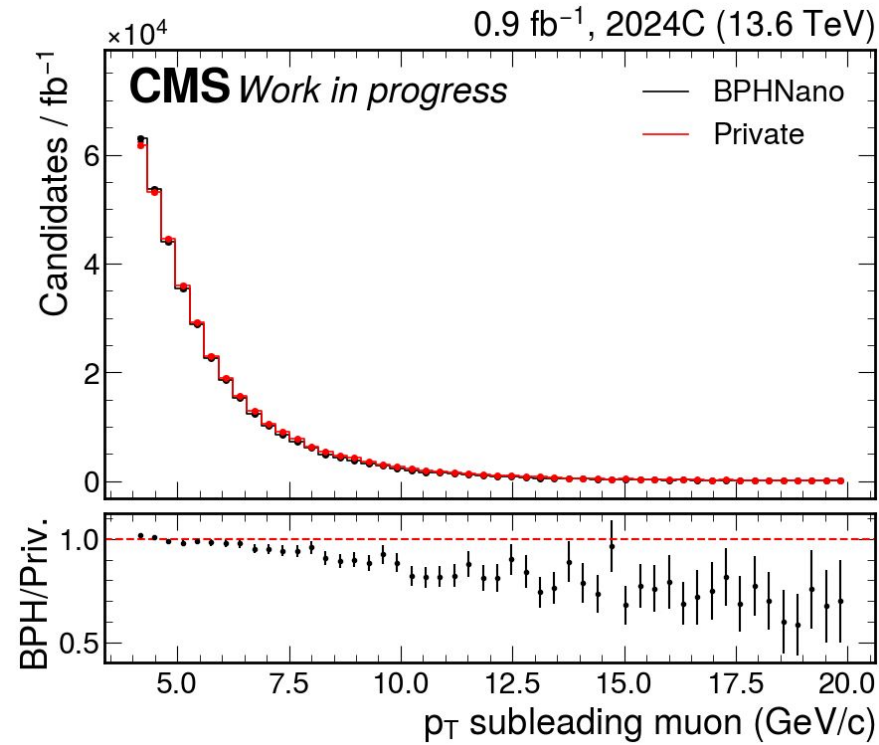
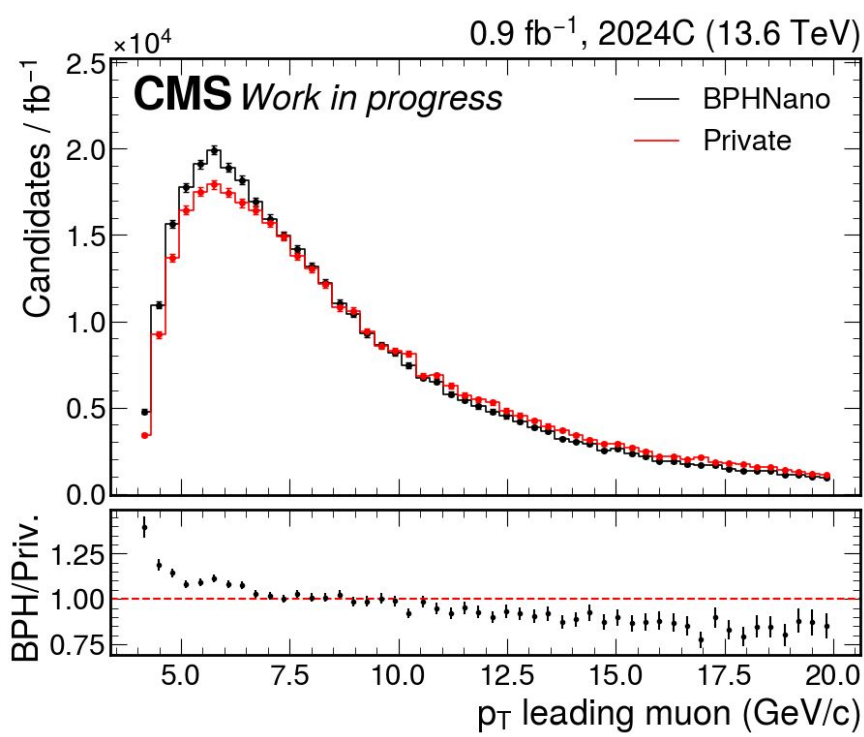


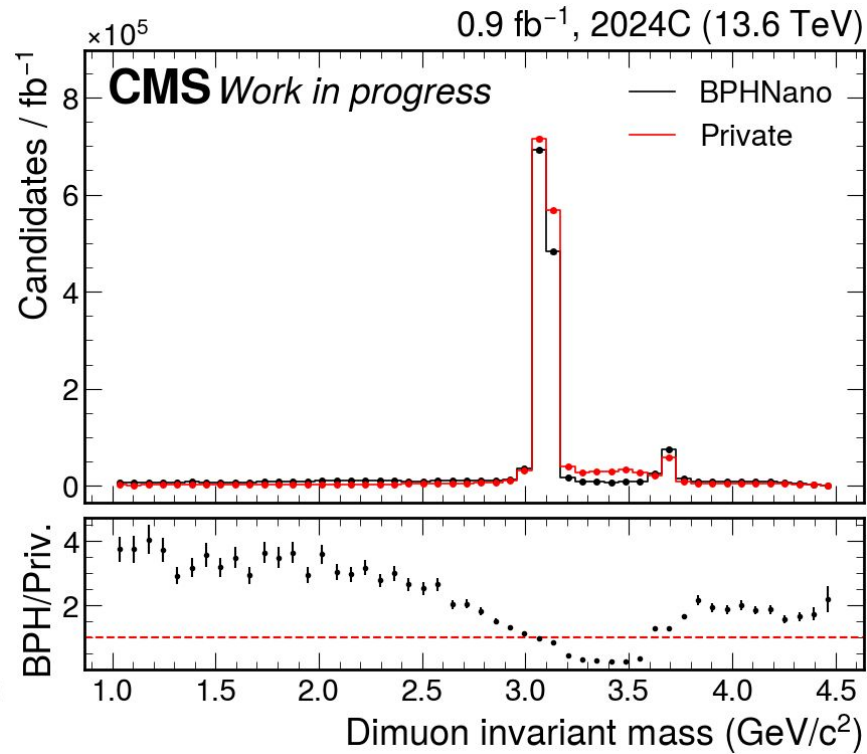
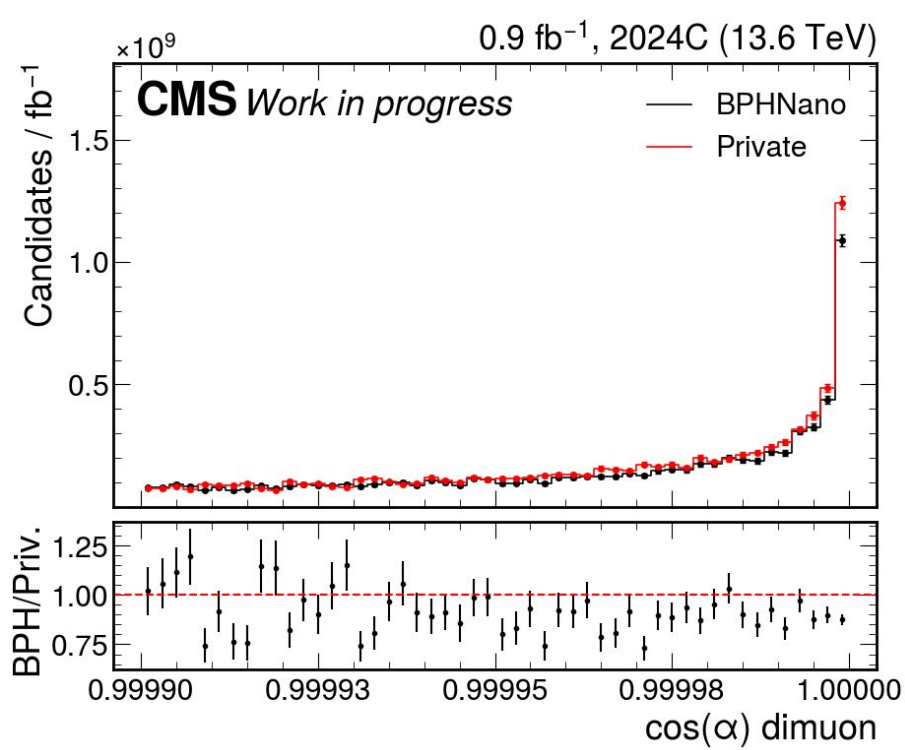




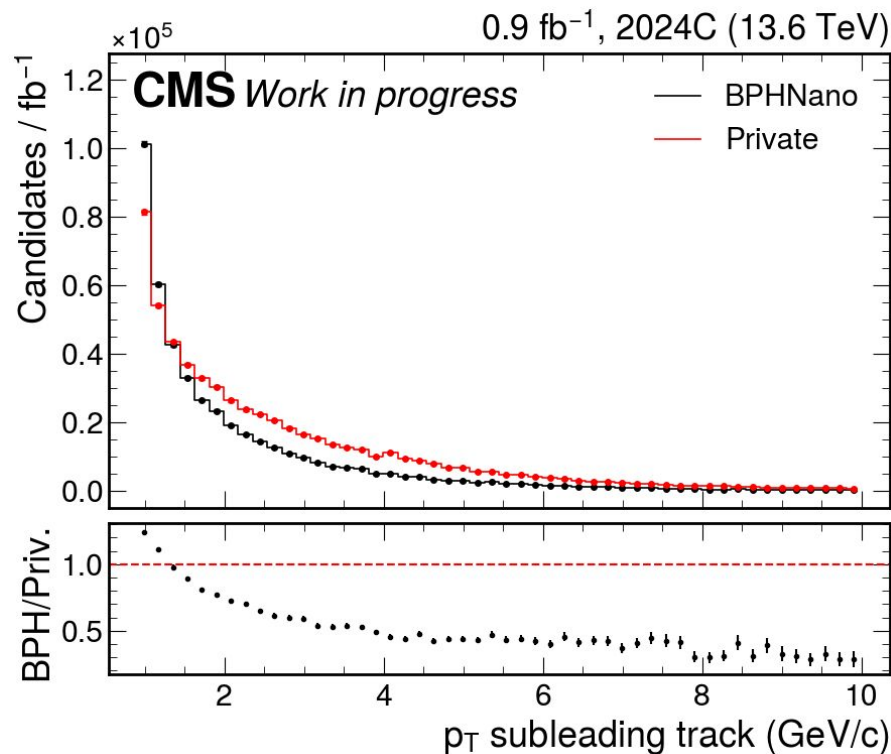
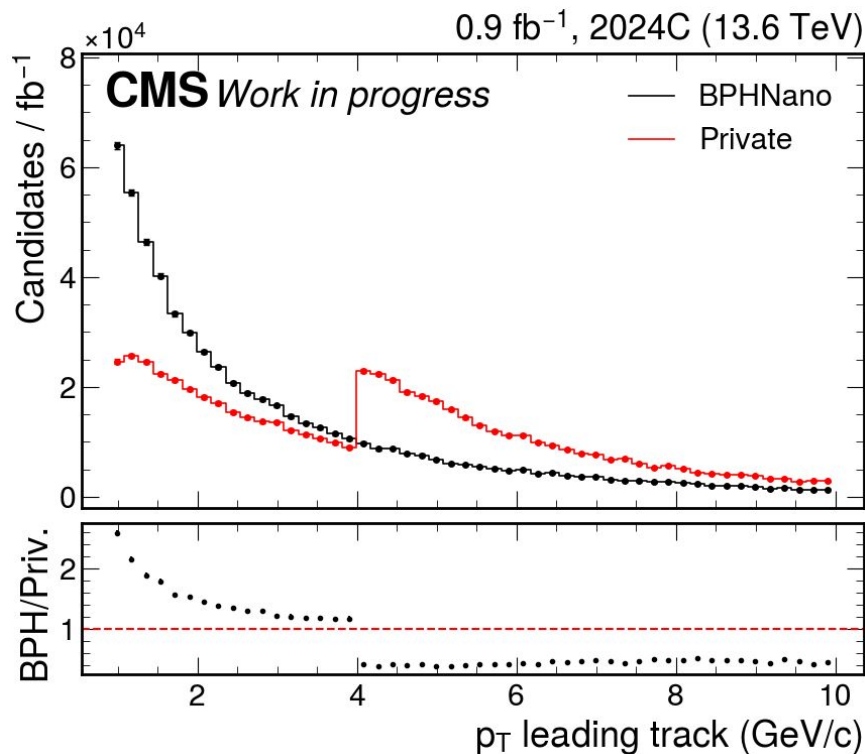




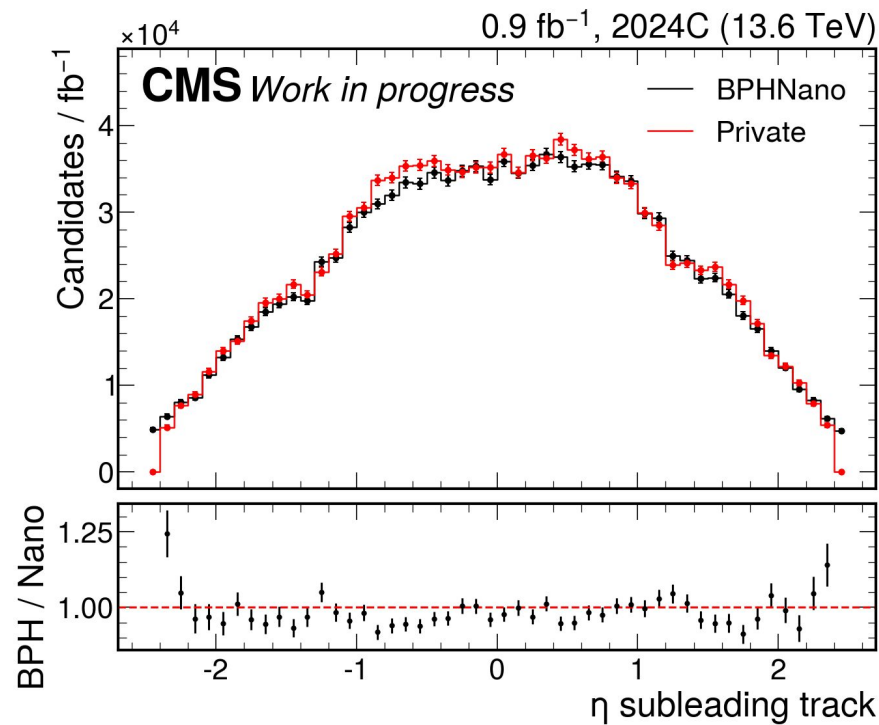
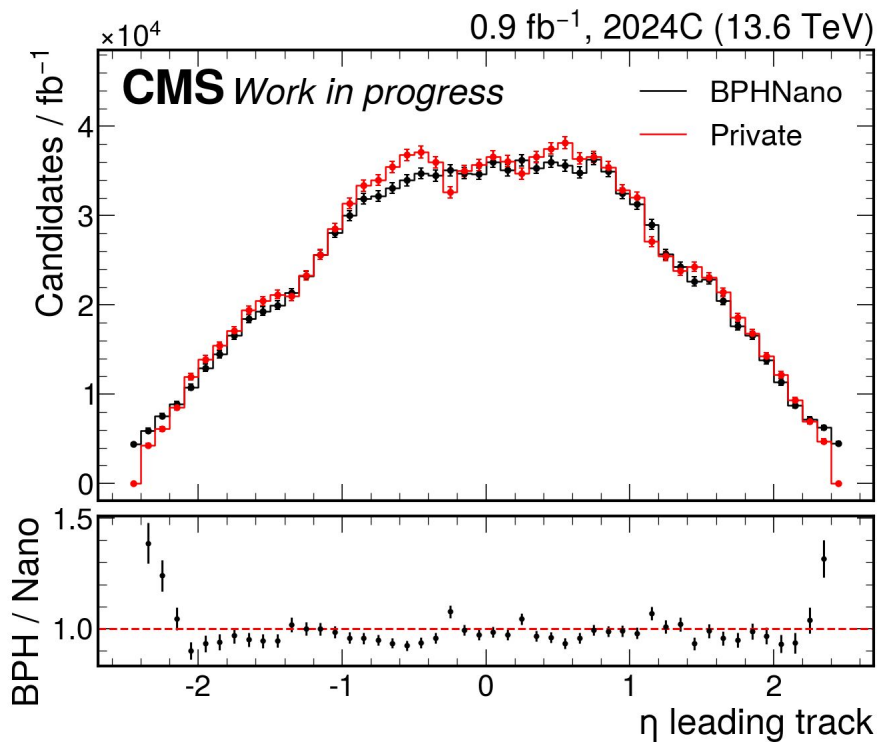




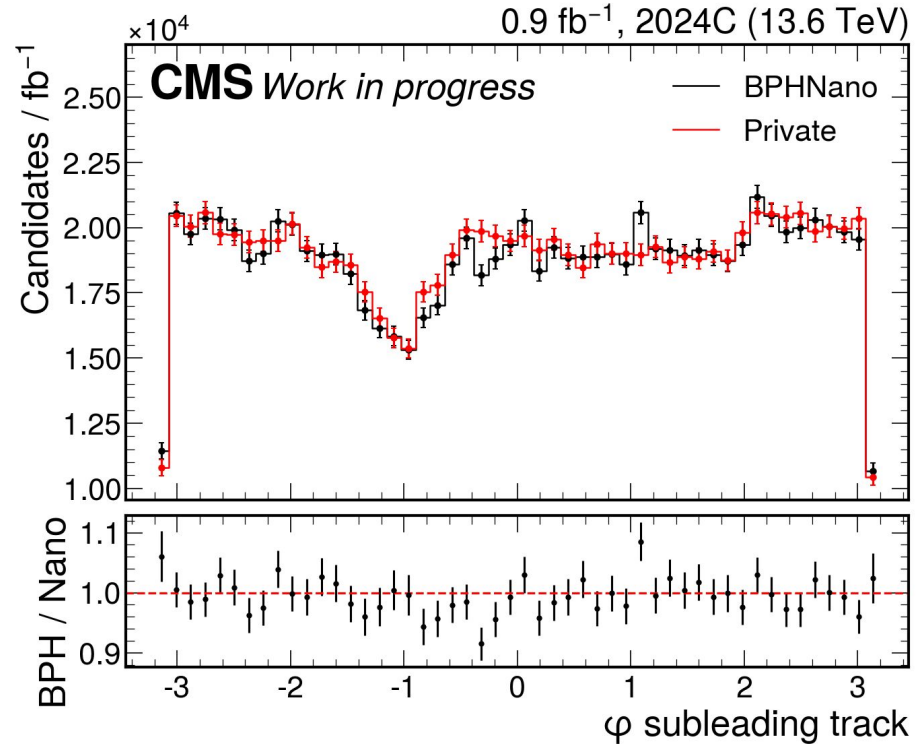
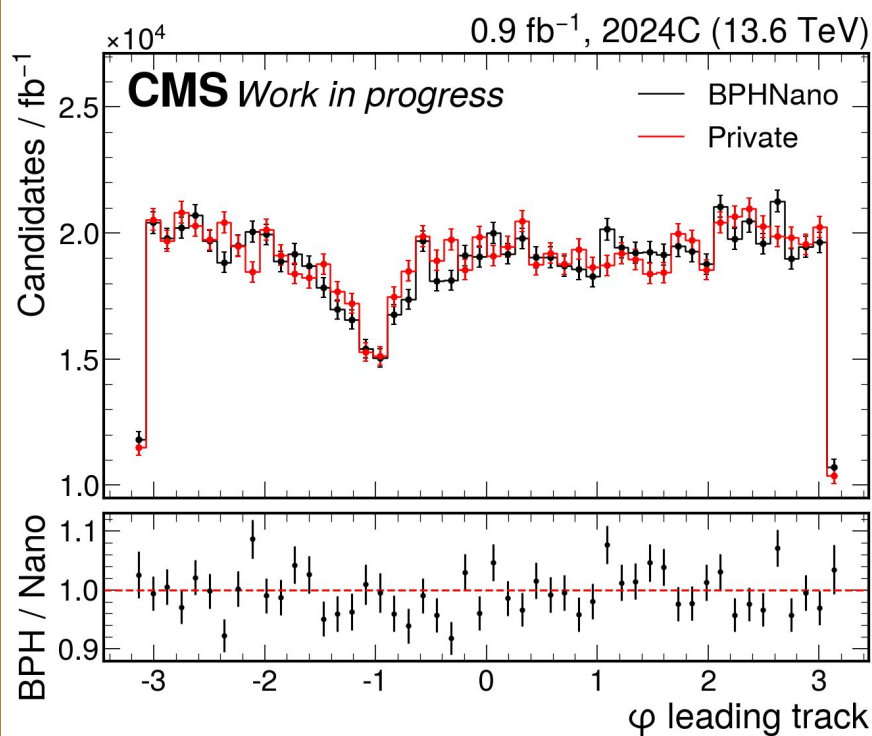
Using RAW - No hadronic selection for private



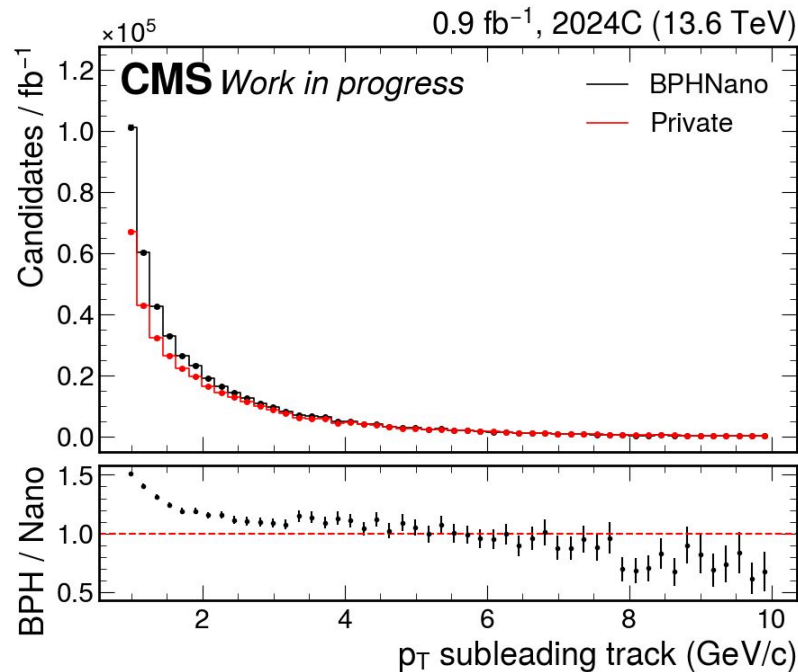
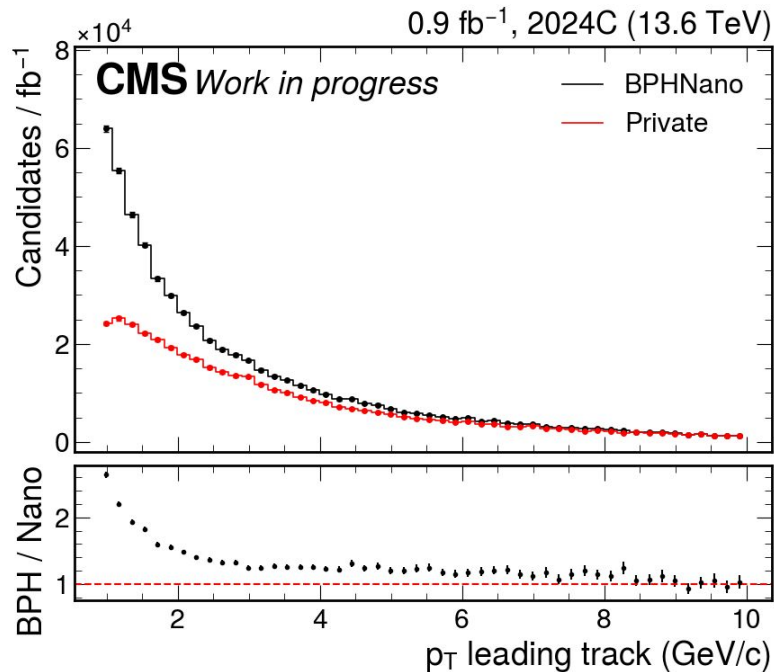
Using RAW - No hadronic selection for private



Using RAW - No hadronic selection for private



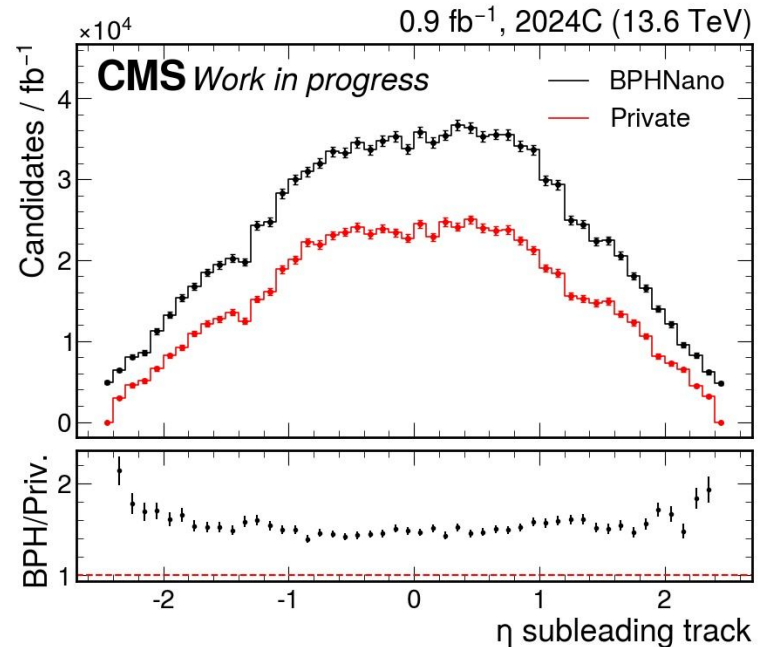
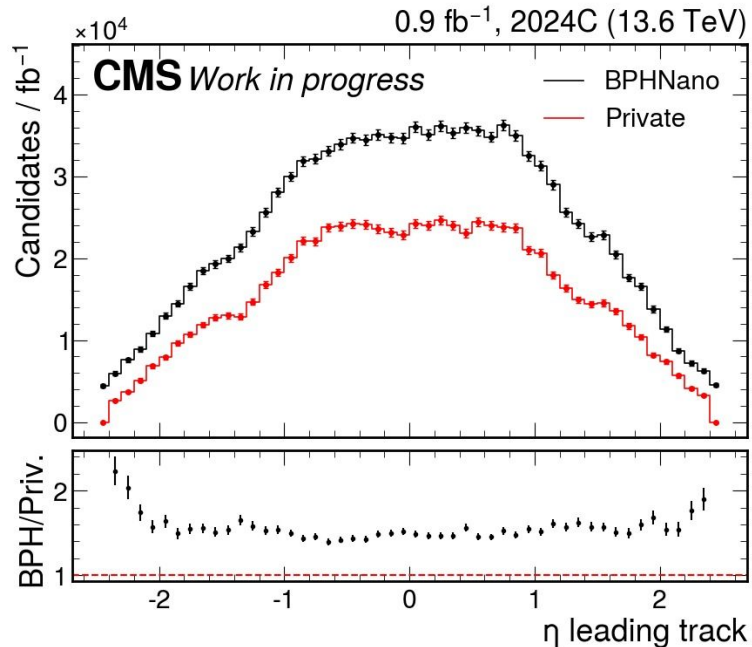
Using RAW and Hadronic selection for private



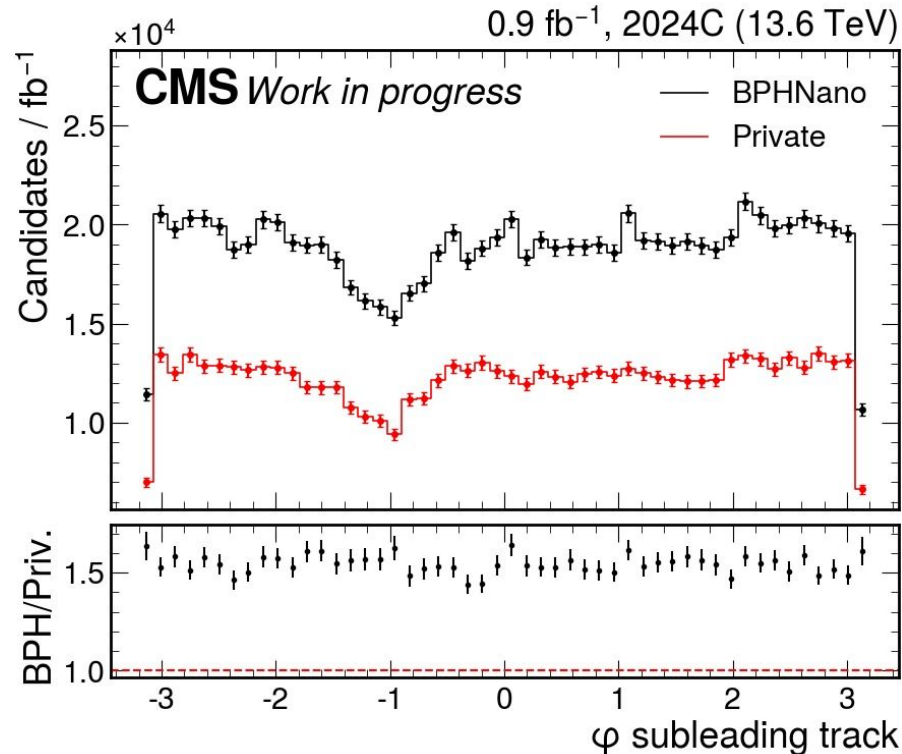
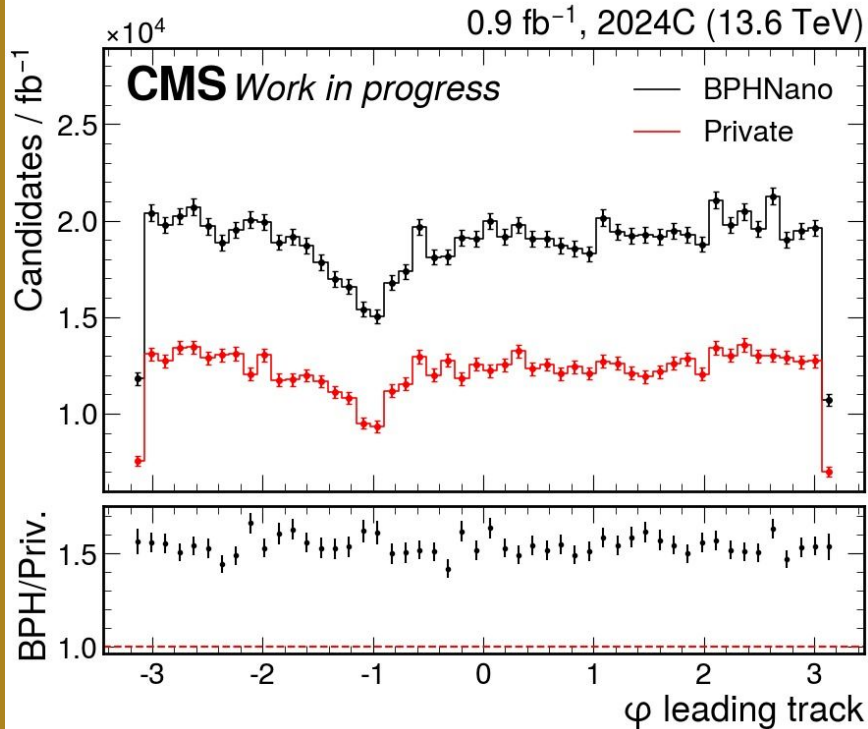
* The 4 GeV peak vanishes, indicating it was indeed caused due to muons

Using RAW and Hadronic selection for private

* Hadronic selection in private track ntuples causes a significant amount of events to be discarded: There are only 2 tracks (+ and -) registered per event, but most events have at least one identified muon



Using RAW and Hadronic selection for private



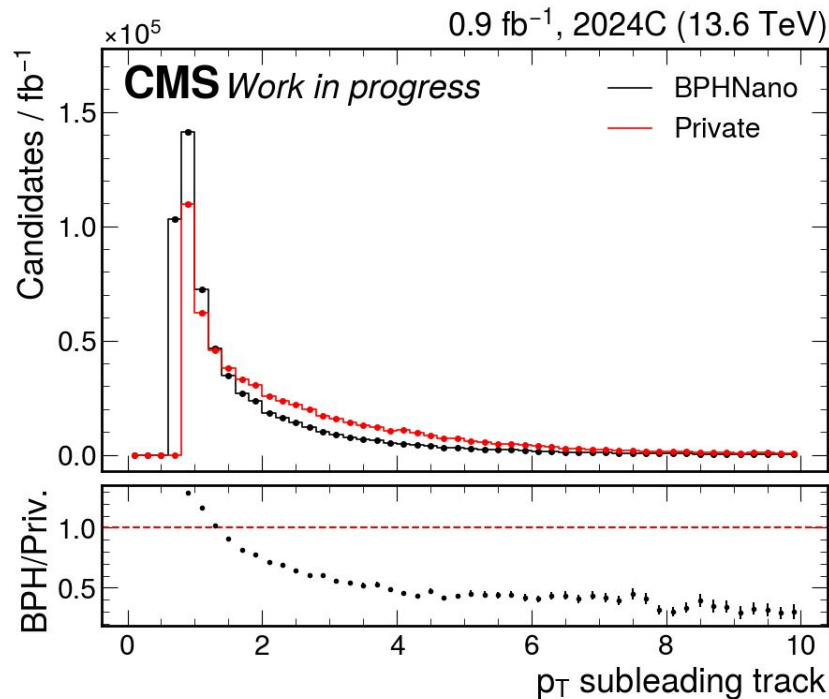
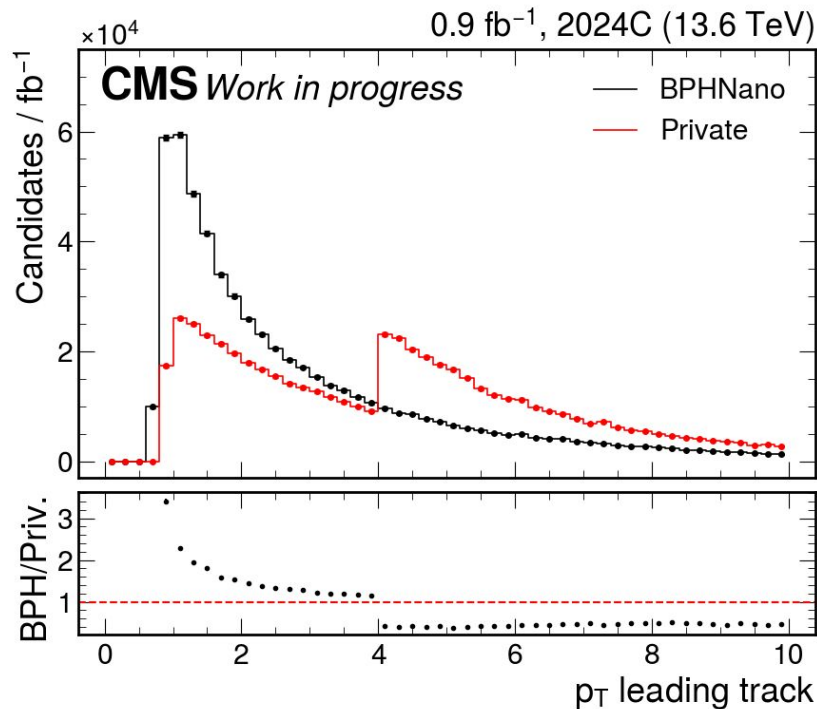
Possible cause

Nano holds 2 tracks (a positive and a negative one) for each B candidate, instead of all four (2 hadrons (H) and 2 muons (L)).

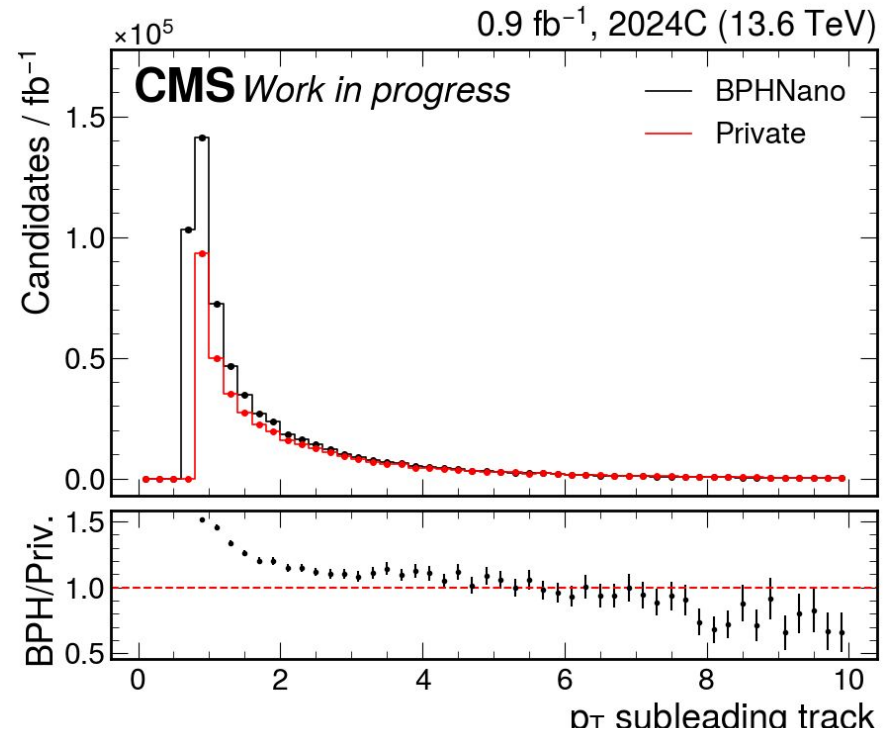
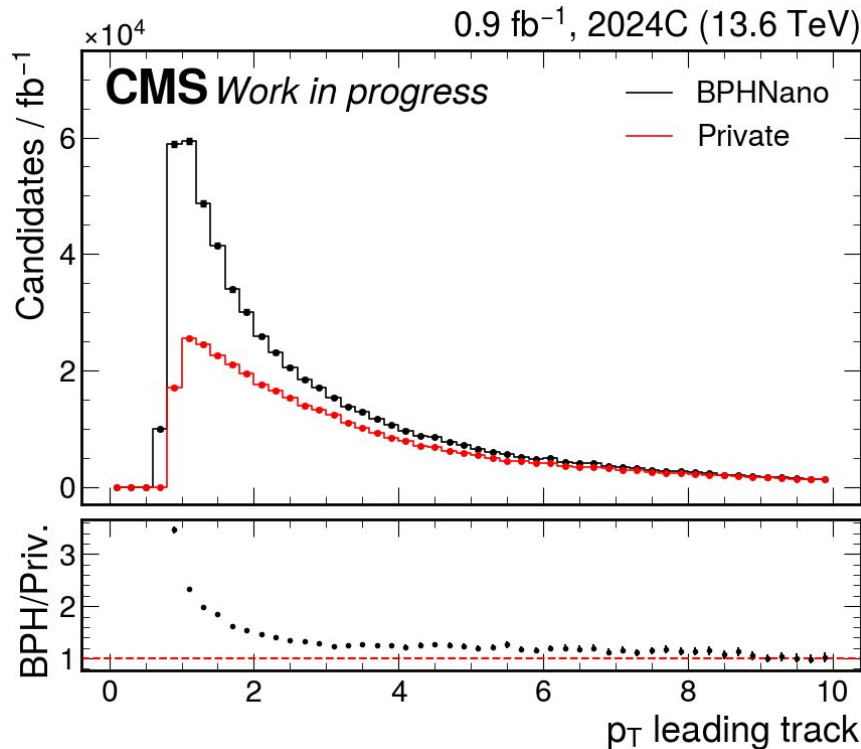
However, these tracks can or not be a hadron. It means if we select only hadrons using MuMatch branches, we end up losing many of event: only combinations of HH survives and all HL/LH/LL are discarded.

Tried using post fit variables for both, in case it holded only hadrons as tracks, but the same 4 GeV p_T peak appears, indicating the same problem.

Plots - Using post-fit - No hadronic selection for private



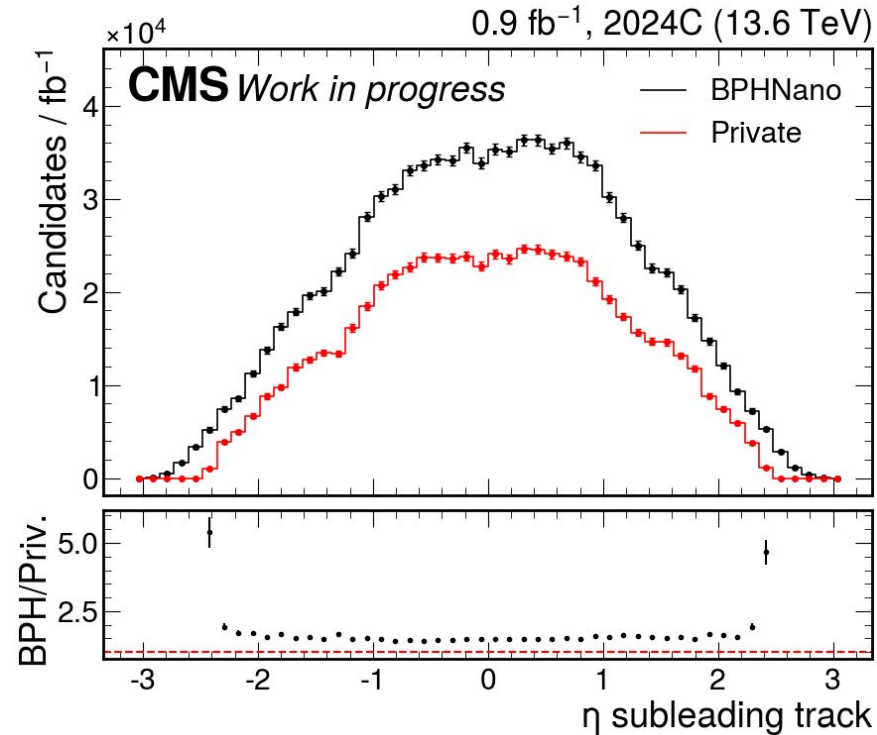
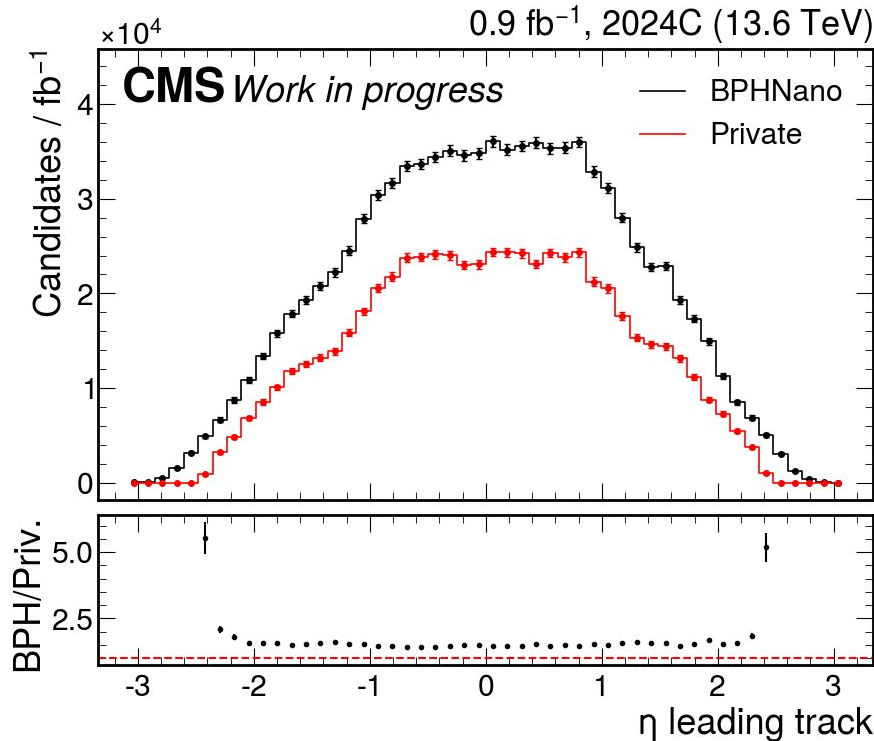
Plots - Using post-fit and hadronic selection for private



Plots - Using post-fit and hadronic selection for private

No private post-fit variable for η .

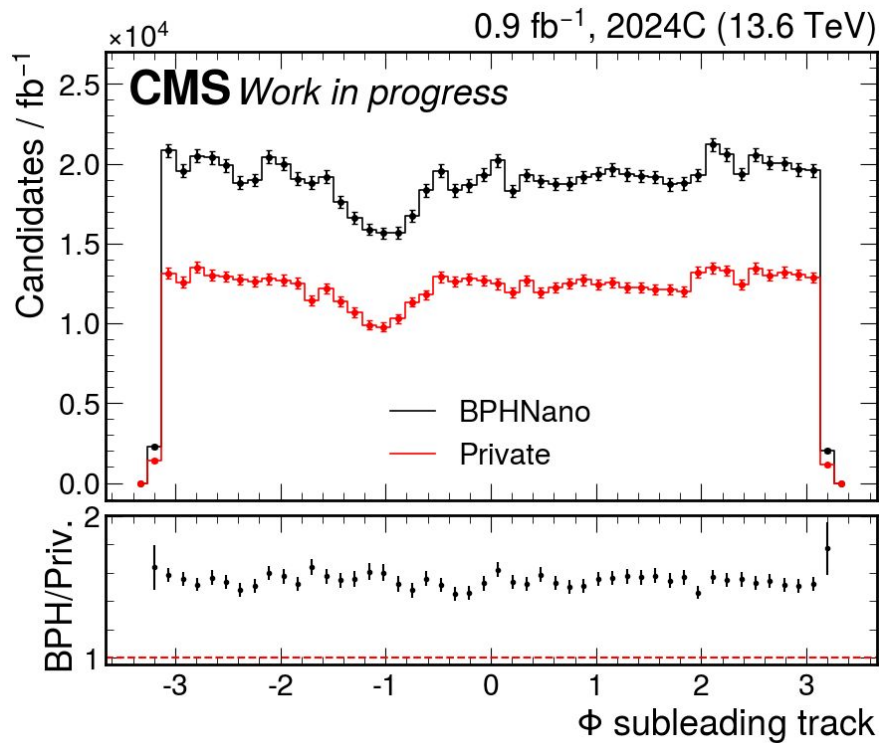
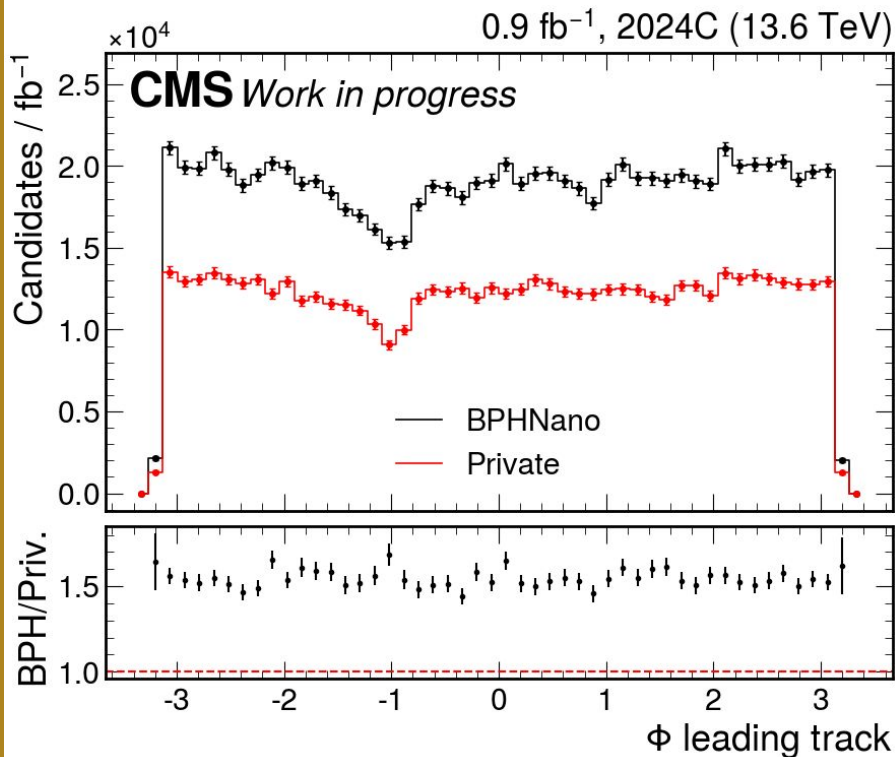
Constructing through $\eta = \text{arcsinh}(P_z/\text{pt})$



Plots - Using post-fit and hadronic selection for private

No private post-fit variable for ϕ .

Constructing through $\phi = \arctan2(P_y, P_x)$



Thanks!

Backup

Variable	Branch BPH	Branch Nano	BPH cuts (file:row)	Nano cuts (file:row)	Best Cut
pT muon	BPHMuon_pt	rawmumPt, rawmupPt (pre-fit)	BPHMuon_pt>3.0	rawmumPt > 4.0, rawmupPt > 4.0 (eff: > 3.96) (miniKstarMuMu.cc:316,345; _cfg.py:103)	Nano
Eta muon	BPHMuon_eta	rawmumEta, rawmupEta (pre-fit)	BPHMuon_eta <2.4	rawmumEta < 2.4, rawmupEta < 2.4 (eff: <2.424) (miniKstarMuMu.cc:316,345; _cfg.py:104)	BPH
muon quality (highPurity)	?	mumHighPurity, mupHighPurity	None	mumHighPurity, mupHighPurity (miniKstarMuMu.cc:1060,1097)	No branch for BPH
DCA muon to Beam Spot	?	mumDCABS, mupDCABS	None	abs(mumDCABS) < 2.0, abs(mupDCABS) < 2.0 (miniKstarMuMu.cc:129-131,161-163; cfg:101).	No branch for BPH
DCA sig. hadron to BS	Track_DCASig	kstTrkmDCABS/kstTrkmDCABSE, kstTrkpDCABS/kstTrkpDCABSE	None	kstTrkmDCABS/kstTrkmDCABSE > 0.8, kstTrkpDCABS/kstTrkpDCABSE > 0.8	Nano
DCA muon-muon	?	mumuDCA	None	mumuDCA < 0.5 (miniKstarMuMu.cc:388; cfg:100)	No branch for BPH
pT dimuon system	MuMu_pt	sqrt(mumuPx^2 + mumuPy^2)	None	mumuPt > 6.9 (miniKstarMuMu.cc:388; cfg:105)	Nano
invariant mass dimuon	BToTrkTrkMuMu_mll_fullfit	mumuMass	0 < fitted_mass < 15.0 (MuMu_cff.py:23)	1.0 < mumuMass < 4.8 (eff: 0.99 & 4.848) (miniKstarMuMu.cc:402; cfg:106,107)	Nano
vertex probability dimuon	MuMu_svprob	mumuVtxCL	sv_prob > 0.001 (MuMu_cff.py:18)	mumuVtxCL > 0.1 (miniKstarMuMu.cc:431; cfg:98)	Nano
decay length sig.dimuon (L/ σ)	MuMu_l_xy / MuMu_l_xy_unc	mumuLBS / mumuLBSE	None	mumuLBS/mumuLBSE > 3.0 (miniKstarMuMu.cc:451; cfg:99)	Nano
cosa dimuon	MuMu_fit_cos2D	mumuCosAlphaBS	None	mumuCosAlphaBS > 0.9 (miniKstarMuMu.cc:468, cfg:102)	Nano
cosa B ⁰	BToTrkTrkMuMu_fit_cos2D	bCosAlphaBS	fitted_cos_theta_2D >= 0.90 (BToTrkTrkLL_cff.py:15)	None	Both post-fit.
pT (K/ π)	Track_pt	rawkstTrkmPt, rawkstTrkpPt	Track_pt > 0.7	Both > 0.8 (eff: > 0.72) (miniKstarMuMu.cc:493; cfg:114)	Nano
Eta (K/ π)	Track_eta	rawkstTrkmEta, rawkstTrkpEta	Track_eta < 2.4	Both < 3.0	BPH
hadron quality (highPurity)	?	kstTrkmHighPurity, kstTrkpHighPurity	None	kstTrkmHighPurity == 1, kstTrkpHighPurity == 1 *	No branch for BPH
Mass K ⁺ (hyp: $\pi^+ K^-$)	BToTrkTrkMuMu_fit_ditrack_mass_Kpi	kstMass	[4.5,6.0] FOR BEST HYP. B MASS (BToTrkTrkLL_cff.py:14)	[0.746, 1.046] FOR BEST HYP. K* MASS (miniKstarMuMu.cc:595)	Fit all on best hypothesis
Mass $\bar{K}^0$ (hyp: $K^+ \pi^-$)	BToTrkTrkMuMu_fit_ditrack_mass_piK	kstBarMass	[4.5,6.0] FOR BEST HYP. B MASS (BToTrkTrkLL_cff.py:14)	[0.746, 1.046] FOR BEST HYP. K* MASS (miniKstarMuMu.cc:595)	Fit all on best hypothesis
Mass B ⁰ (hyp: K ⁺)	BToTrkTrkMuMu_fit_mass_Kpi	bMass	[4.5,6.0] FOR BEST HYP. B MASS (BToTrkTrkLL_cff.py:14)	4.5 < bMass < 6.5 (miniKstarMuMu.cc:865; cfg:109,110).	Fit all on best hypothesis
Vertex probability B ⁰	BToTrkTrkMuMu_svprob	bVtxCL	sv_prob > 0.001 (BToTrkTrkLL_cff.py:15)	Mini: Corte bVtxCL > 0.01 (miniKstarMuMu.cc:558; cfg:98).	Nano
2D IP: hadrons:dimuon vertex	BToTrkTrkMuMu_trk1_svip2d BToTrkTrkMuMu_trk2_svip2d	?	Both < 0.045 (BToTrkTrkLL_cff.py:15)	None	No branch for Nano

Backup

