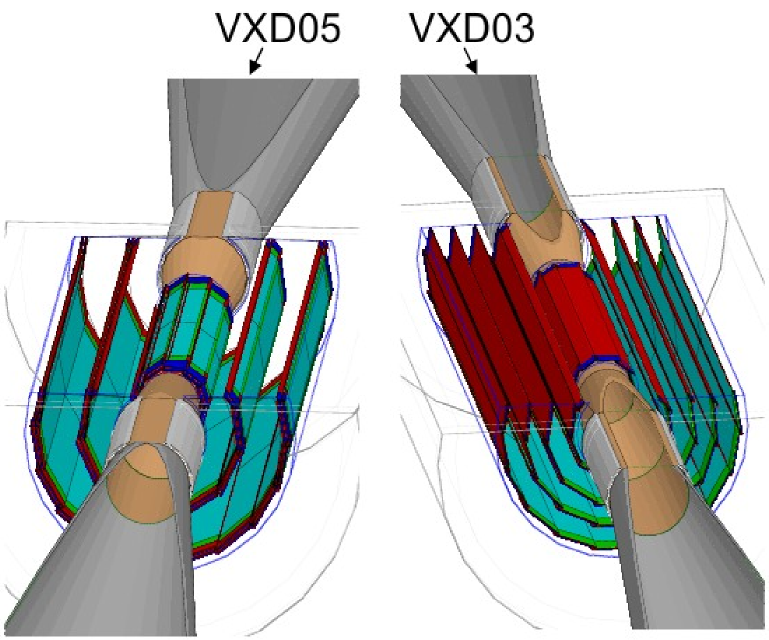
Optimisation of the vertex detector for the ILD

Yorgos Voutsinas
on behalf of IPHC Strasbourg

- Comparative studies of the 2 main candidate VXD geometries on heavy flavour tagging and hadronic higgs BRs extraction
- VXD performance including beam pair bkg hits
  - Studies are based on LOI ZH$\rightarrow$llqq branching ratios analysis

VXD candidate geometries

- 2 main candidate geometries for ILD VXD
  - VXD05: with 3 double layers equipped with silicon pixel sensors
  - VXD03: 5 single layers



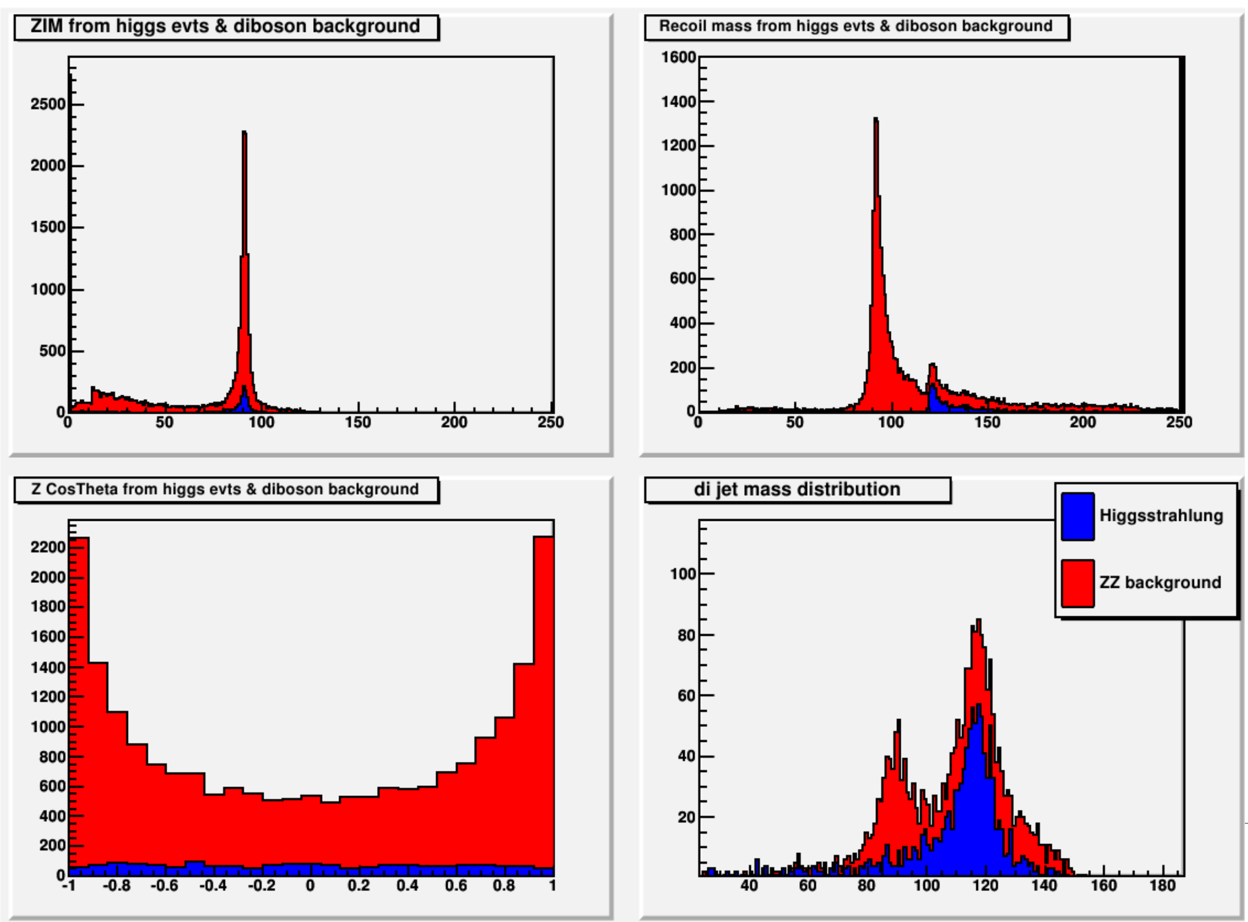
	VXD03	VXD05
layers	5	3 x 2
sensitive length (mm)	62.5	125
sensitive width (mm)	11-15-22	11-22
radii (mm)	15-60	16–60
sensitive thickness (μm/ladder)	50	50
graphite insensitive thickness (μm/ladder)	134	134

Event reconstruction

- Higgsstrahlung channel $e^+e^- \rightarrow ZH \rightarrow \mu^+\mu^- X$
  - ➔ $\sqrt{s}$ 250GeV, M_H 120GeV
  - ➔ Higgs decaying according to its SM BR – Z decaying to a pair of muons
    - ➢ Z recon. out of best candidate pair of muons
    - ➢ Rest of particles forced to 2 jets, using Durham algorithm
- MC file from LoI data samples – unpolarized beams, cross section ~ 7fb
- Simulated with Mokka -06-07 release
  - ➔ Detector model ILD00
  - ➔ VXD models VXD03 (single layers) & VXD05 (double layers)
  - ➔ s.p. Resolution assumed 2.8μm for all layers
- Reconstructed with ilcsoft v01-08-01, 250fb^{-1}
  - ➔ New pandora for particle ID
- An independent sample of 500fb^{-1} has been reconstructed to be used at the fit for the BR extraction

Physics background – event selection

- $e^+e^- \rightarrow ZZ \rightarrow \mu^+\mu^- qq_{bar}$, beam polarization 0, σ = 79.0fb
  - $250fb^{-1}$ events reconstructed
- $e^+e^- \rightarrow WW \rightarrow \mu\ \nu_\mu\ qq_{bar}$, beam polarization 0, σ = 2278.55fb
  - Out of 10k events reconstructed, 1event passes the cuts=> assumed negligible
- 2f-4f background found negligible



Event selection

(1) 70GeV < muon pair IM < 110GeV

(2) 1 only Z candidate

(3) 117GeV < Recoil mass < 150GeV

(4) $|\cos\theta_z| < 0.9$

(5) 100GeV < di-jet IM < 140GeV

$S/\sqrt{S+B}$ = 21.4

Beam background

- Random noise clusters superimposed – VTXNoiseClusters processor
- Hits densities
  - ILC nominal values considered (√s 500GeV)
  - Simulated with ILD_00fw model
  - Anti did field included
  - Hits densities / cm^2 / BX

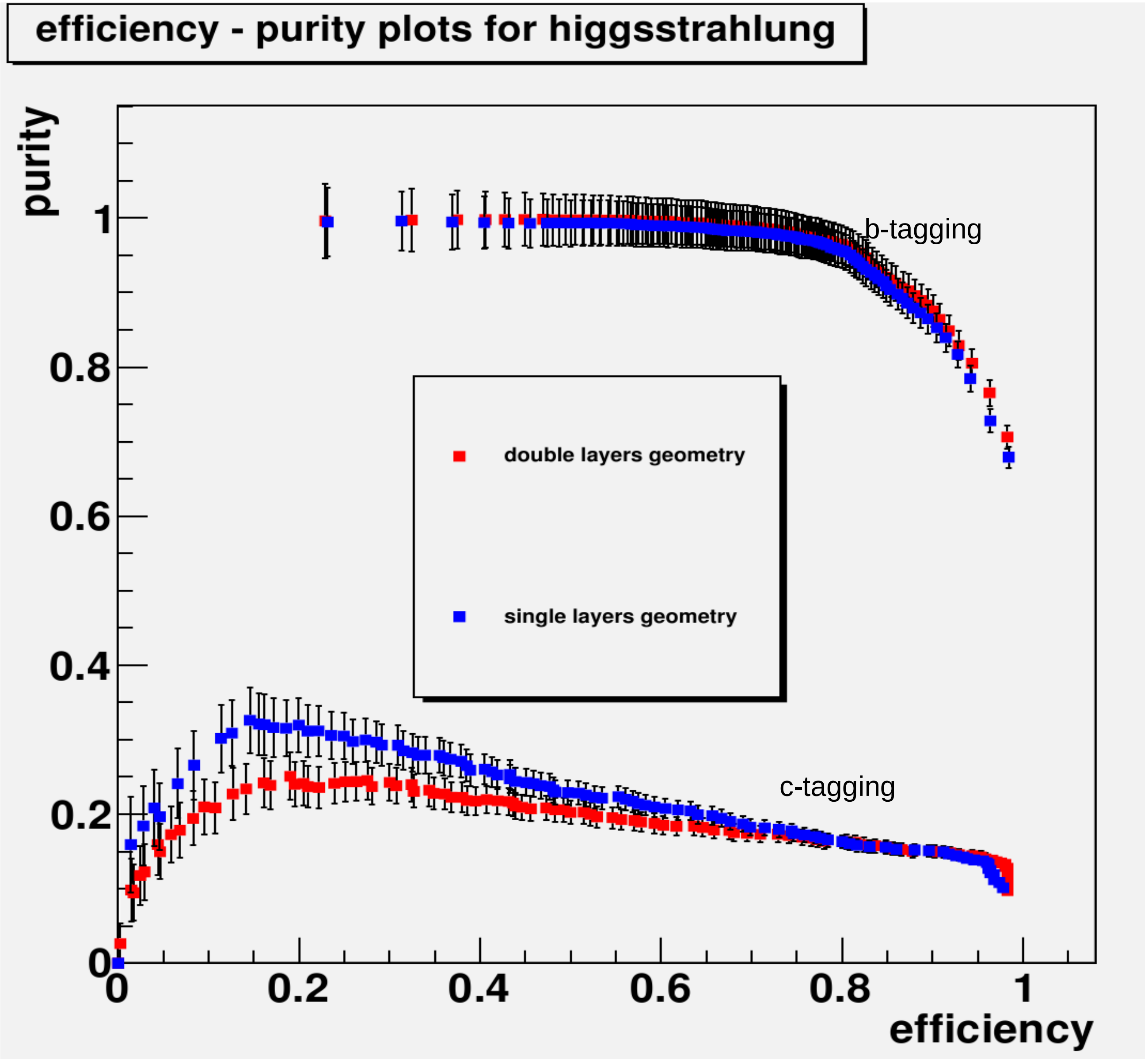
layer	VTX-DL	VTX-SL
1	4.4 ± 0.5	5.3 ± 0.5
2	2.9 ± 0.4	$6.0 \pm 0.5 \times 10^{-1}$
3	$1.54 \pm 0.14 \times 10^{-1}$	$1.9 \pm 0.13 \times 10^{-1}$
4	$1.34 \pm 0.11 \times 10^{-1}$	$6.9 \pm 0.6 \times 10^{-2}$
5	$3.2 \pm 0.7 \times 10^{-2}$	$3.1 \pm 0.4 \times 10^{-2}$
6	$2.7 \pm 0.5 \times 10^{-2}$	

layer	Readout (μs) - (#BXs superimposed)	
	SL	DL
0	25 (68)	25 (68)
1	50 (136)	25 (68)
2	100 (272)	100 (272)
3	100 (272)	100 (272)
4	100 (272)	100 (272)
5		100 (272)

- Values taken from Rita's ILC note

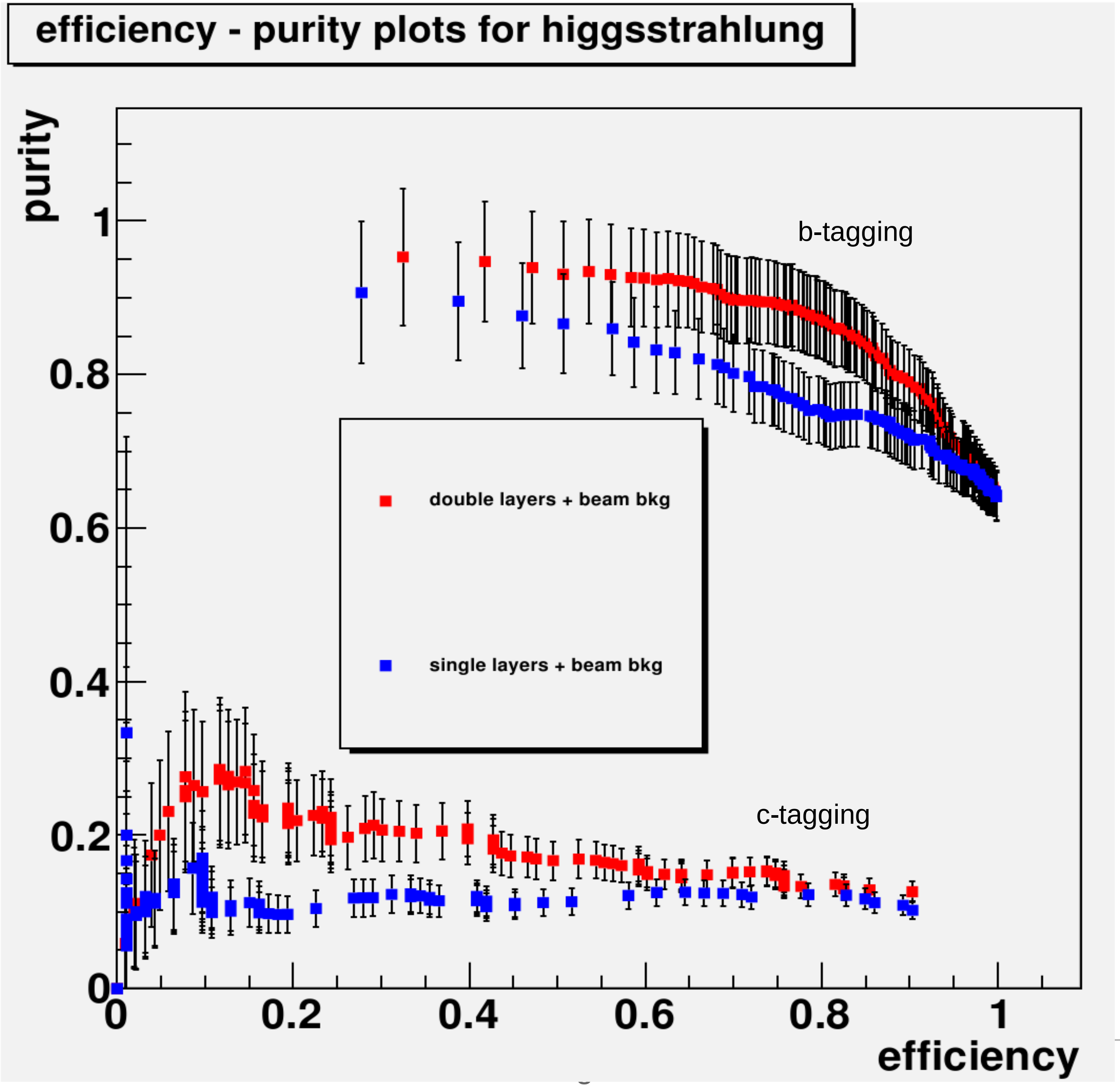
Flavour tagging w/o beamstrahlung

- LCFI nets used for flavour tagging
- Training sample: Z→qqbar @ √s = 91.2GeV, 10k for each geometry



- $700fb^{-1}$ of Higgsstrahlung analyzed
- No beam bkg superimposed
- Statistical errors shown in plot
- Nets uncertainties ~ 1% - less than statisticals
- B tagging performance almost identical
- C tagging performance : single layer option has a region for low and moderate efficiency with higher purity
  - Due to smaller distance from IP (?)

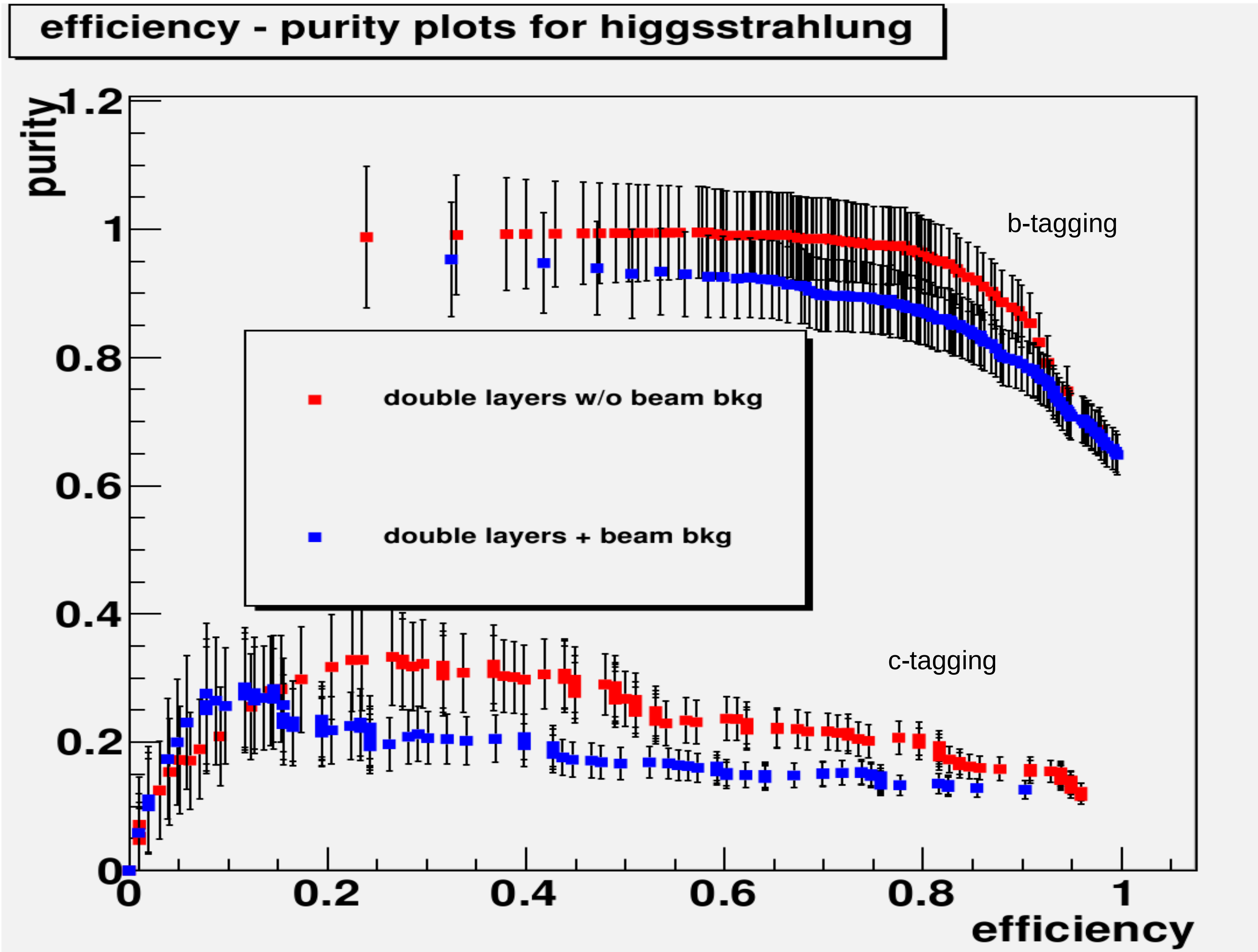
Flavour tagging with beamstrahlung



- Similar study but now with salt n' pepper background superimposed according to layer's r.o. time
- 250fb^{-1} of Higgsstrahlung analyzed
- Silicon tracking slightly modified to gain processing time
  - ✓ Negligible effect on the performance
- Better performance for double layers geometry
- Maybe consequence of tracking
  - ~1k silicon tracks/evt for DL geometry
  - ~5k silicon tracks /evt for SL geometry
  - ~ 30/evt for both geometries w/o beam background

Flavour tagging with and w/o beamstrahlung

- VXD05 comparison with and w/o beamstrahlung added
- Degraded overall performance



Higgs branching ratios extraction

- Following LOI studies – focus on VXD models comparison
- b(c) likeness: event wise variable
  - Likeness = x1x2/(x1x2+(1-x1)(1-x2)) , where x1,2 are the outputs of the neural nets
- Previous studies shown that a cut based extraction of the flavours does not yield the best sensitivity
- There is no analytic distribution function so we use MC samples for the fitting
  - Split the initial sample to “data” and monte carlo
  - Split the monte carlo sample to $H\rightarrow bb$, $H\rightarrow cc$, $H\rightarrow gg$, non hadronic higgs decays + physics background
  - Create 2D templates with b-c likeness and fit the data by changing the normalisations of each sample – fix bkg sample factor to 1
  - Extract branching ratios from the normalisation factors
- Limitations for the fit
  - Finite statistics of MC samples
  - Bins with zero or very few events
  - Templates with the majority of the events at only 1 bin

Fitting results

- $BR(H \rightarrow xx) = r_{xx} \times BR(H \rightarrow xx)_{SM}$, where r_{xx} are the fit results for each hadronic decay channel (bb,cc,gg) – these factors expected to be 1 for SM
- Comparison between relative errors for the candidate models – especially for c-tagging

	Double layers	Single layers
r_{bb}	0.93 ± 0.06	0.99 ± 0.06
r_{cc}	0.93 ± 0.59	0.86 ± 0.54
r_{gg}	1.68 ± 0.58	0.88 ± 0.61

- Trying different fitting methods
  - Finally choose χ^2 mostly due to low statistics of MC templates
  - χ^2 (cope with limited data but not with very few evts @ 1 bin) – cut at bins with <5 entries

$$X^2 = \Sigma_{bins} (D_{bins} - (N_D / N_{MC}) \Sigma_s r_s N_s^{bins})^2 / \sigma_{bins}^2$$

Higgs BRs + pair bkg hits

- Study of $100fb^{-1}$
- Shape of the templates is changing
  - Light jets have a significantly bigger b-jet probability
- Seems like a retrain of the neural nets, including pair beam background hits, is required
- On going..

Conclusions – to do

- Flavour tagging w/o beam background
  - Single layers geometry has better performance at the region of high purity – low efficiency
  - Maybe due to smaller distance of inner layer from IP (15mm vs 16mm)?
- Flavour tagging + superimposed beamstrahlung hits
  - Degradation of overall performance
  - Double layers performs better – should be an effect of tracking
- Higgs hadronics branching ratios
  - Similar performance of both candidate geometries
- To do
  - Retrain neural nets including pair beam bkg
  - Increase statistics at Higgs BR study in the presence of beamstrahlung

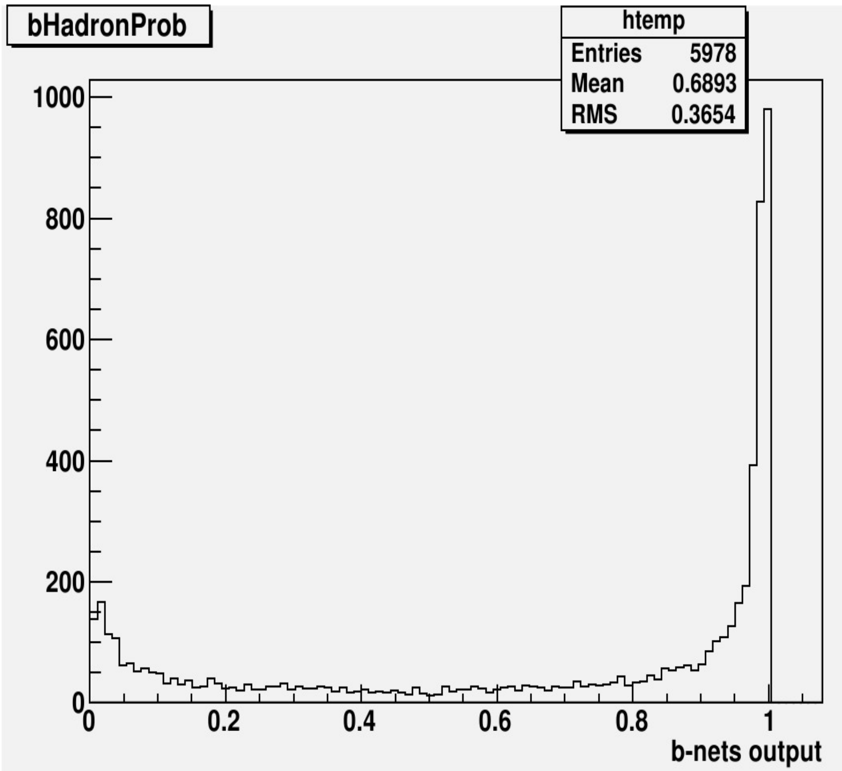
georgios.voutsinas@ires.in2p3.fr

Backup slides

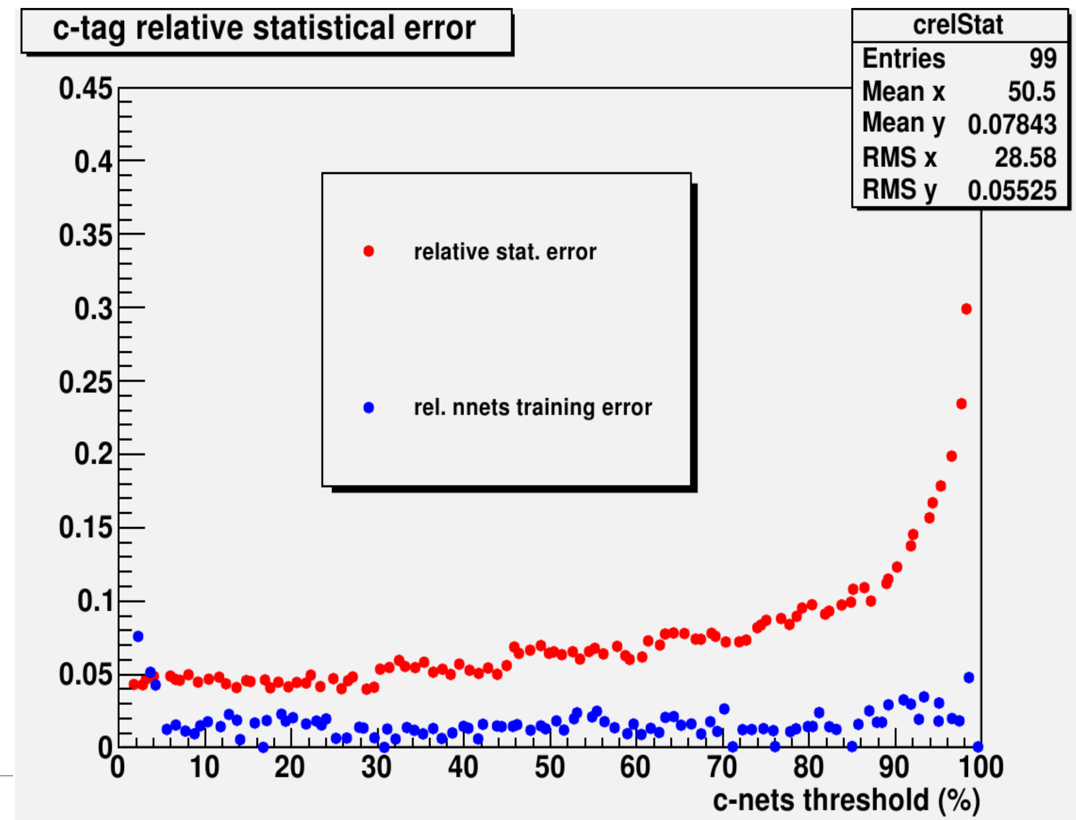
Neural nets training

- LCFI nets used for flavor tagging
- Training sample: Z→qqbar @ √s = 91.2GeV, 10k for each geometry

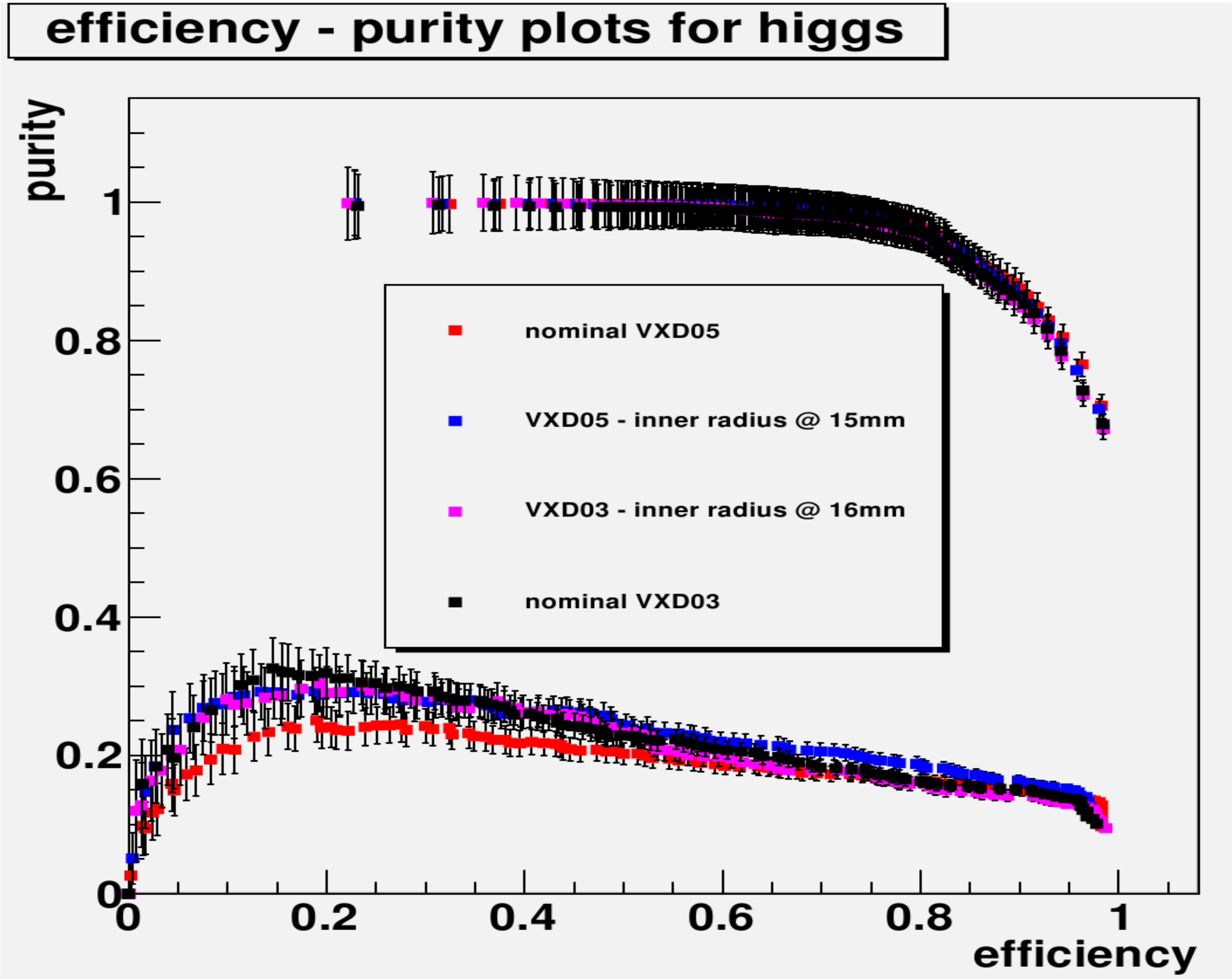
Uncertainties coming from neural nets training after 5 independent trainings compared to relative stat.error



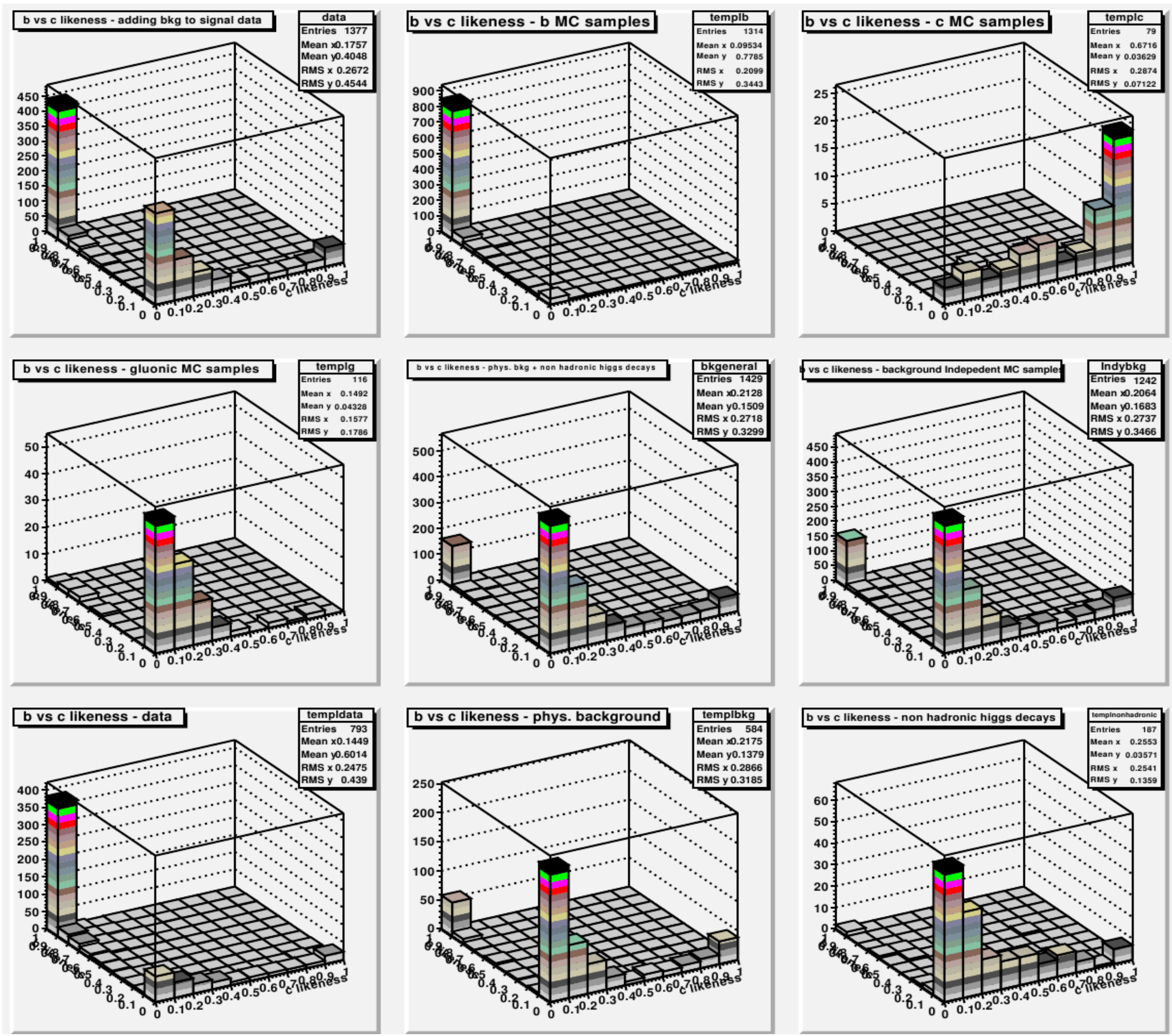
Test for overtraining: output of b-nets for pure b-sample



Radius study of VXD candidate geometries



MC templates for VXD05 - 500fb^{-1}



MC templates – 100fb^{-1} + pair bkg hits