Physics-performance optimisation of the CLIC vertex detector

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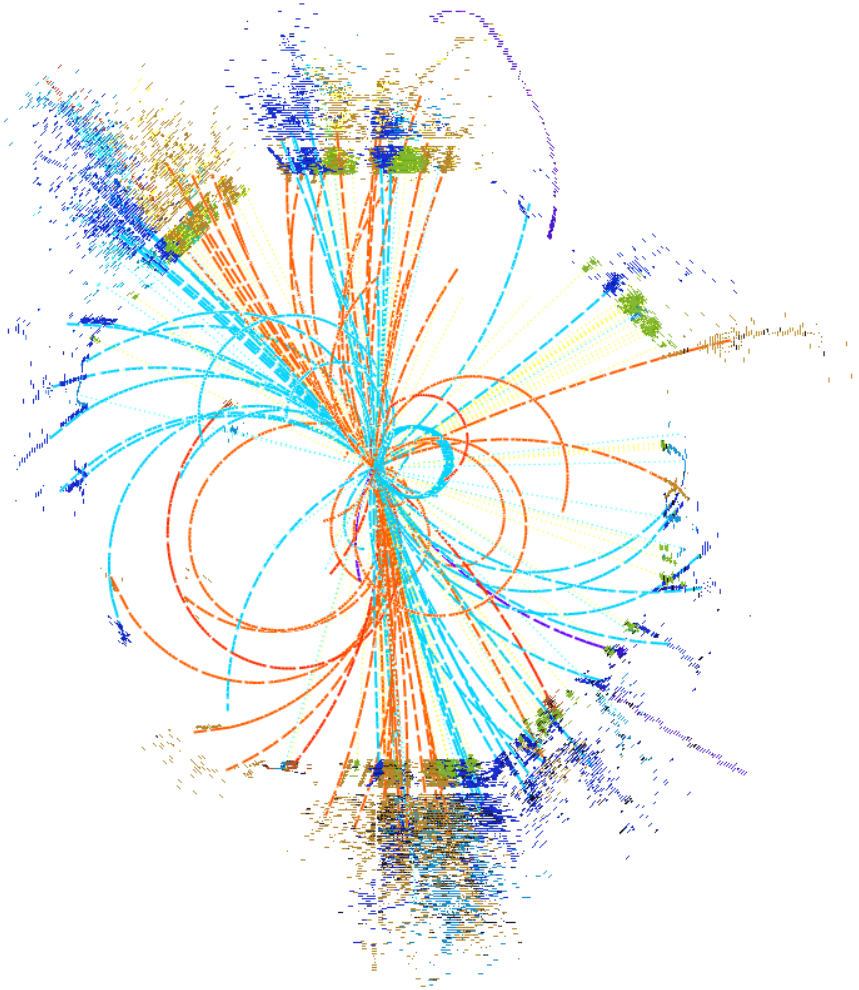
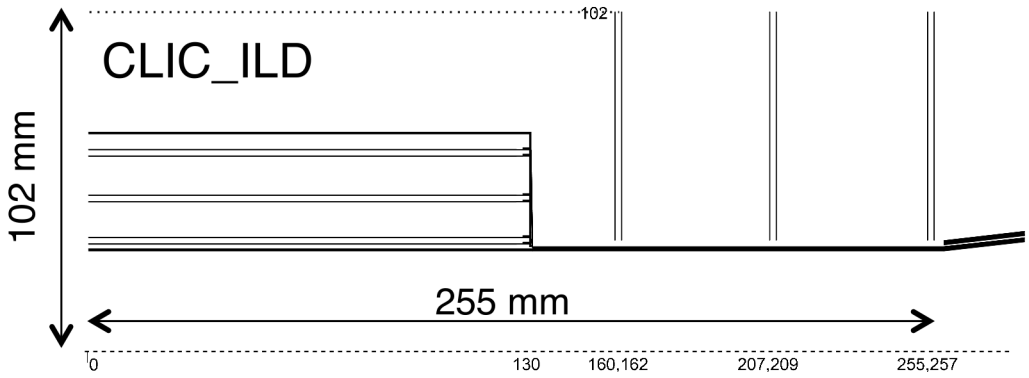
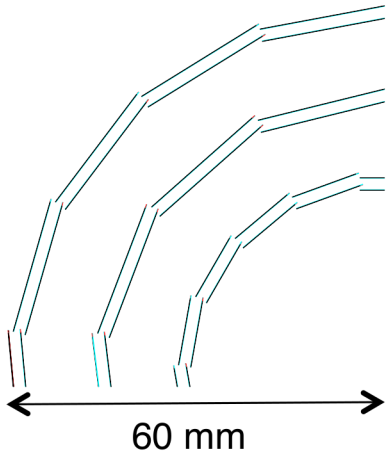


ECFA LC2013, 28/05/2013, DESY Hamburg

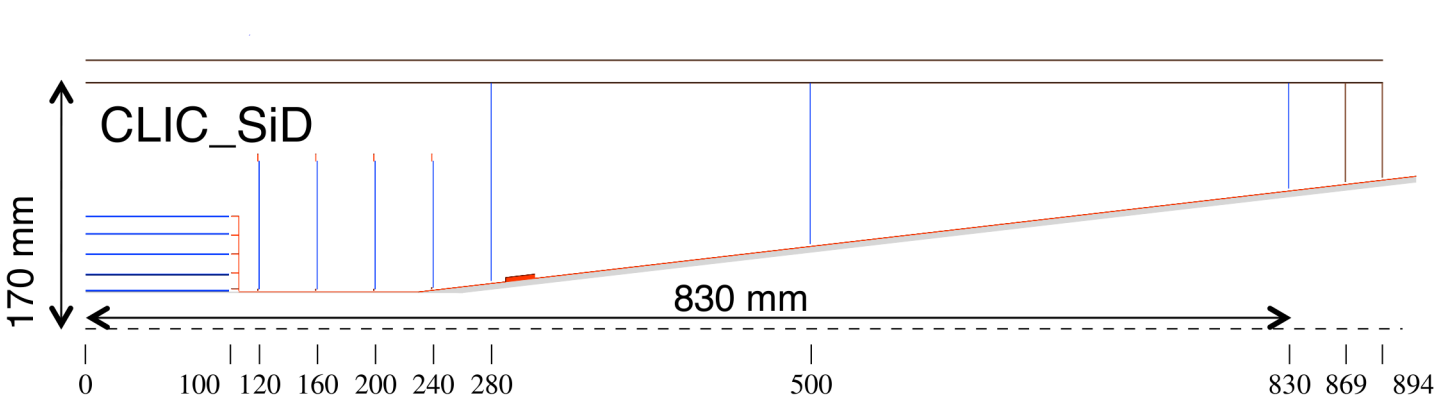
CLIC_SiD and CLIC_ILD

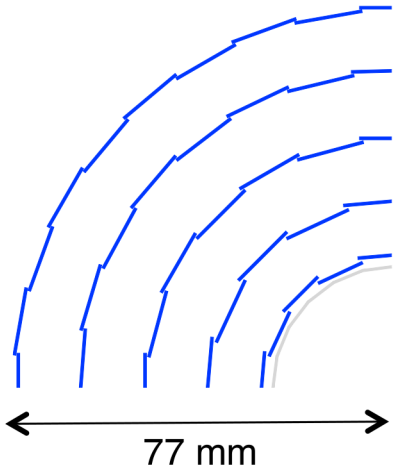
CLIC_ILD: 3 double layers in barrel, 1.84 · 10^9 pixels





CLIC_SiD: 5 single layers in barrel, 2.76 · 10^9 pixels





Vertex regions in the CLIC CDR

	CLIC_ILD	CLIC_SiD
Central beam pipe	Beryllium	
	$R_i = 29.4$ mm	$R_i = 24.5$ mm
	$d = 0.6$ mm	$d = 0.5$ mm
Barrel region	3 double layers	5 single layers
	$\|z\| < 130$ mm	$\|z\| < 98.5$ mm
	$R_i = 31,\ 44,\ 58$ mm	$R_i = 27,\ 38,\ 51,\ 64,\ 77$ mm
Forward region	3 double layers	7 single layers
	$z = 160, 207, 255$ mm	$z = 120, 160, 200, 240,$ $280, 500, 830$ mm
Sensors	20 µm × 20 µm, $\sigma_{sp} \approx 3$ µm	
	$X/X_0 = 0.18\%$ per double layer	$X/X_0 = 0.11\%$ per single layer
Surface area	0.736 m^2	1.103 m^2
Number of channels	1.84×10^9	2.76×10^9

Introduction

Use flavour tagging performance to:

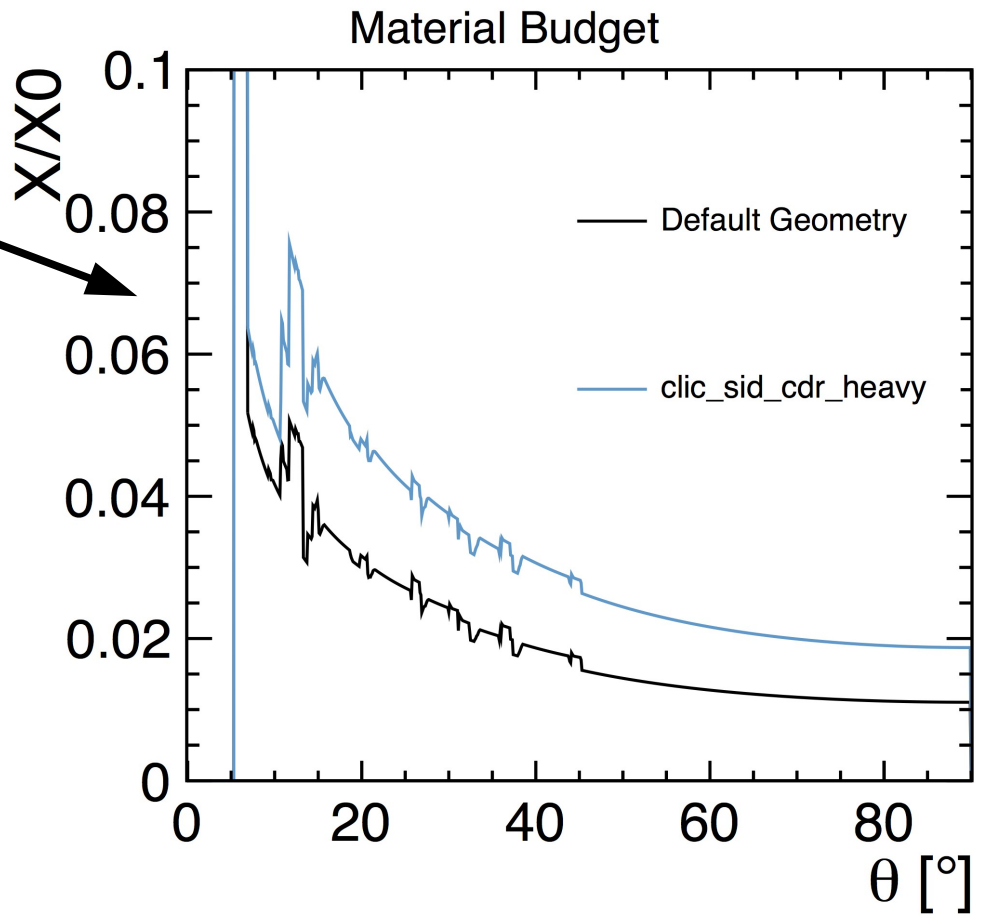
- Illustrate impact of material budget in the vertex region on the physics performance
- Compare single layer and double layer designs
- Test impact of spiral disk geometry on the physics performance

→ All comparisons will be done keeping the rest of the detector unchanged (CLIC_SiD)

- Recent software versions used as for DBD (SLIC v3r0p3, org.lcsim 2.5, LCFIPlus v0.52)

Impact of material budget

Integrated material budget in the vertex region (beam pipe, vertex modules, support) as a function of the polar angle



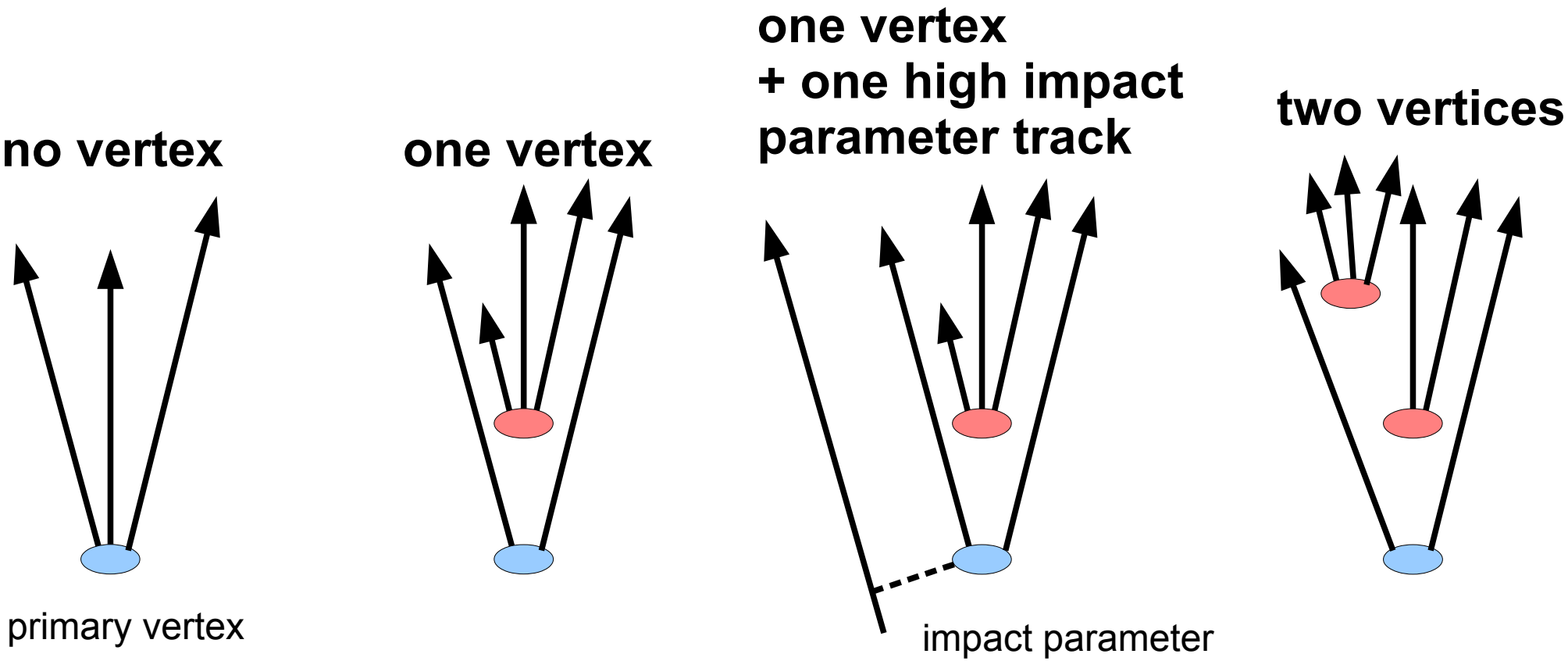
The baseline design is lacking material

Comparison of default detector to geometry with more material in the vertex region:

	clic_sid_cdr	**clic_sid_cdr_heavy**
Beam pipe	0.5 mm Be	1 mm Be
Vertex module	50 µm Si + 130 µm C	50 µm Si + 260 µm C
Support	2 x 0.5 mm C	2 x 1 mm C

Flavour tagging and jets

- The flavour tagging in this study is uses LCFIPlus v00-05-02
- Jets are reconstructed using the Durham algorithm
- Each jet is grouped in one of the following categories:



Vertex reconstruction performance

45000 light quark jets of 250 GeV:

	clic_sid_cdr	clic_sid_cdr_heavy
no vertex	43342	43054
one vertex	1219	1455
one vertex + high impact par. track	177	208
two vertices	222	245

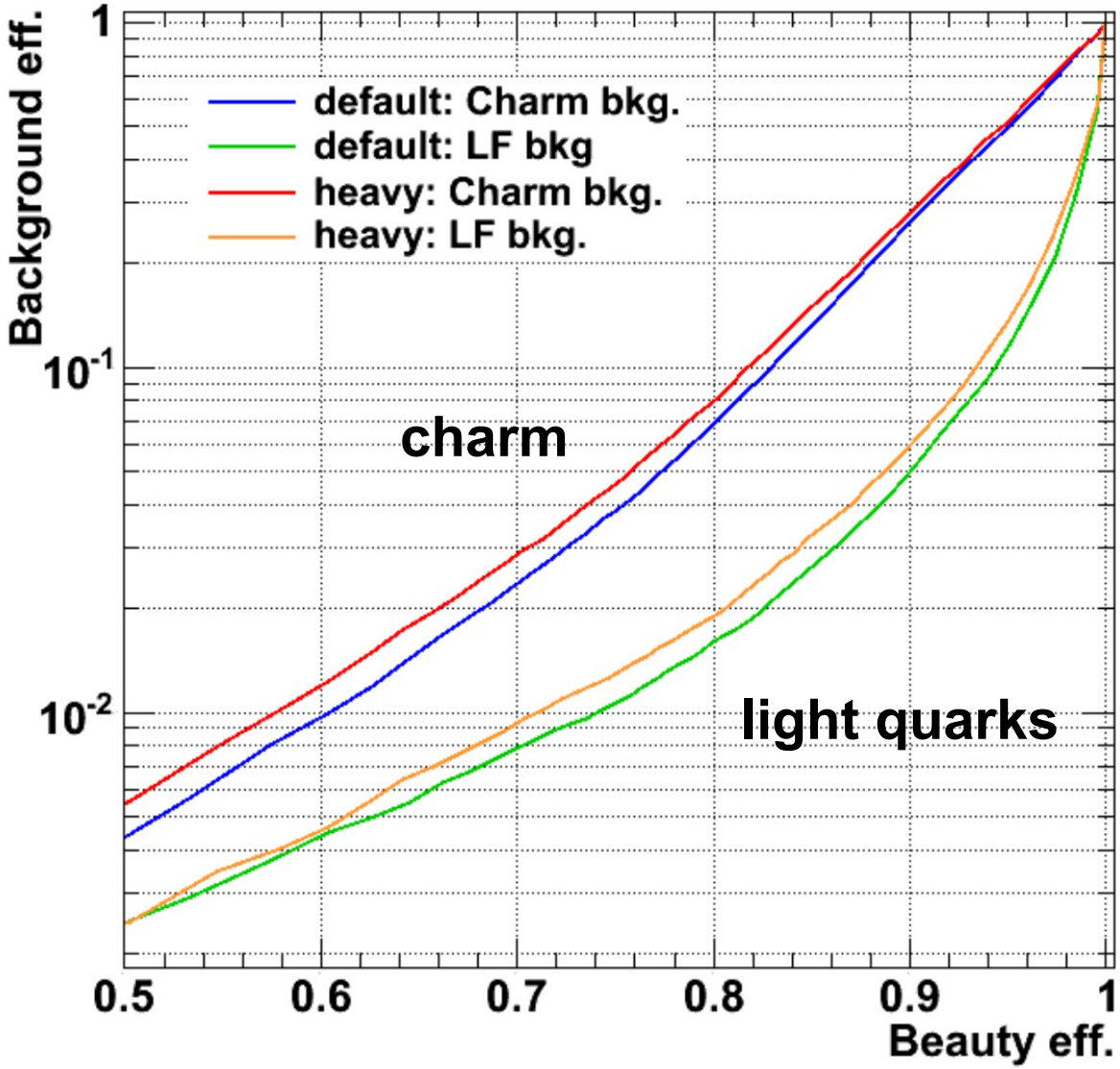
→ With more material the number of secondary vertices in light quark jets increases due to secondary interactions

45000 beauty quark jets of 250 GeV:

	clic_sid_cdr	clic_sid_cdr_heavy
no vertex	6326	6474
one vertex	16200	16393
one vertex + high impact par. track	10438	10195
two vertices	11976	11898

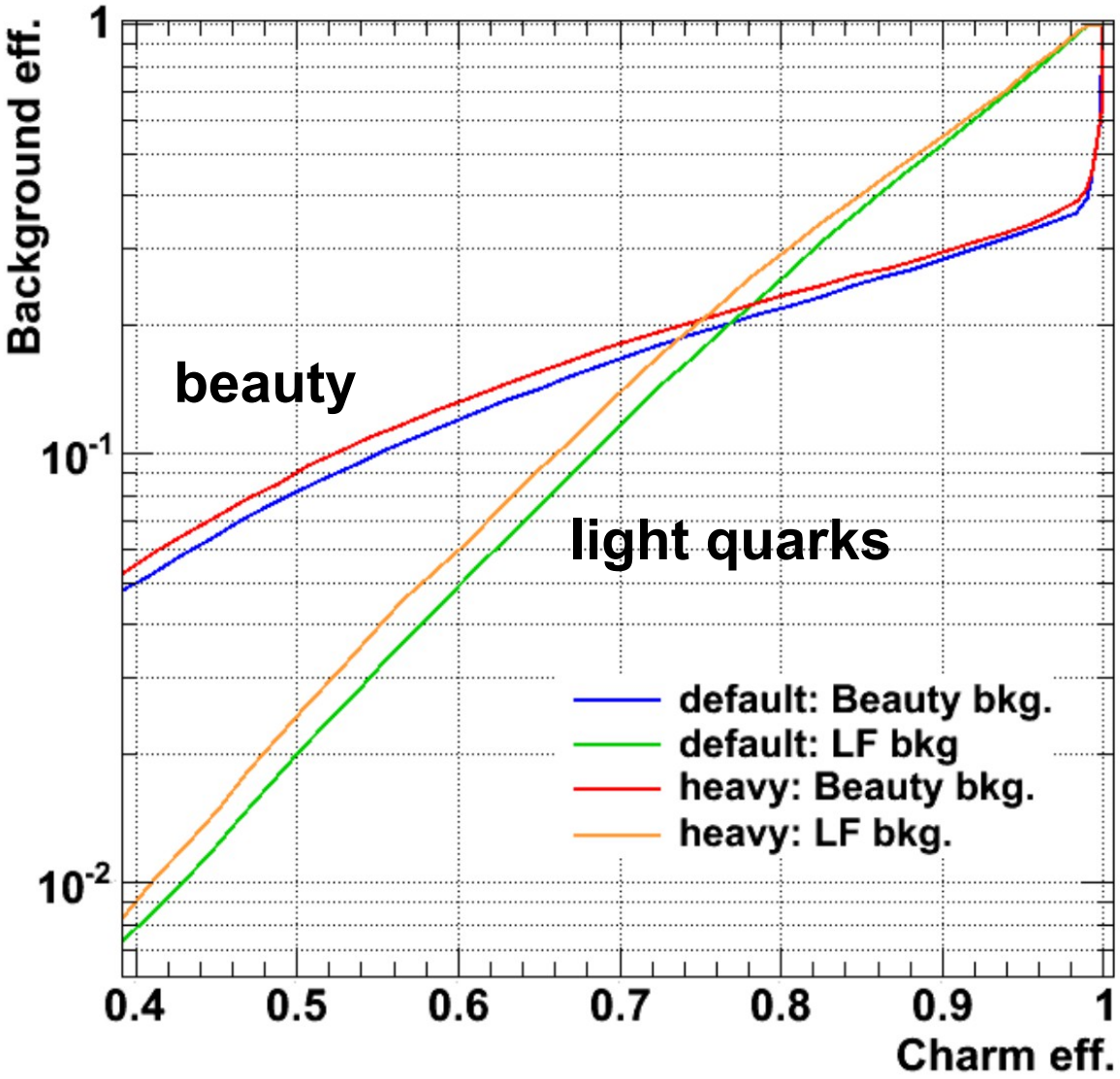
→ The additional material reduces the number of secondary vertices found in b-jets

Comparison of b-tag performance



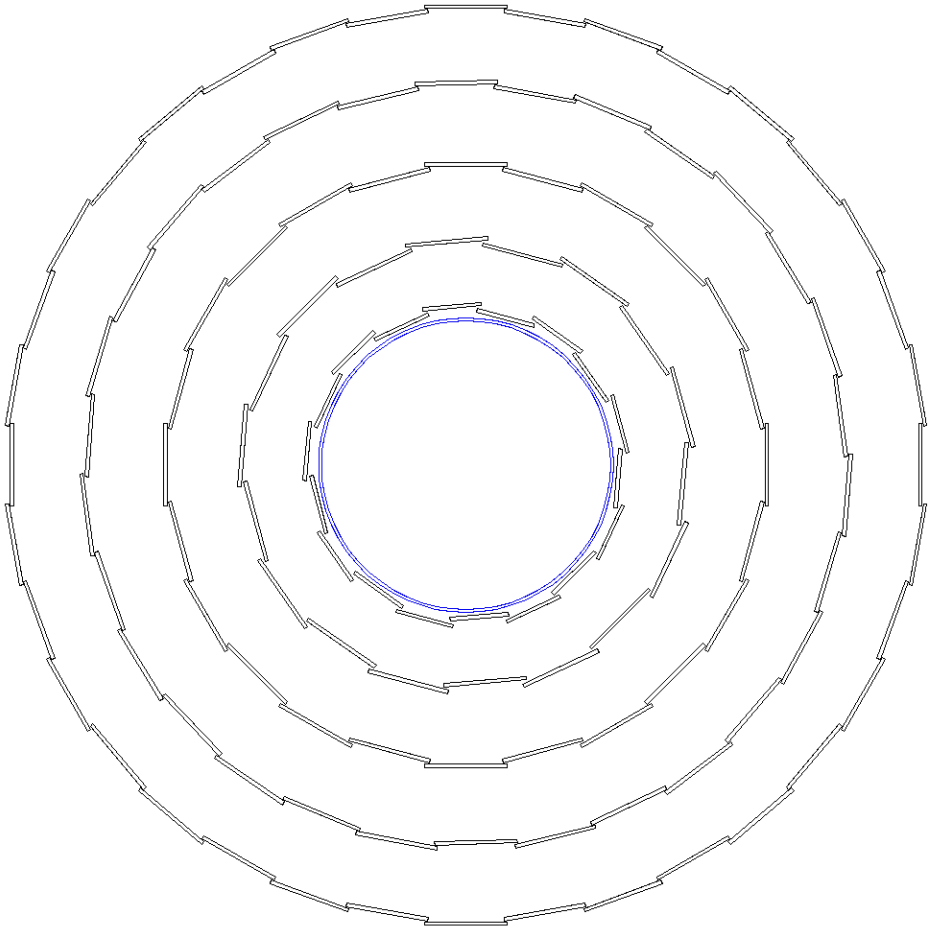
- Typically 10 – 20% higher mis-identification efficiencies for clic_sid_cdr_heavy

Comparison of c-tag performance

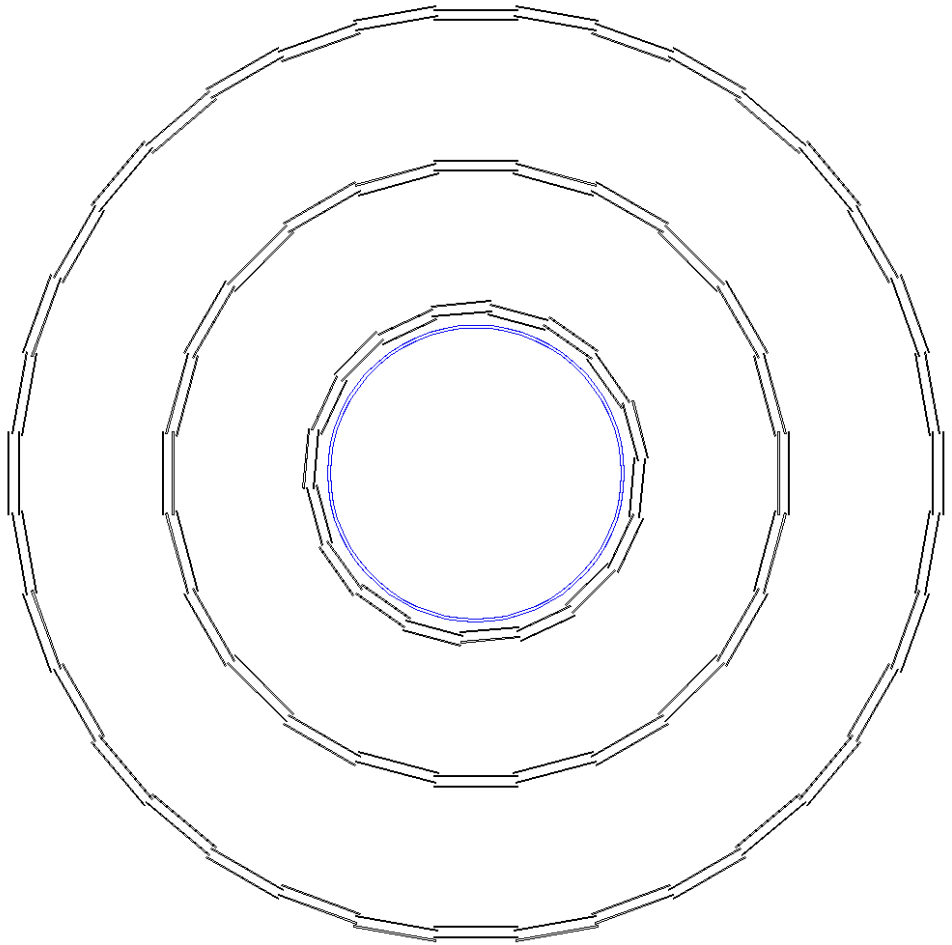


- Typically 10 – 20% higher mis-identification efficiencies for clic_sid_cdr_heavy

Different barrel geometries



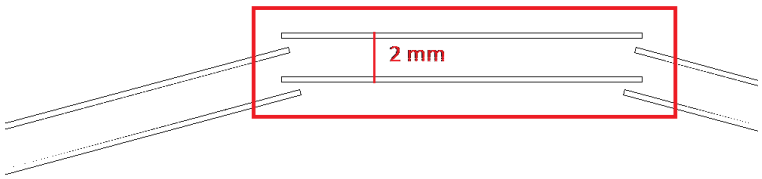
5 single layers
(default, as in CLIC_SiD)



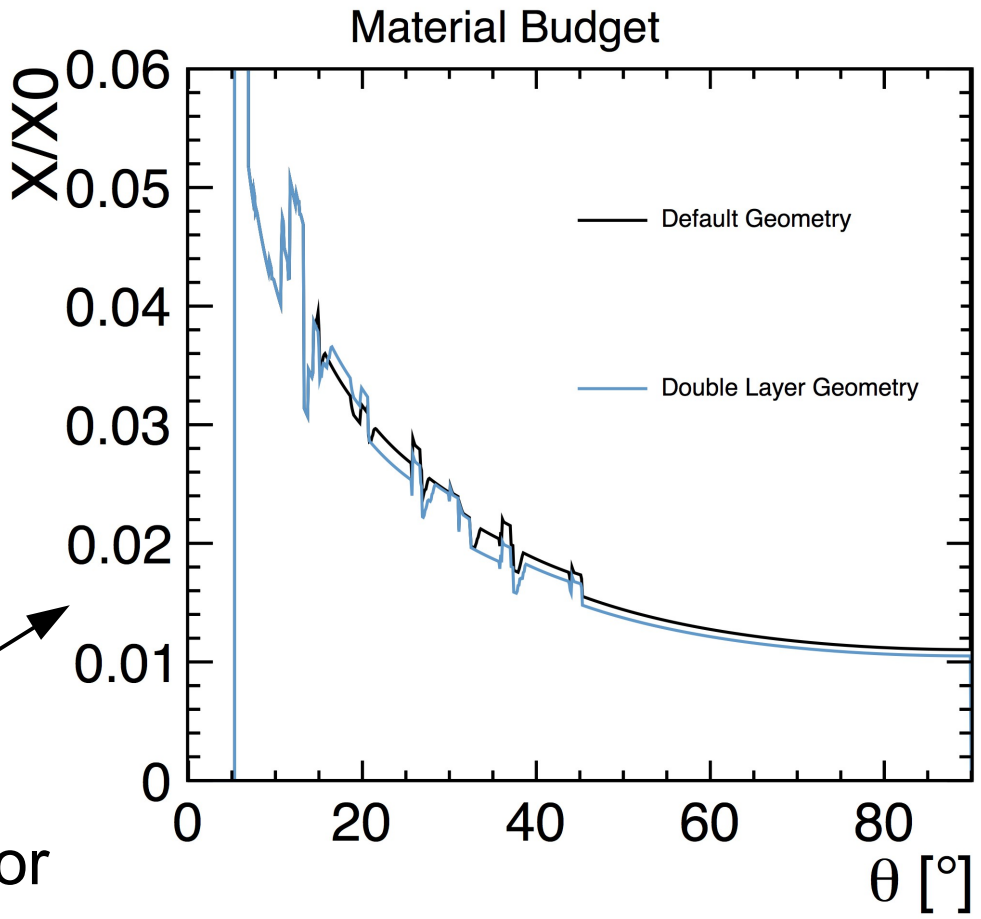
3 double layers
(similar to CLIC_ILD)

More details

Each double layer:
2 x 50 µm Si in 2 mm distance
+ 130 µm C

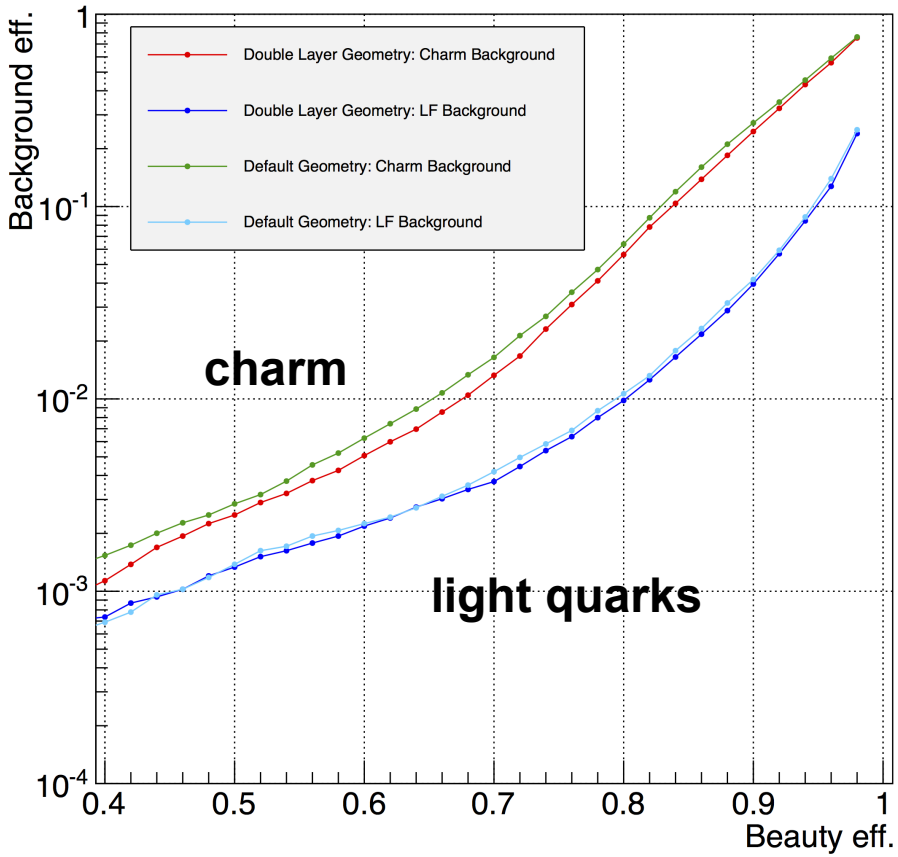


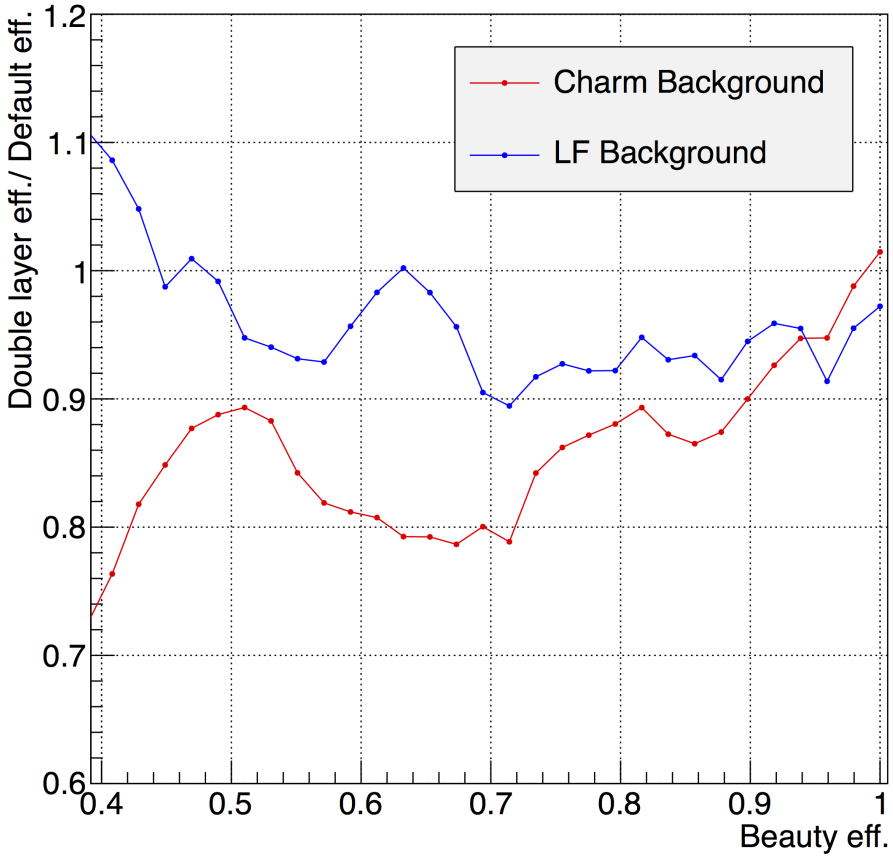
Double layer module



The double layer barrel detector has slightly less material for most polar angles

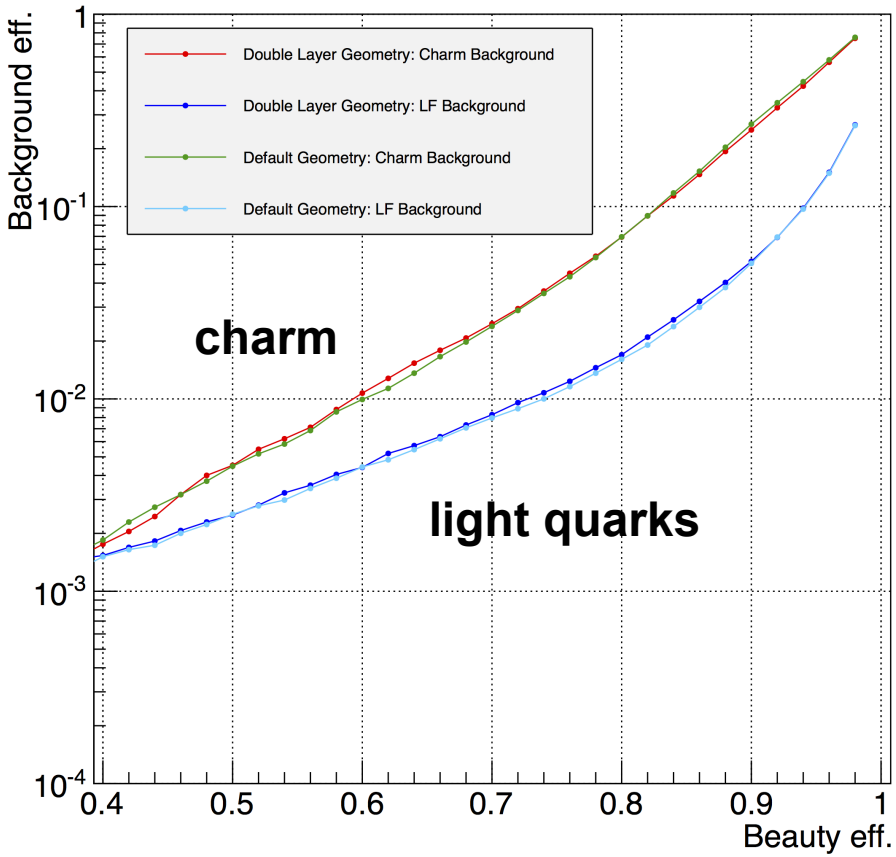
b-tag performance for jets at 100 GeV

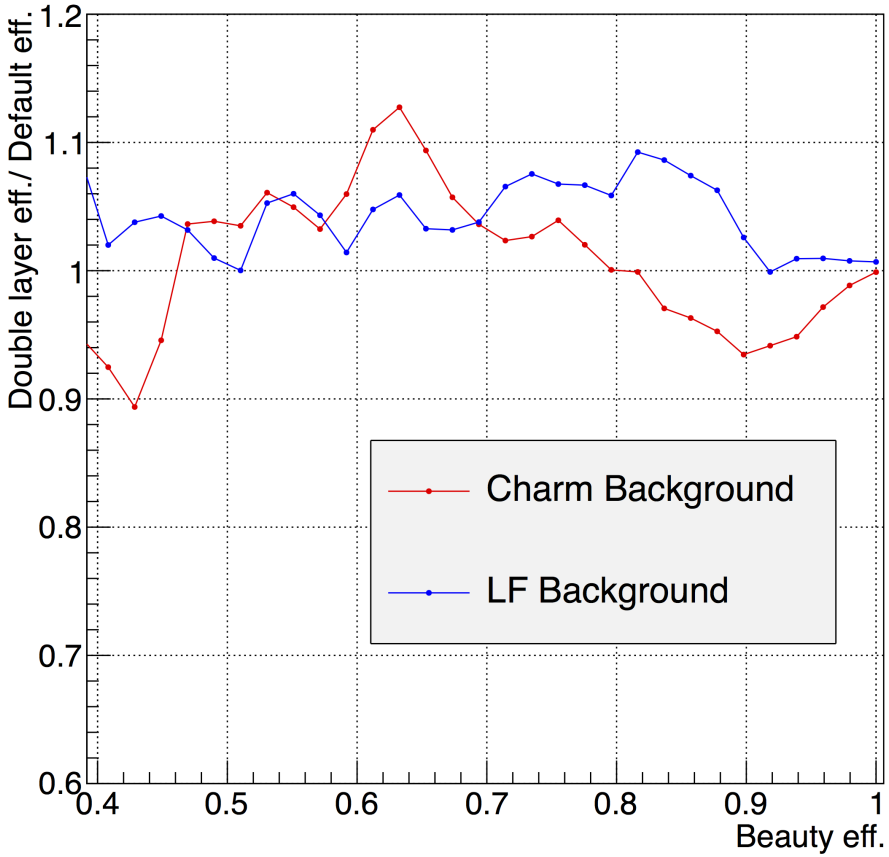




- Double layer geometry shows better charm rejection

b-tag performance for jets at 250 GeV

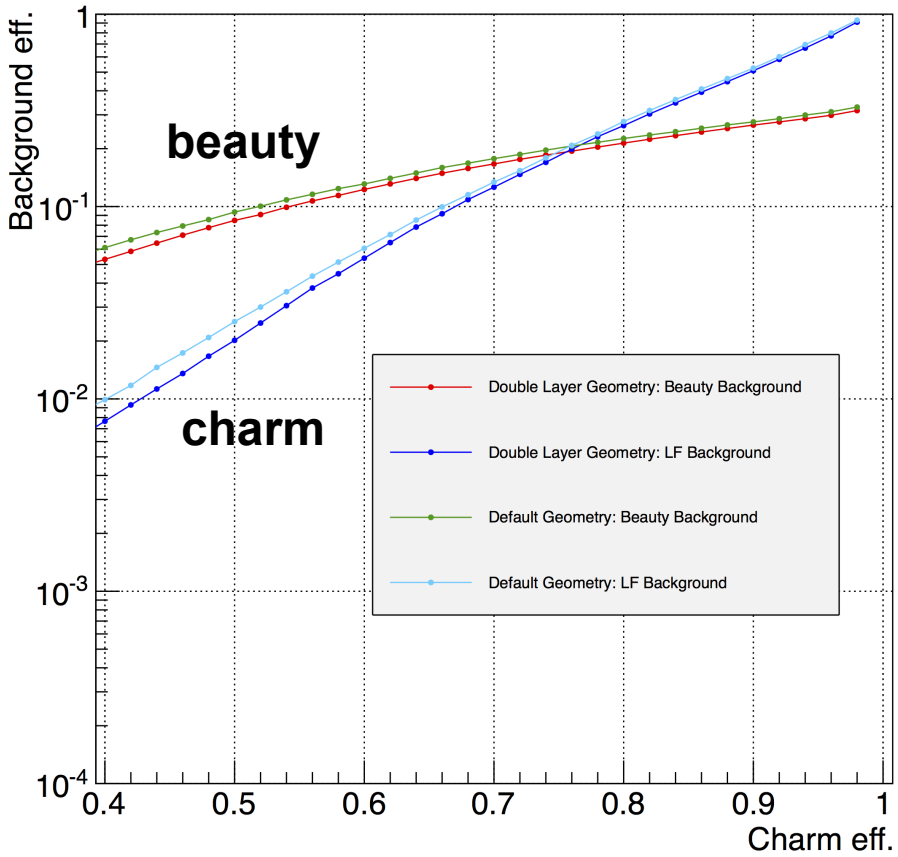


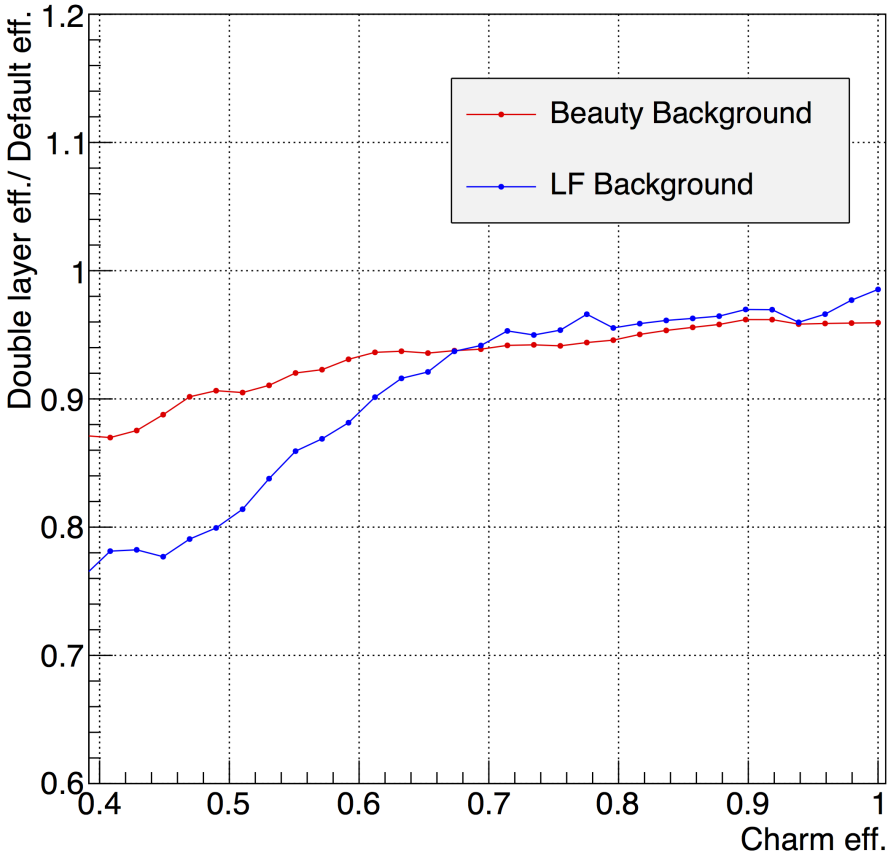


- Similar performance for both geometries

(a significant part of the b-quarks decays after the first layer)

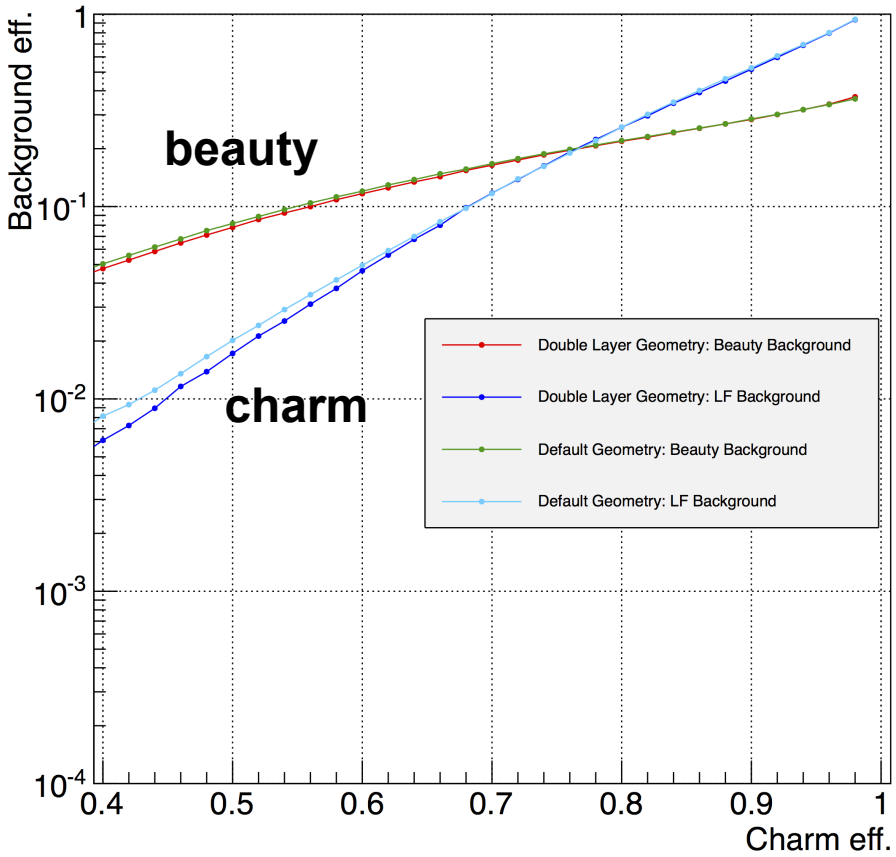
c-tag performance for jets at 100 GeV

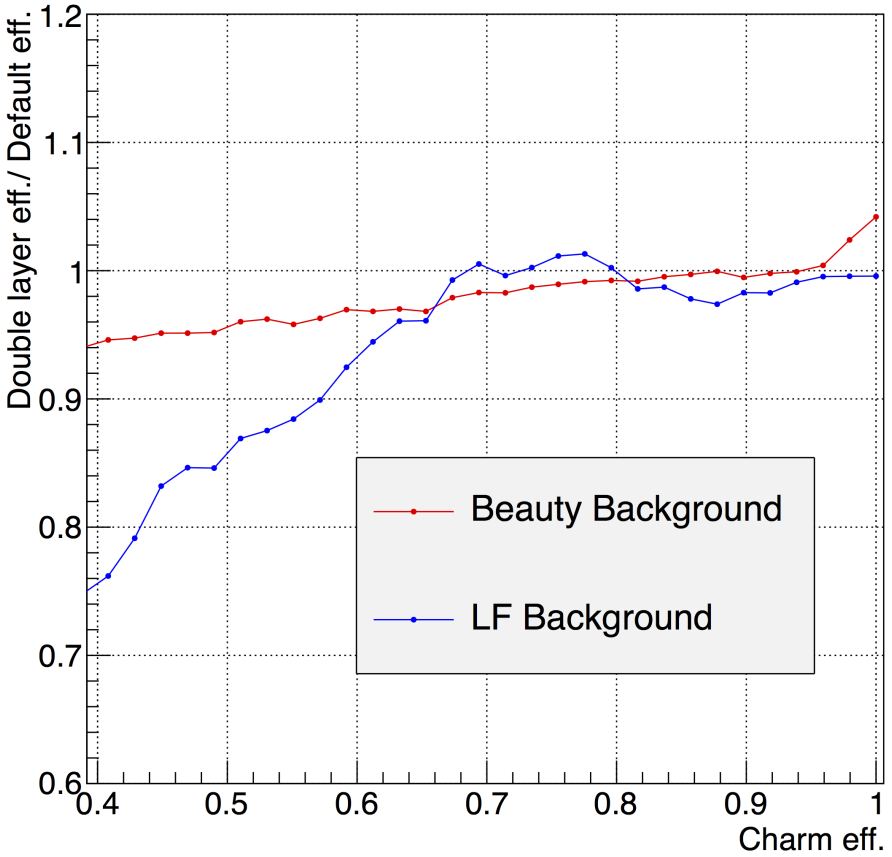




- Double layer geometry shows better beauty and LF rejection

c-tag performance for jets at 250 GeV

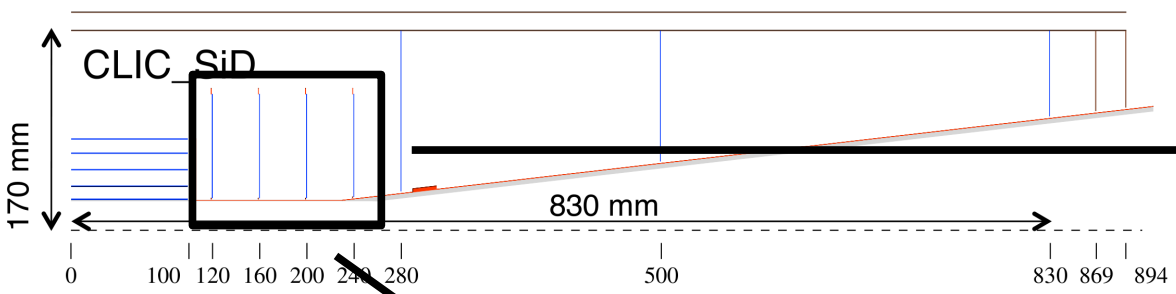


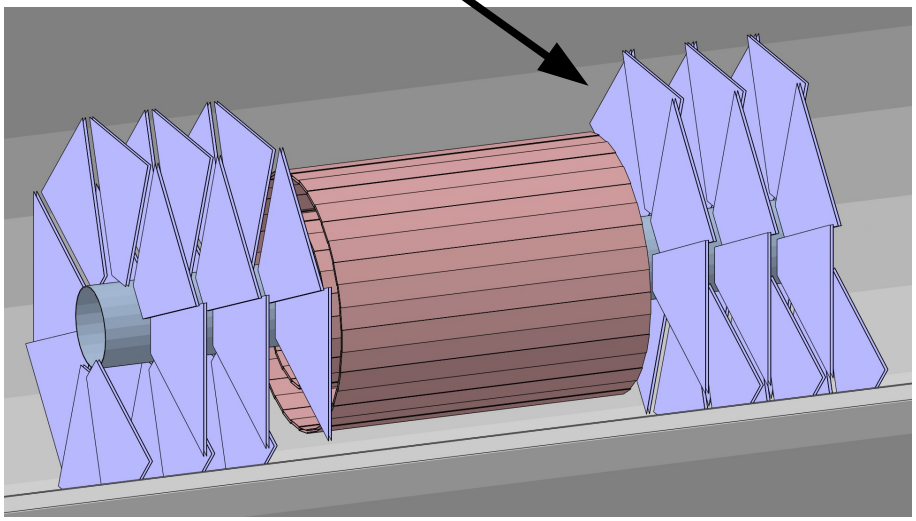


- Double layer geometry shows better LF rejection in the high purity region

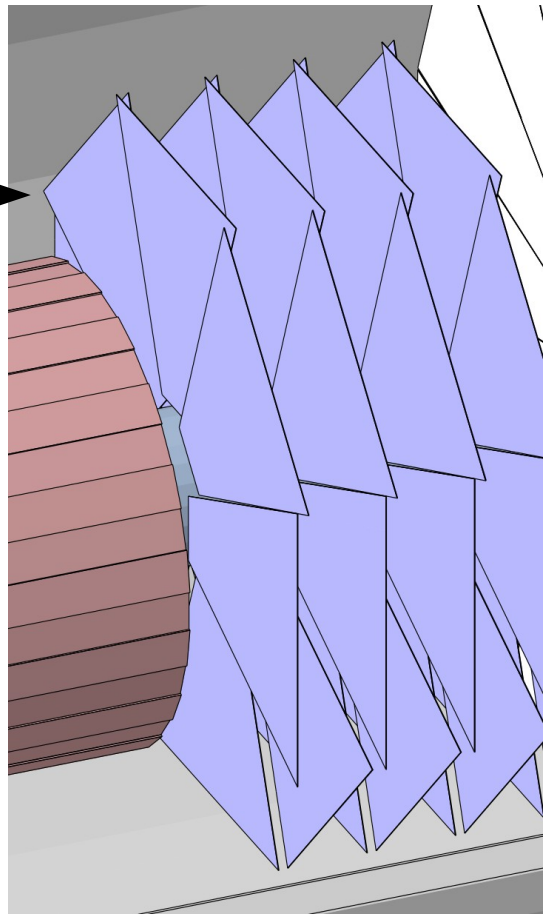
Next steps: alternative forward geometries

Spiral disk geometry is a suitable option for air cooling
(see talk by Fernando Duarte Ramos)





Spiral forward region with
three double layers



Spiral forward region with
four single layers

Summary and outlook

• Investigated the impact of the material budget and of the barrel detector geometry on the flavour tagging performance

• The barrel geometry with double layers has better performance for c-tagging and b-tagging for low-energy jets

• Implemented spiral forward region in the geometry description

• The results are dependent on the jet energy
→ full scan at different jet energies (45 GeV, 100 GeV, 250 GeV and 500 GeV) for θ = 10°, 20°, …, 90° in progress comparing:

- double layer barrel & double layer spiral forward region
- single layer barrel & single layer spiral forward region
- default detector (in the forward only)