ECFA Roadmap – Input Session I – February 19, 2021

Detector R&D requirements for Muon Colliders

Specific long-term detector technology R&D requirements of a muon collider operating at 10 TeV and with a luminosity of the order of 10^{35} cm^{-2} s^{-1}

- *Status of existing and on-going studies at 1.5 and 3 TeV center-of-mass energy*
- *Future steps towards 10 TeV and higher center-of-mass energy to exploit physics reach*

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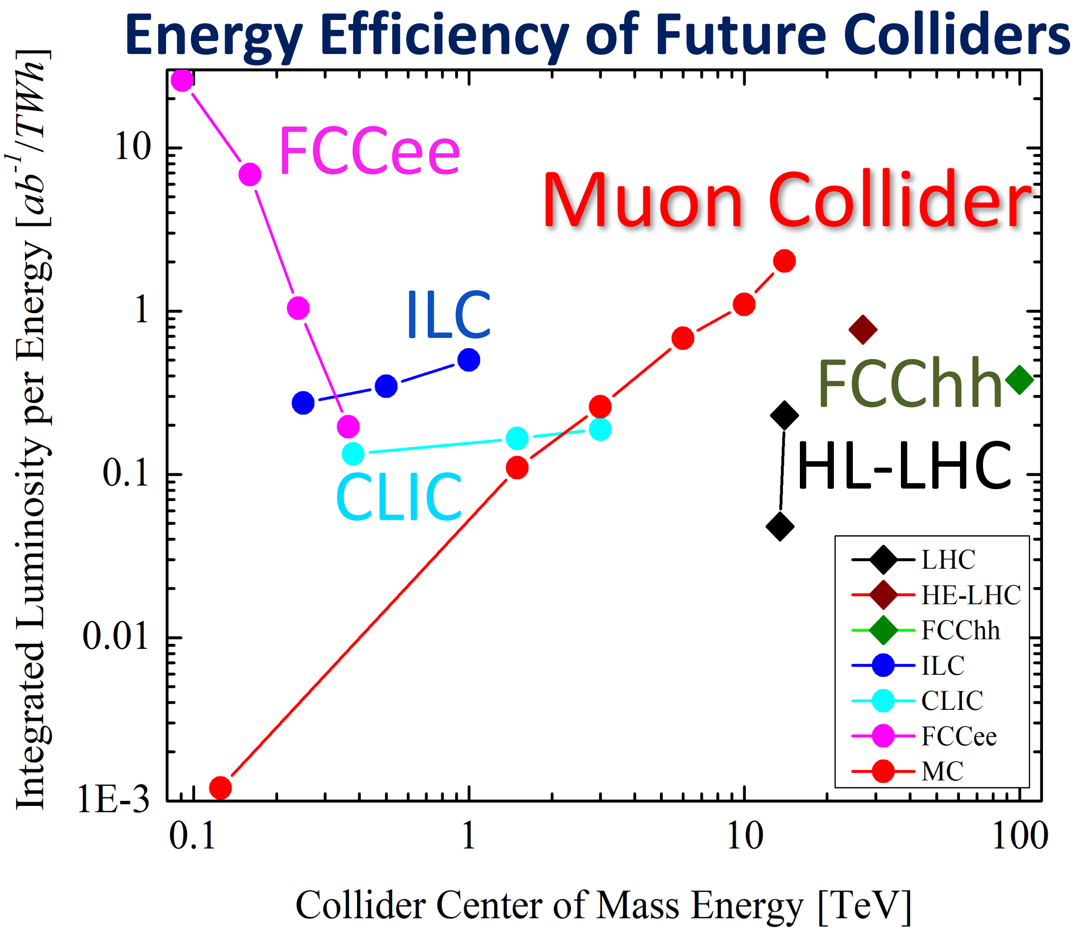
INFN TORINO

on behalf of the

MuonCollider-Detector-Physics Group

https://indico.cern.ch/category/11839/

Why a multi-TeV muon collider?



[Muon colliders to expand frontiers of particle physics]

Following the EU Strategy Update recommendation a collaboration is forming to work on the international design study for a muon collider as it represents a unique opportunity to achieve a multi-TeV energy domain beyond the reach of ee colliders, and potentially within a more compact circular tunnel than for a hadron collider. The biggest challenge remains to produce an intense beam of cooled muons, but novel ideas are being explored.

Overwhelming physics potential:
- **Precision measures**
- **Discovery searches**

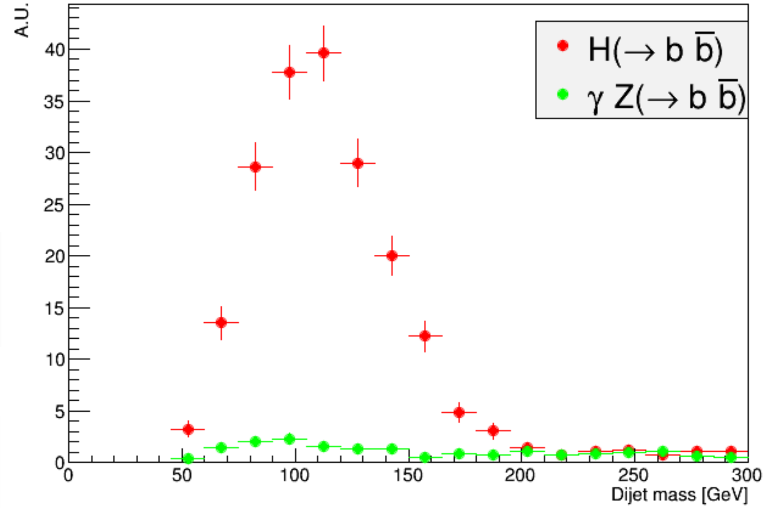
Challenging Machine Design:
- **Key issues/risks**
- **R&D plan - synergies**

H→bb @ 1.5 TeV

JINST 15 (2020) 05, P05001

D. Lucchesi et al.

$\mu^+\mu^- \rightarrow H\nu\bar{\nu} \rightarrow b\bar{b}\nu\bar{\nu}$ + beam-induced background fully simulated



Higgs $b\bar{b}$ Couplings Results

- The instantaneous luminosity, $\mathcal{L}$, at different √s is taken from MAP.
- The acceptance, A, the number of signal events, N, and background, B, are determined with simulation.

$\sqrt{s}$ [TeV]	A [%]	ϵ [%]	$\mathcal{L}$ [cm^{-2}s^{-1}]	$\mathcal{L}_{int}$ [ab^{-1}]	σ [fb]	N	B	$\frac{\Delta\sigma}{\sigma}$ [%]	$\frac{\Delta g_{Hbb}}{g_{Hbb}}$ [%]
1.5	35	15	$1.25 \cdot 10^{34}$	0.5	203	5500	6700	2.0	1.9
3.0	37	15	$4.4 \cdot 10^{34}$	1.3	324	33000	7700	0.60	1.0
10	39	16	$2 \cdot 10^{35}$	8.0	549	270000	4400	0.20	0.91

	$\sqrt{s}$ [TeV]	$\mathcal{L}_{int}$ [ab^{-1}]	$\frac{\Delta g_{Hbb}}{g_{Hbb}}$ [%]
Muon Collider	1.5	0.5	1.9
	3.0	1.3	1.0
	10	8.0	0.91
CLIC	0.35	0.5	3.0
	1.4	+1.5	1.0
	3.0	+2.0	0.9

CLIC numbers are obtained with a model-independent multi-parameter fit performed in three stages, taking into account data obtained at the three different energies.

Results published on JINTST as Detector and Physics Performance at a Muon Collider

Motivation: Higgs potential

M. Chiesa et al. arXiv:2003.13628 [hep-ph]

determine the Higgs potential by measuring trilinear and quadrilinear self coupling

$$V = \frac{1}{2} m_h^2 h^2 + (1 + k_3)\lambda_{hhh}^{SM} v h^3 + (1 + k_4)\lambda_{hhhh}^{SM} h^4$$

Trilinear coupling k_3

$\sqrt{s}$=10 TeV $\mathcal{L} \sim 2 \cdot 10^{35} cm^{-2} s^{-1}$

20 ab^{-1} ➔ $k_3$sensitivity ~ 3%

Best sensitivity ~ 5% FCC combined
arXiv:1905.03764 **[hep-ph]**

Quadrilinear coupling k_4

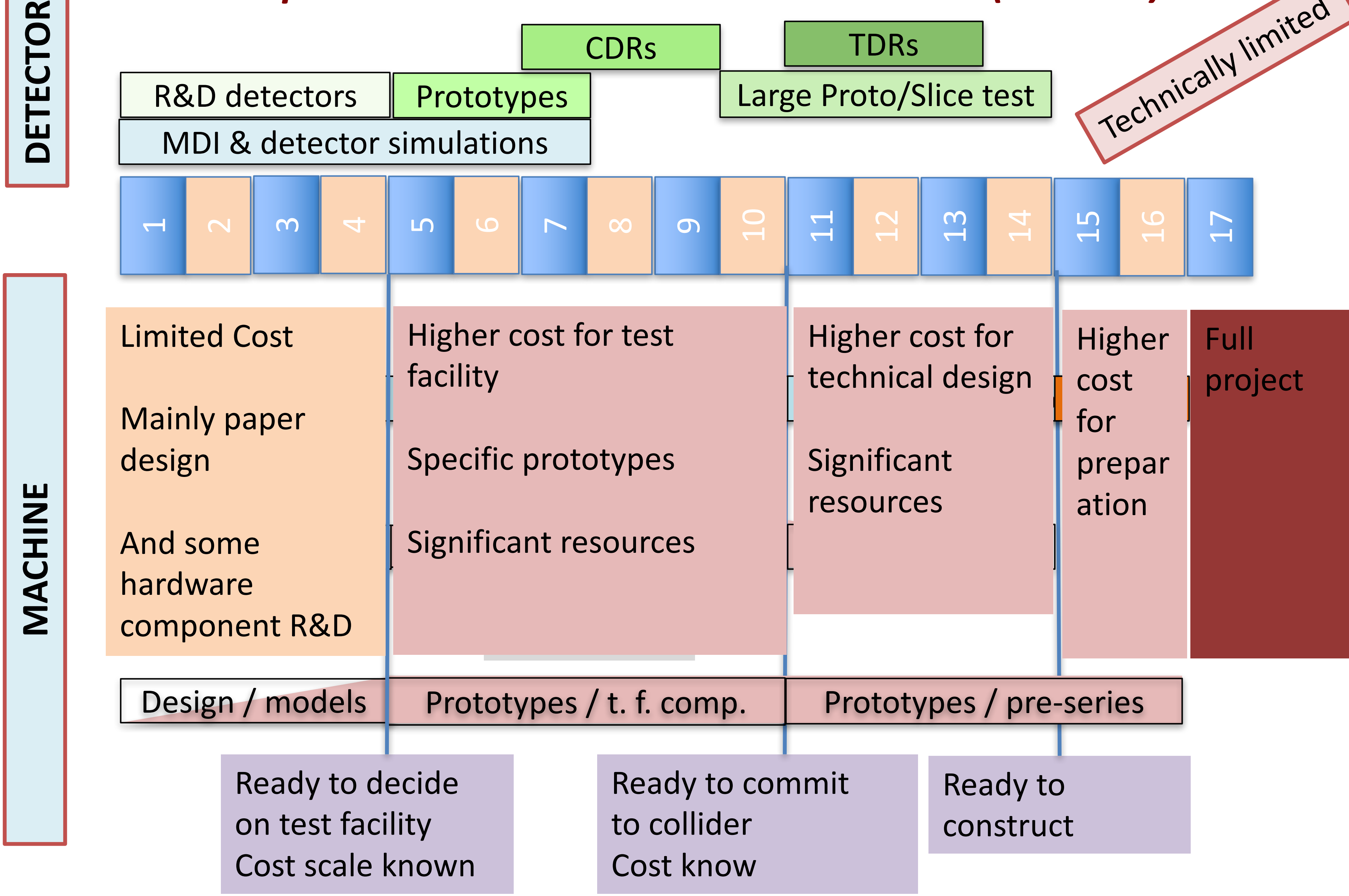
$\sqrt{s}$=14 TeV $\mathcal{L} \sim 3 \cdot 10^{35} cm^{-2} s^{-1}$

~30 ab^{-1} ➔ $k_4$sensitivity few 10%

significantly better than what is currently expected to be attainable at the FCC-hh with a similar luminosity
arXiv:1905.03764 **[hep-ph]**

This just looking at the Higgs sector!
Top and new physics sectors also to be scrutinized

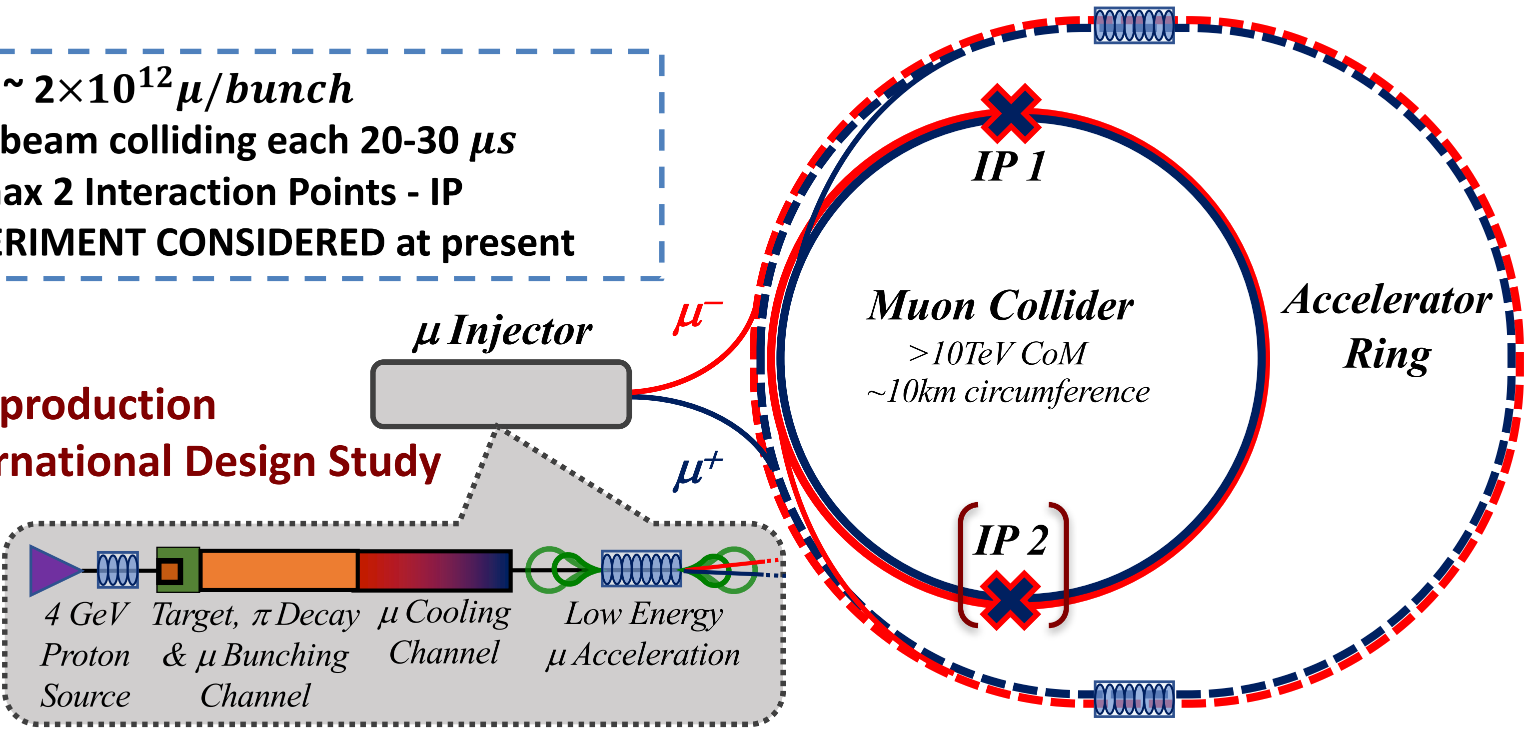
Proposed Tentative Timeline (2020)



Sketch of the facility – working points

~ $2\times10^{12}\mu/bunch$
1 bunch/beam colliding each 20-30 μs
➔ max 2 Interaction Points - IP
ONLY 1 EXPERIMENT CONSIDERED at present

Proton driver μ production
Baseline @ International Design Study



Hp: $\mathcal{L} = 2\times10^{35} cm^{-2}s^{-1}$ @ 10 TeV

$\int \mathcal{L}dt =$ $(E_{CM}/10TeV)^2 \times 10\ ab^{-1}$

@ 3 TeV ~ 1 ab^{-1} 5 years

@ 10 TeV ~ 10 ab^{-1} 5 years

@ 14 TeV ~ 20 ab^{-1} 5 years

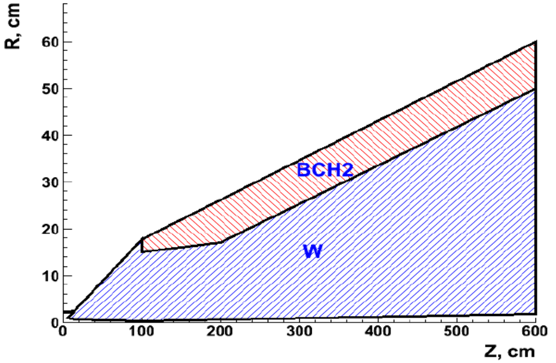
Parameter	Unit	3 TeV	10 TeV	14 TeV
C	km	4.5	10	14
σ_E / E	%	0.1	0.1	0.1
σ_z	mm	5	1.5	1.1
β	mm	5	1.5	1.1
ε	µm	25	25	25
$\sigma_{x,y}$	µm	3.0	0.9	0.6

Beam Induced Backgroud

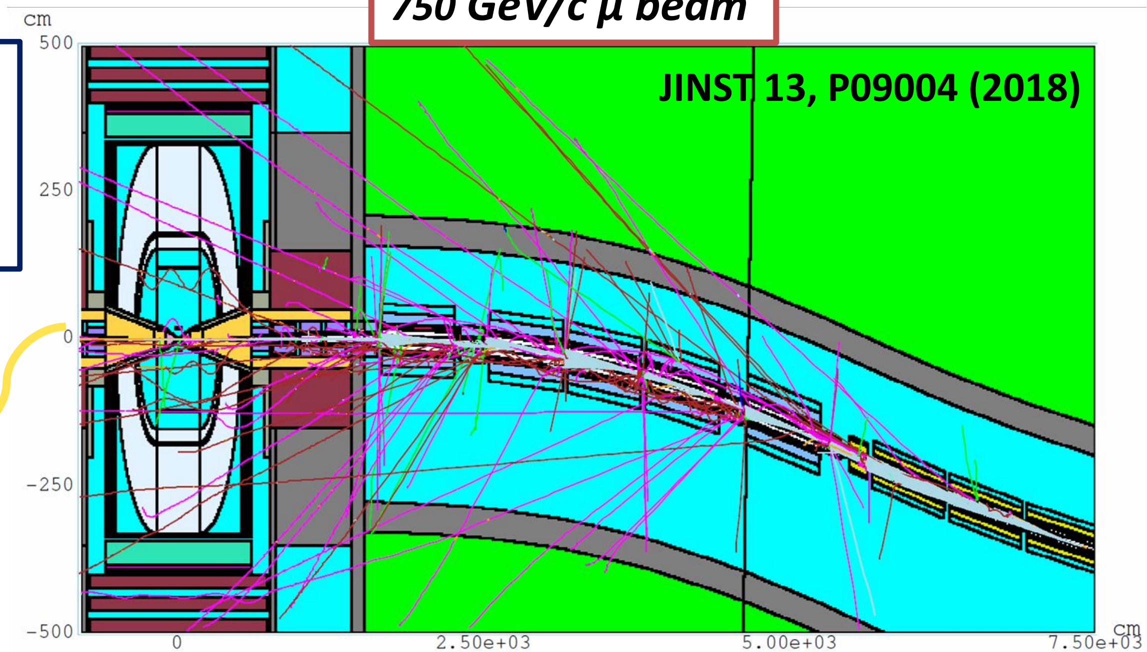
For each collider energy the machine elements, the Machine Detector Interface (MDI) and Interaction Region (IR) have to be properly designed and optimized

BIB characteristics strongly effect detectors design, → BIB has to be studied in details

Two $\sim 10^0$ shielding tungsten nozzles, cladded with a 5-cm layer of borated polyethylene, play a crucial role in background mitigation inside the detector.



750 GeV/c μ beam



MAP developed realistic simulation of beam-induced backgrounds in the detector:

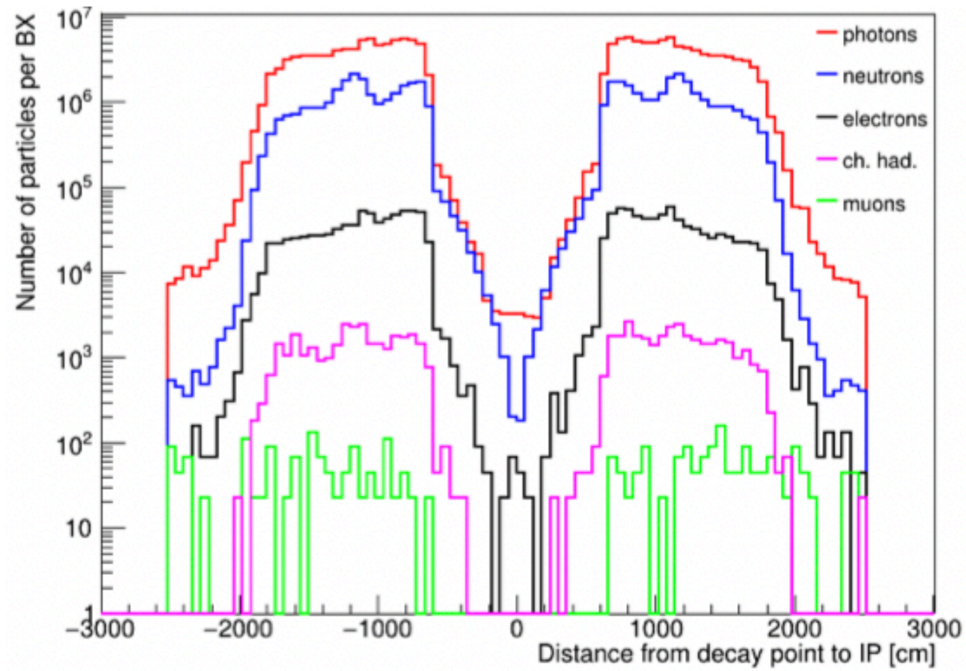
- model of the tunnel ±200 m from the interaction point, with realistic geometry, materials distribution, machine lattice elements and magnetic fields, the experimental hall and the machine-detector interface (MDI)
- secondary and tertiary particles from muon decay are simulated with MARS15 then transported to the detector borders

Beam Induced background @ 1.5 TeV

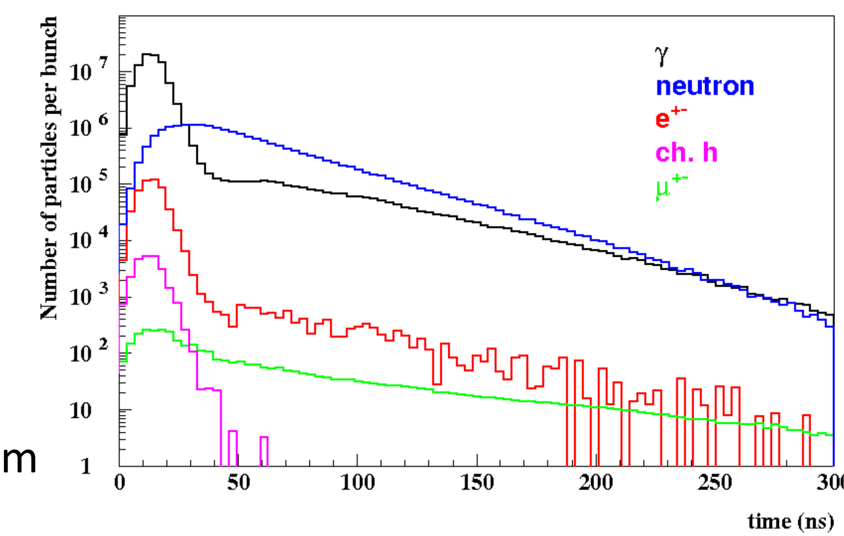
***JINST* 15 (2020) 05, P05001**

Beam muons decay products interact with machine elements and cause a continuous flux of secondary and tertiary particles (mainly γ, n, e$^{\pm}$, h$^{\pm}$) that eventually reach the detector

The amount and characteristics of the beam-induced background (BIB) depend on the collider energy and the machine optics and lattice elements



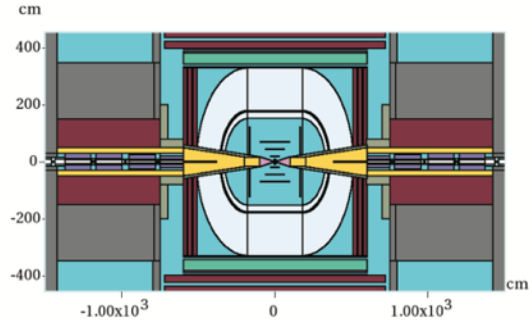
muon beams
@ **0.75 TeV** with **2×10^{12}muons/bunch ➔**
4×10^{5} muon decays/m single bunch crossing

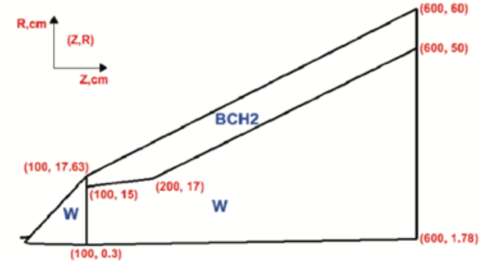


Secondary and tertiary particles have low momentum and different arrival time in the Interaction Point

On-going MDI - BIB studies

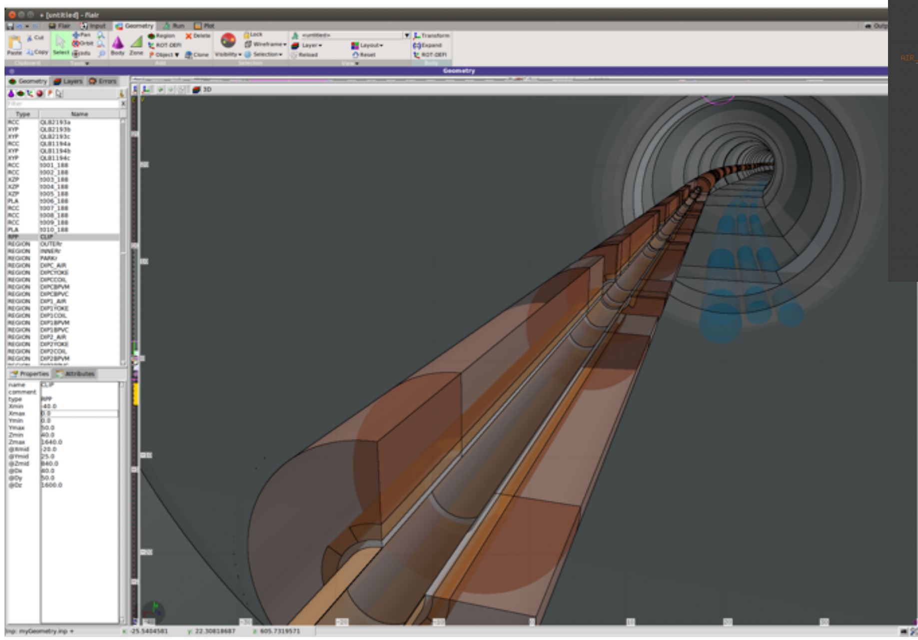
A new flexible FLUKA tool from machine optics to simulation is now available to generate BIB distributions at different $\sqrt{s}$

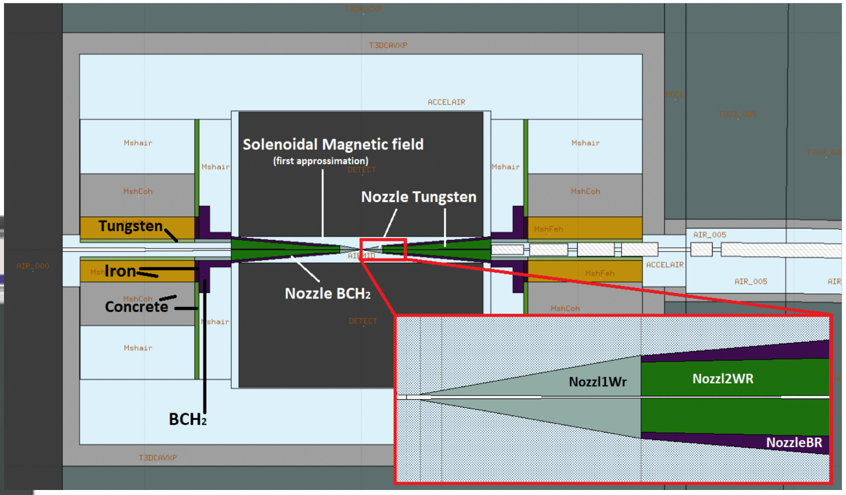




Existing MAP machine lattice @ 1.5 TeV and 3 TeV….. 6 TeV under evaluation

FLUKA LineBuilder:
read machine lattice
and produce elements





Good agreement of results obtained by LineBuilder+FLUKA and MAP results from MARS15

BIB characteristics at $\sqrt{s} = 1.5$ TeV, 125 GeV

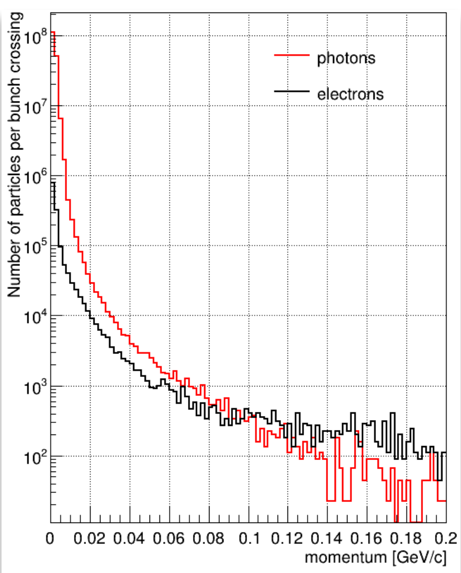
beam energy [GeV]	62.5	750
μ decay length [m]	3.9×10^5	4.7×10^6
μ decays/m per beam	5.1×10^6	4.3×10^5
photons ($E^{kin}_{\mathrm{ph.}} > 0.2$ MeV)	3.4×10^8	1.6×10^8
neutrons ($E^{kin}_{\mathrm{n}} > 0.1$ MeV)	4.6×10^7	4.8×10^7
electrons ($E^{kin}_{\mathrm{el.}} > 0.2$ MeV)	2.6×10^6	1.5×10^6
charged hadrons ($E^{kin}_{\mathrm{ch.had.}} > 1$ MeV)	2.2×10^4	6.2×10^4
muons ($E^{kin}_{\mathrm{mu.}} > 1$ MeV)	2.5×10^3	2.7×10^3

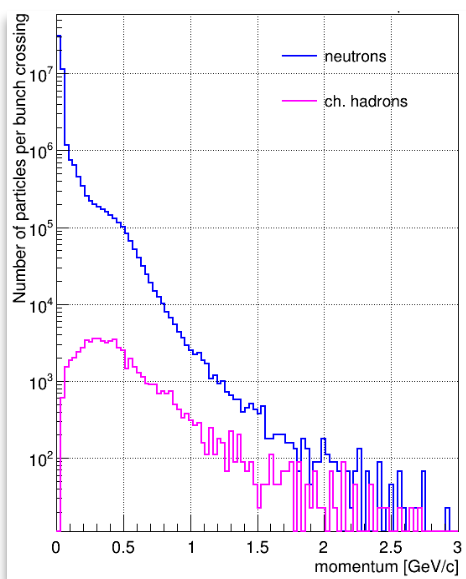
arXiv:1905.03725

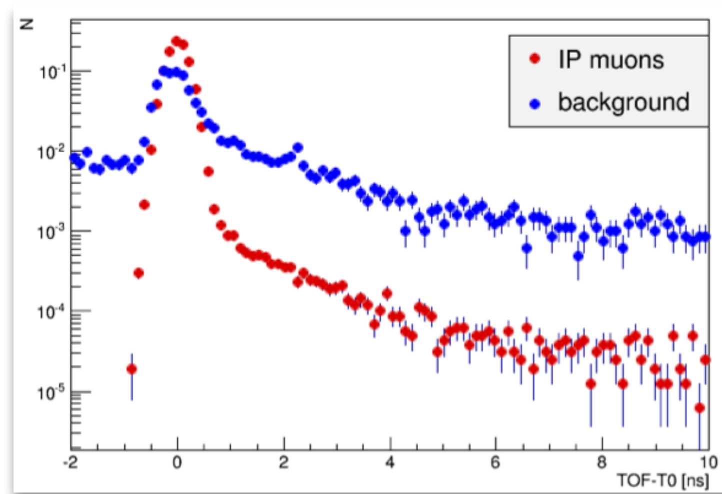
➔ *Need distributions @ 3 TeV under developing*

➔ *Missing lattice @ 10 TeV*

Time information important to mitigate BIB effects at $\sqrt{s}$=1.5 TeV

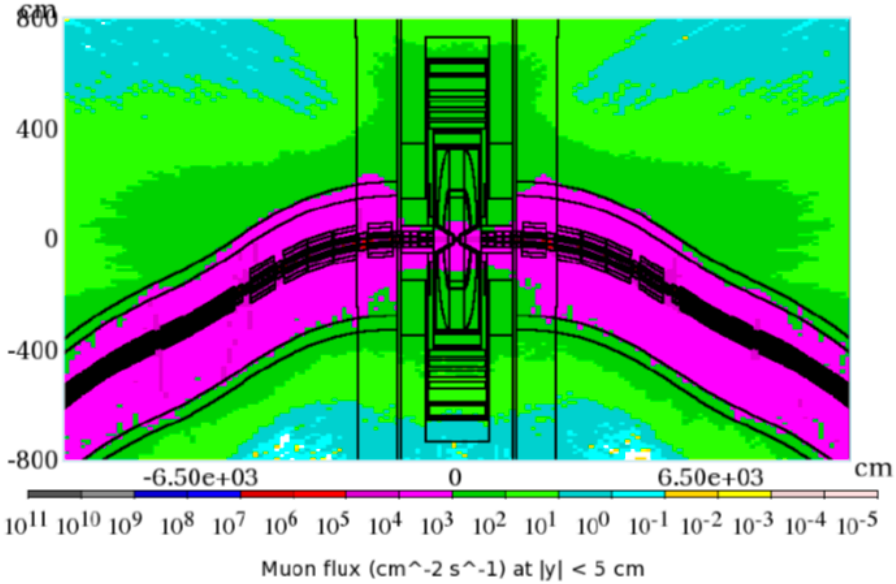


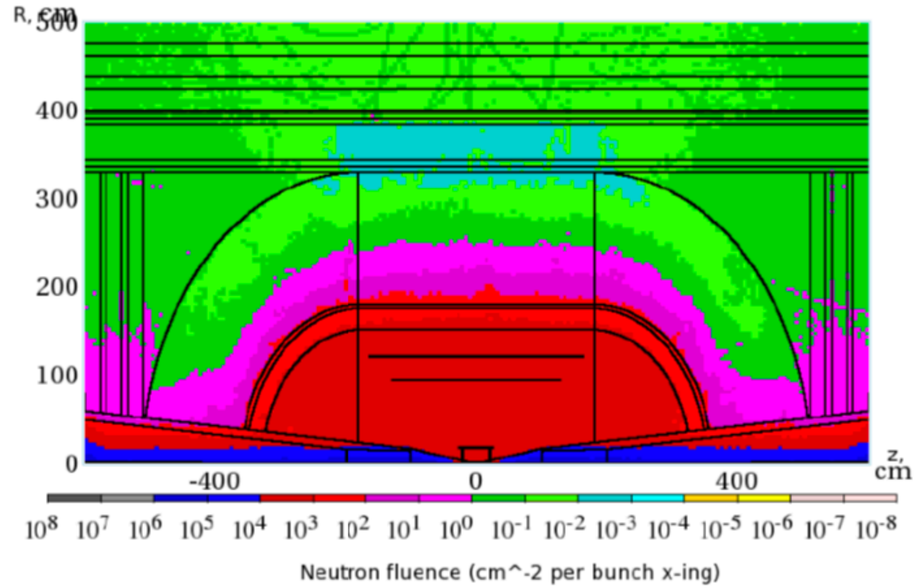




Secondary and tertiary particles have low momentum

Muon and neutron fluences @ 1.5 TeV

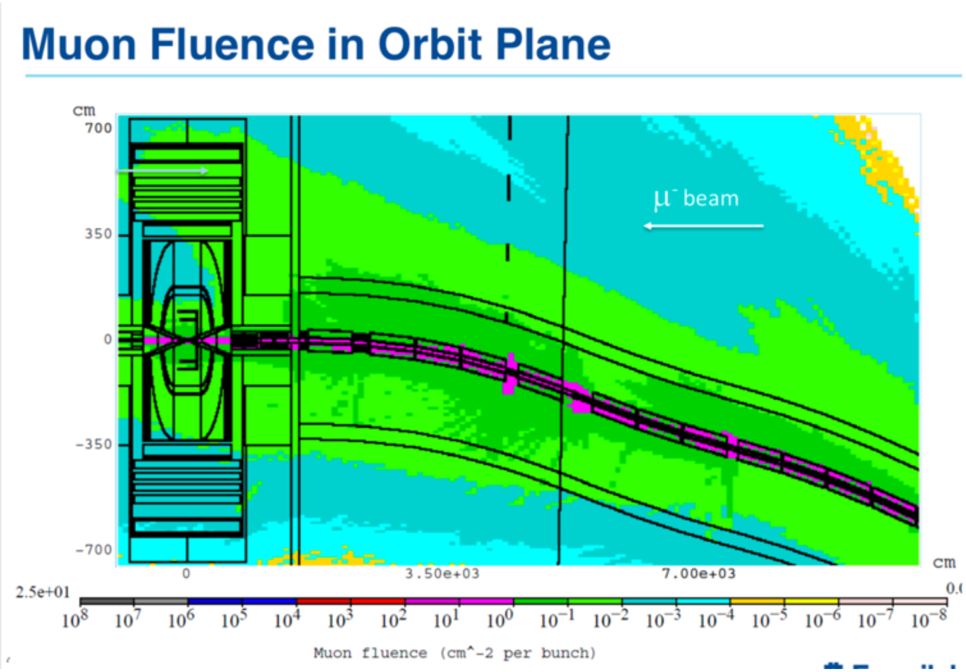




Muon flux map in IR.
Muons – with energy of tens and hundreds GeV – illuminate the whole detector. They are produced as Bethe-Heitler pairs by energetic photons in EMS originated by decay electrons in lattice components.

Neutron fluence map inside the detector.
Maximum neutron fluence and absorbed dose in the innermost layer of the Si tracker for a one-year operation are at a 10% level of that in the LHC detectors at the nominal luminosity. High fluences of photons and electrons in the tracker and calorimeter exceed those at LHC, and need more work to suppress them.

Muon and neutron fluences @ 1.5 TeV



- Expected fluence < HL-LHC
- HL-LHC < Expected dose < FCC-hh
- Still expecting radiation hardness to play a significant role, but unlikely to be a major problem
- Leaves more flexibility in adapting detector design to such requirements

- Environment somewhat different than LHC
- Dominated by neutrons and photons
- Weak radial dependence

BIB @ 10 TeV

- At the moment only general consideration
- It’s not expected to dramatically change compared to lower energies
- BIB timing distributions to be verified

General requirements for the detector

- ✓ Track efficiency and momentum resolution – for feasibility and precision of many physics studies e.g. final states with leptons
- ✓ Good ECAL energy and position resolution for e/gamma reconstruction
- ✓ Good jet energy resolution
- ✓ Efficient identification of a secondary vertex for heavy quark tagging
- ✓ Other considerations (Missing Energy/MET, taus, substructure)

- ✓ Many ILC or CLIC considerations apply to Muon Collider detectors, although beam background conditions are different and much more challenging requiring a dedicated design for Muon Collider experiment: vertex/tracking – calorimetry – triggerless DAQ
- ✓ Detector design considerations should be driven by physics requirements and BIB considerations
- ✓ **Optimal design will very likely be different for different collision energies**

Key considerations

- ✓ **Most tracker hits and calorimeter clusters produced in the detector originate from BIB**
- ✓ Example: inner layers of the vertex tracker detector have occupancy ~x10 larger than CMS pixels in HL-LHC
  - Requires **large bandwidth for sending data off the detector**
  - High complexity of data reconstruction
- ✓ Applying filtering at various stages of data processing (both on and off the detector) is important
- ✓ Explore characteristics of the BIB that are different from the hard scatter:
  - Position, Time, Energy, Particle ID, Correlations of the above
- ✓ Higher bandwidth requires power, filtering on detector requires power

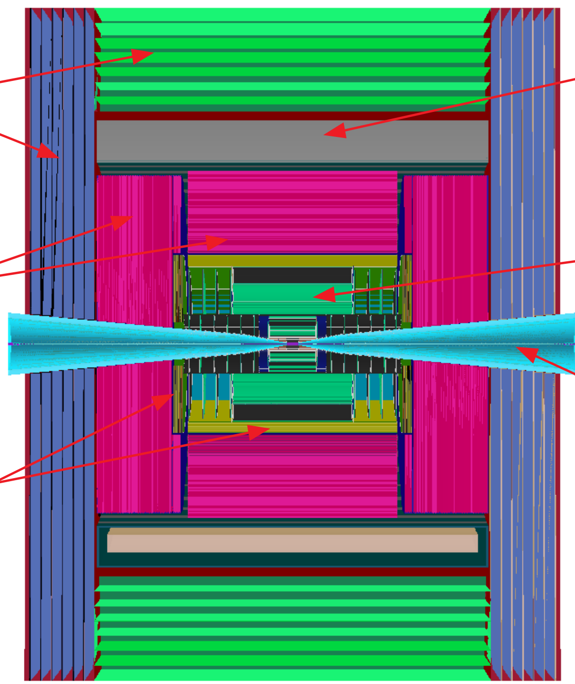
- ✓ Considering large bunch crossing intervals at the muon collider (~10-20 us), it is probably best to consider a triggerless DAQ system
- ✓ **Bunch crossing time is ~20-30 ps, defines natural time resolution**

Detector @ $\sqrt{s}$ = 1.5 TeV – full simulation

- CLIC Detector technologies adopted with important tracker modifications to cope with BIB
- Detector design optimization at $\sqrt{s}$=1.5 (3) TeV one of the primary goals

available on github

B = 3.57 T to be studied and tuned



Vertex Detector (VXD)
- 4 double-sensor barrel layers 25x25μm^2
- 4+4 double-sensor disks 25x25μm^2

Inner Tracker (IT)
- 3 barrel layers 50x50μm^2
- 7+7 disks ”

Outer Tracker(OT)
- 3 barrel layers 50x50μm^2
- 4+4 disks ”

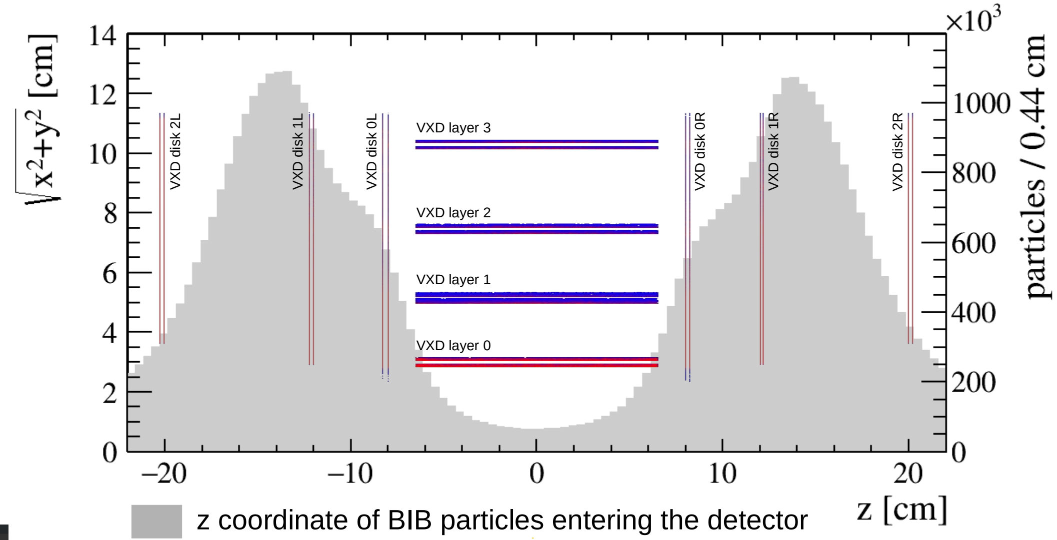
Electromagnetic Calorimeter (ECAL)
- 40 layers W absorber and silicon pad sensors, 5x5 mm^2

Hadron Calorimeter (HCAL)
- 60 layers steel absorber & plastic scintillating tiles, 30x30 mm^2

Different stages of design depending on CoM energy

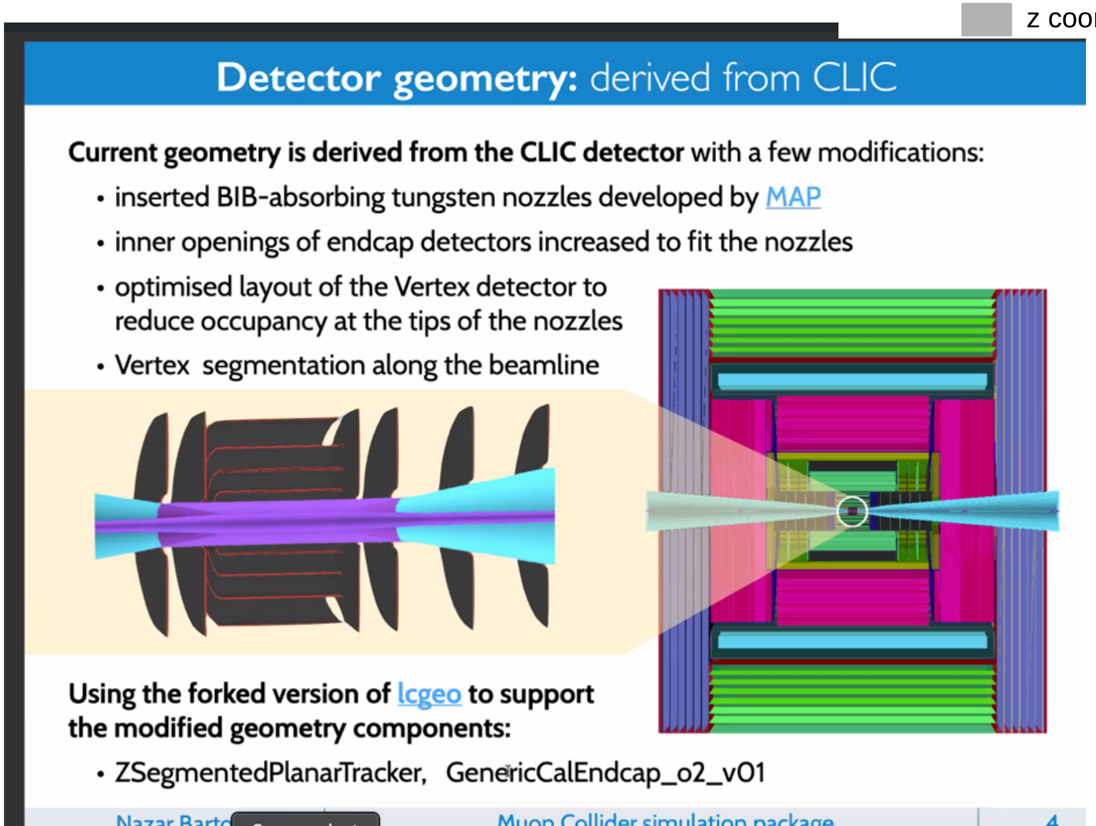
Quite advanced conceptual design for Higgs factory, 1.5 TeV and 3 TeV

Experiment design to be improved



Impact of BIB on tracking system could be severe if not mitigated:

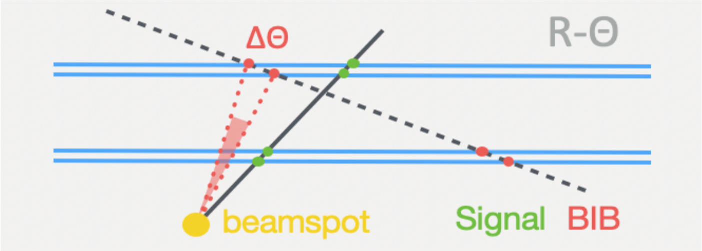
- vertex detector barrel designed in such a way not to overlap with the BIB hottest spots around the interaction region

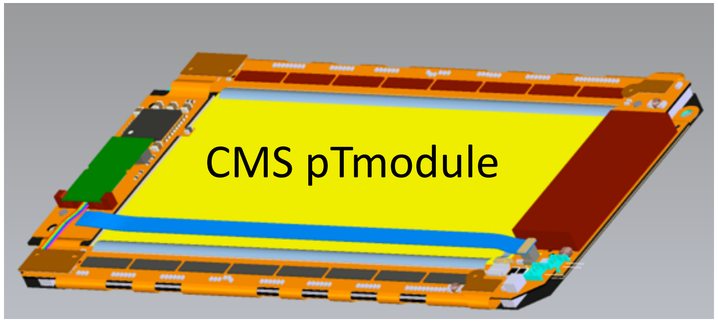


Key findings for background discrimination:

- Precise timing and Directional information (not from IP)
- Energy deposit (especially for low-energy γ/n interaction in Si)
- Majority of particles with low transverse momentum

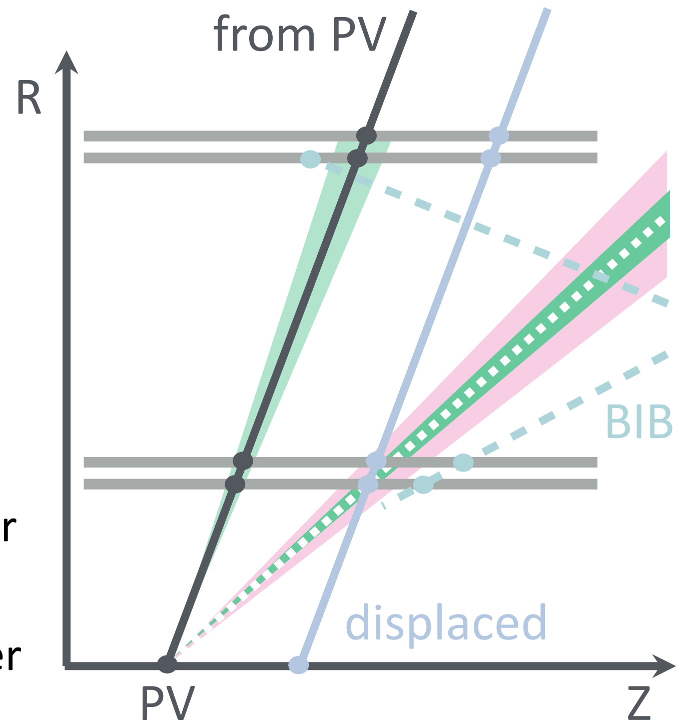
Tracker doublets





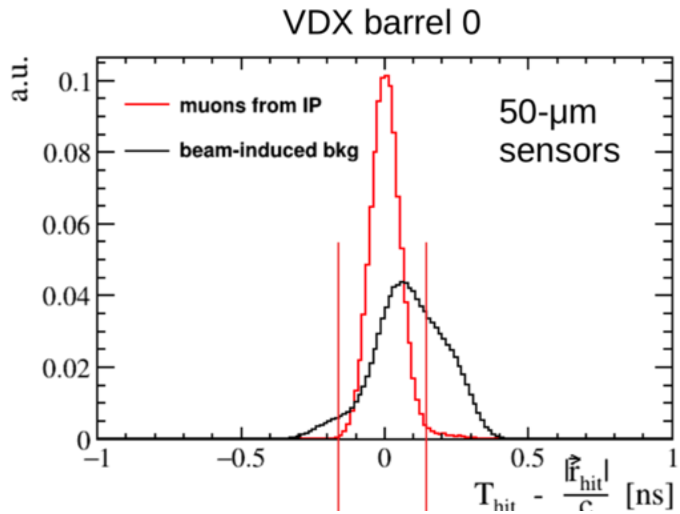
Selecting doublets pointing towards the Primary Vertex dramatically reduces occupancy

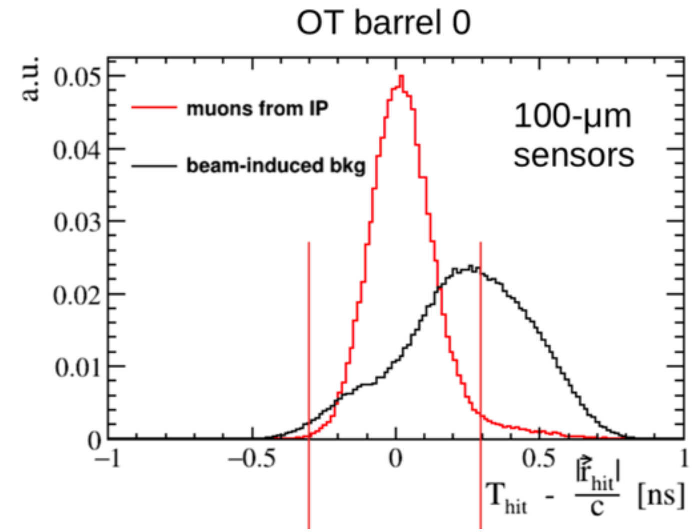
- ✓ Tracking detector bombarded by huge amount of low-energy electrons ~ 10^5 randomly distributed hits/BX
- ✓ Extremely challenging to produce real tracks
- ✓ Angles can be measured by correlating hits between adjacent sensors ➔ used by CMS track trigger
- ✓ The PS module uses short and long strips and is essentially a 1D problem
- ✓ Pixels are 2D and there is the additional complexity of encoding and decoding of hit positions to the target IC for position correlation. This will add power and complexity
- ✓ Studies of single sensor track angle filter (based on cluster shapes) are valuable



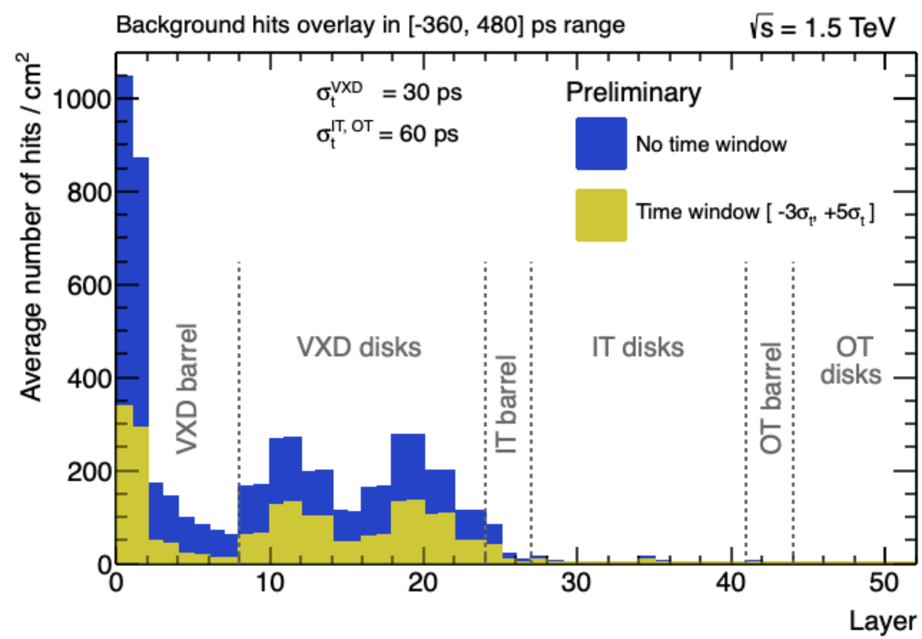
Explore triplets?

Tracking timingg requirements





- ±150ps window at 50ps time resolution in the Vertex detector a strongly reduce the occupancy (by ~30%)

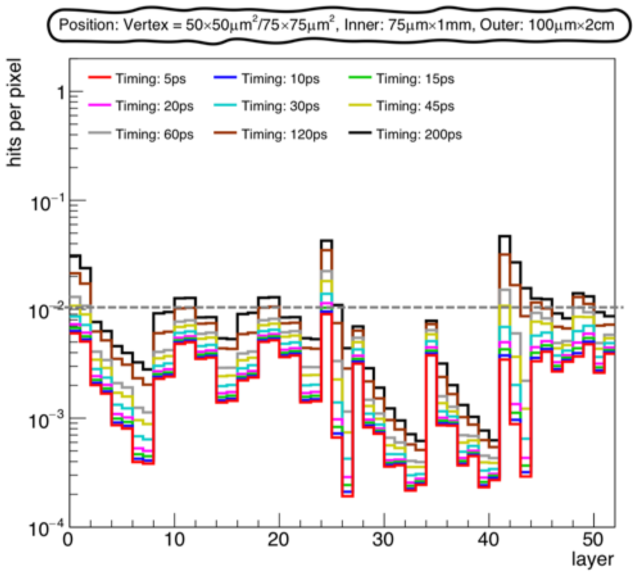


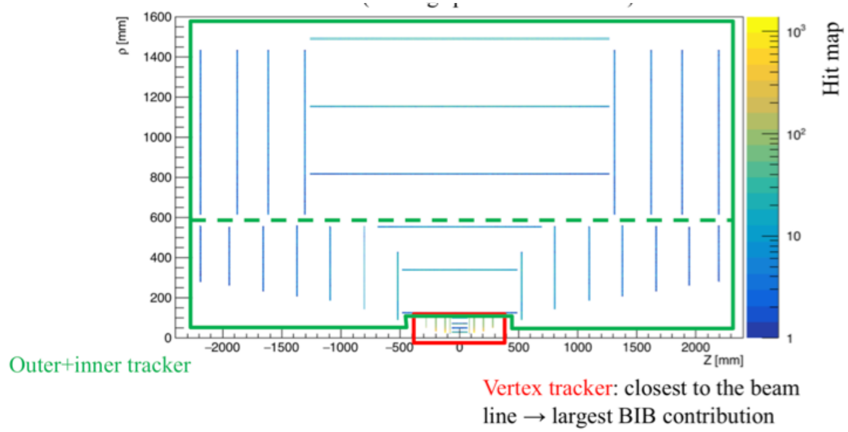
- Handles to reject spurious hits from BIB
  - applying a time window to readout only hits compatible with particles originating from interaction region;
  - exploiting energy deposited in the tracker sensors (under development);
  - correlating hits on double-layer sensors (under development).

State of the art fast tracking sensors can push this even further: σ_t~10ps

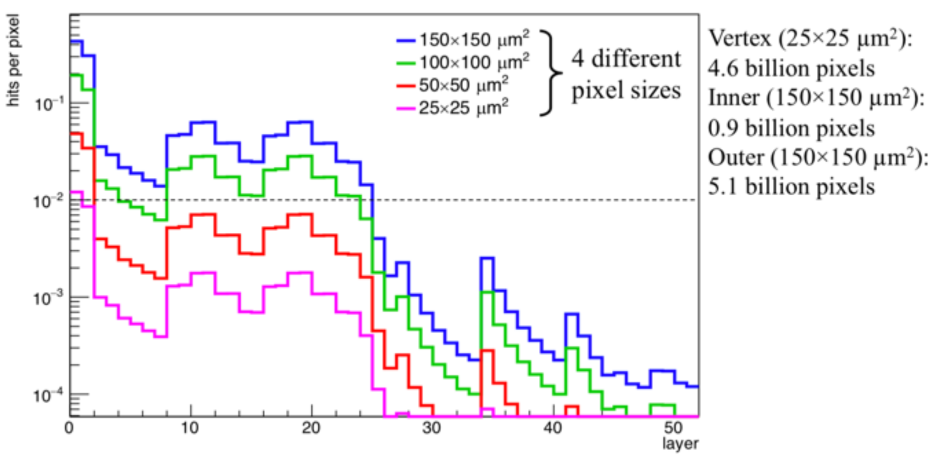
Tracker: timing

- ✓ Smaller pixel/strip size ➔most of the detector can reach timing resolution of ~60 ps
- ✓ Innermost vertex/inner barrel layer, will benefit for better timing of 20-30 ps
- ✓ Leads to tracker with total number of channels ~ 2B (similar to Phase-2 ATLAS/CMS)



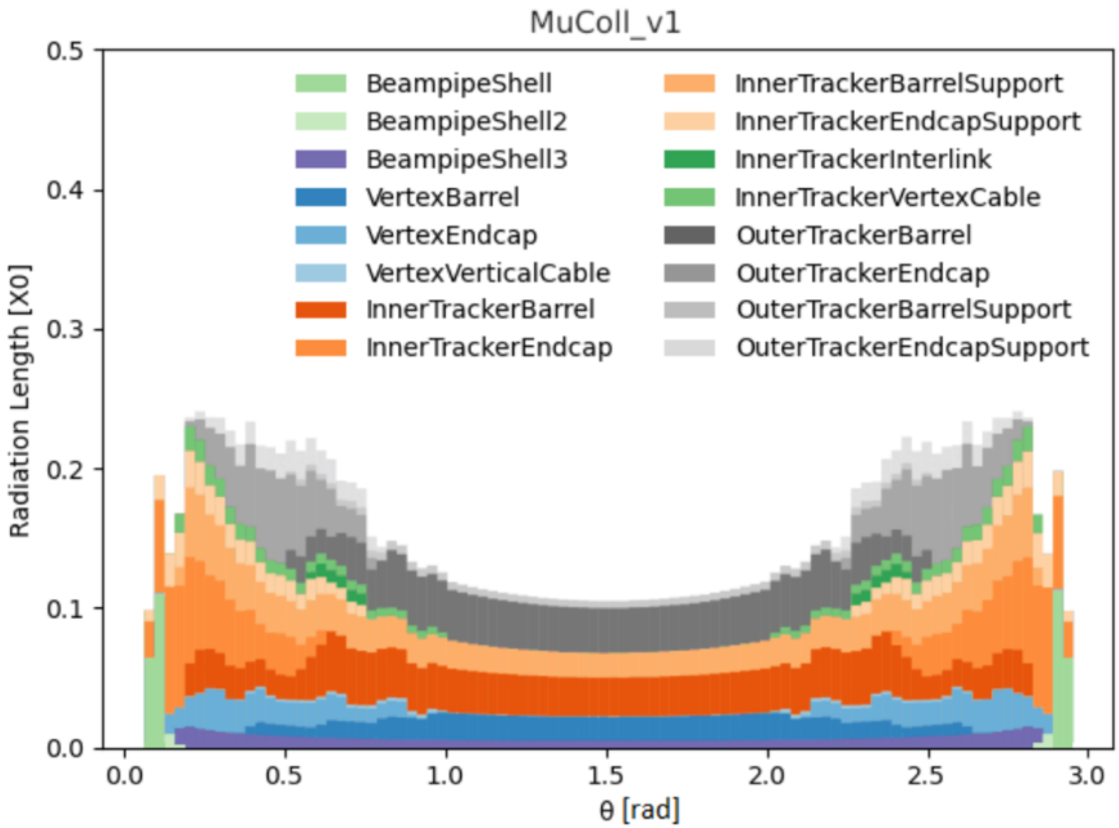


- **The goal of occupancy in the tracker is under ~1%**
- Without timing information, this is achievable with small pixel size ~25-25 microns
- This would lead to the pixel detector with very large number of channels



Tracker Key considerations

Pixel sensors: ~ 0.5 m^2
Strip/long pixels sensors: ~ 88 m^2
Barrel: ~ 69 m^2
Endcap: ~ 19 m^2



- We know how to deal with these doses in silicon
- Operate at low temperature (CO_2 cooling and some additional mass)
- Operating voltage increases with dose
- Increased leakage currents as well – means large VI, power dissipation and danger of thermal runaway
- Prefer thin sensors, high drift fields to minimize charge trapping and improve speed

TF3 Solid State Detectors

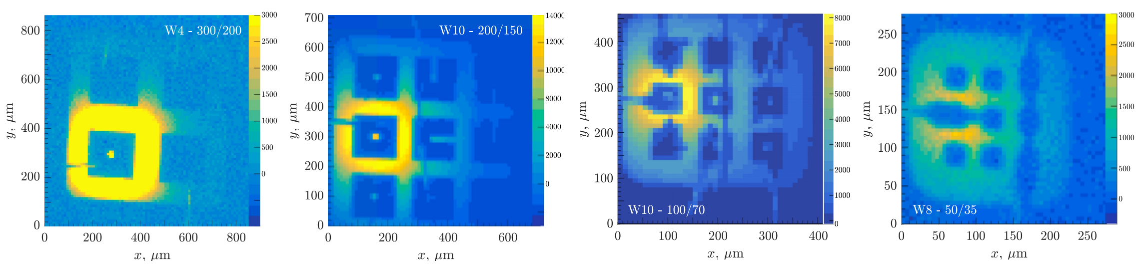
BiB not originating from IP and out of time ➔

- Double layers: size, material budget, timing

Triple layer? Topology ?

Timing is a crucial handle to

- LGAD ➔ RSD
- Could we instrument the nozzles?

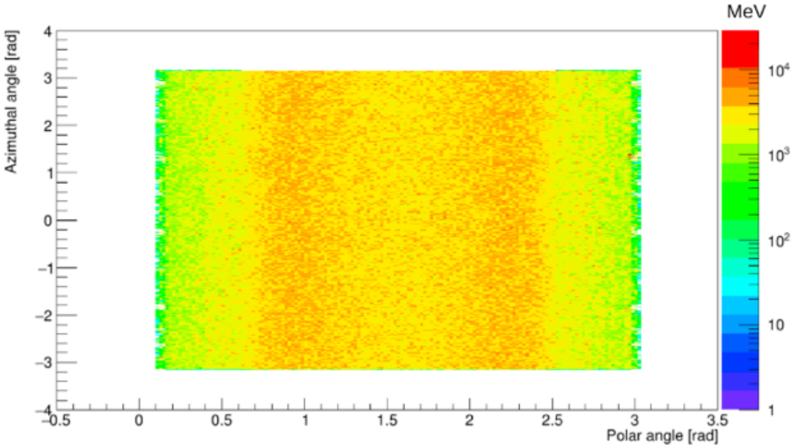


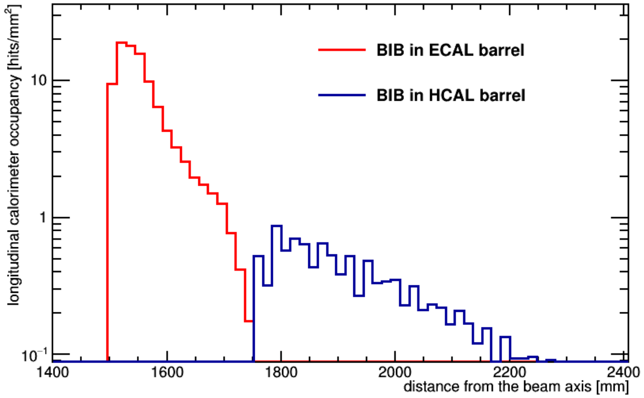
⇨ σ_x = ~5 μm and σ_t = ~40 ps

(rate capability: **50-100 MHz**)

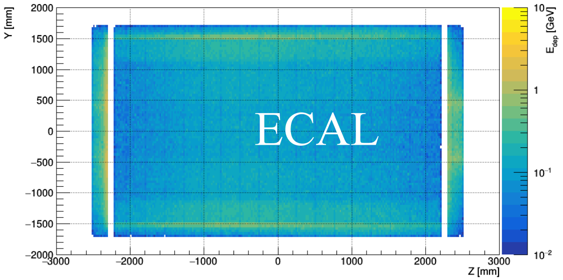
Calorimeter @ 1.5 TeV

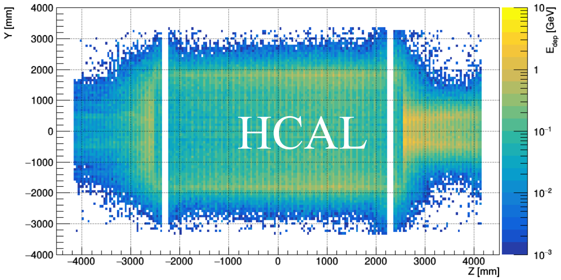
BIB almost flat distributed in $\theta - \phi$ space

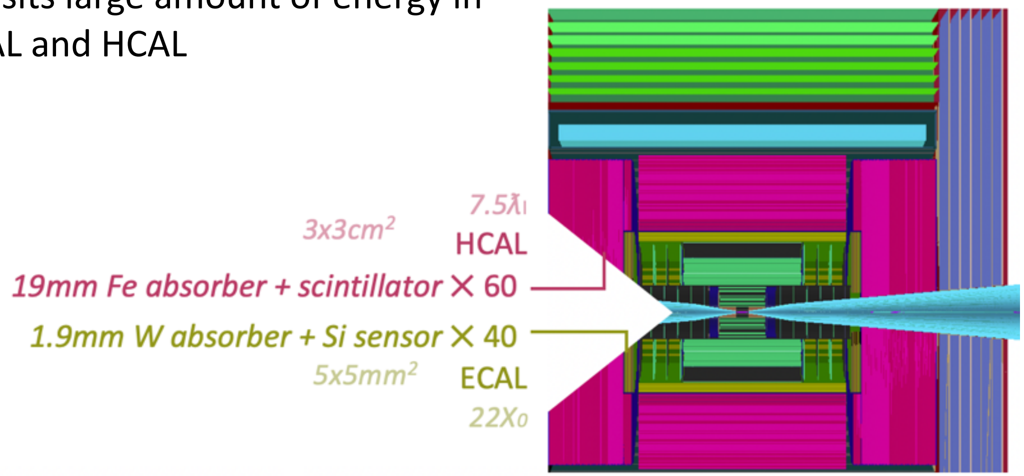




- ✓ based on CLIC configuration
  - Silicon + tungsten for ECAL, Iron+Scintillator for HCAL
- ✓ BIB deposits large amount of energy in both ECAL and HCAL



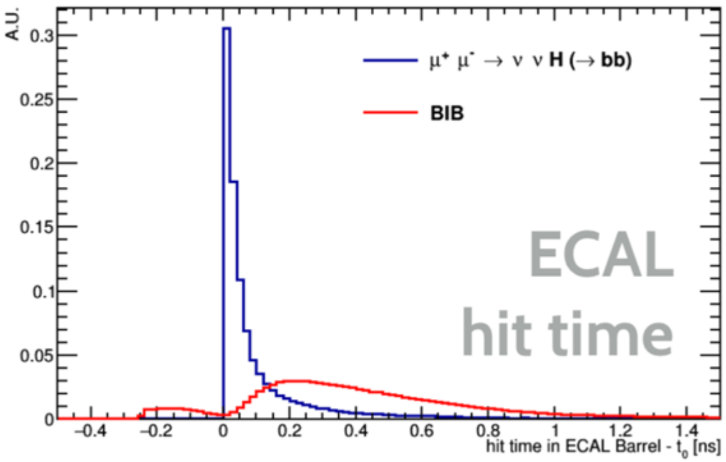


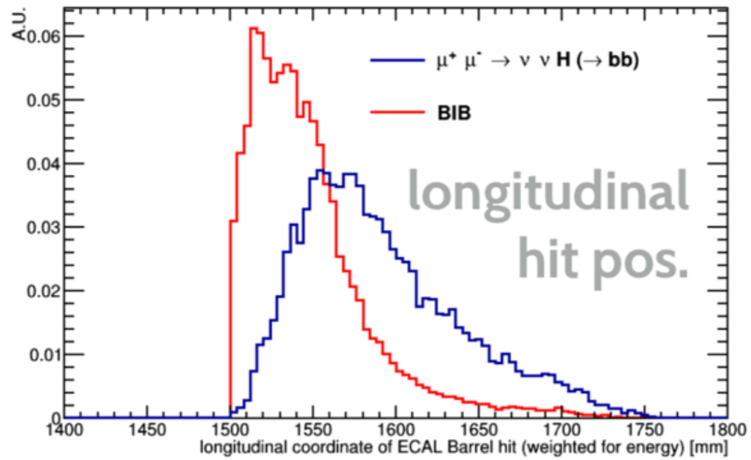


Calorimeter volume: 127 m^3
ECAL: 115 m^3 - HCAL: 112 m^3

Calorimeter optimization

Timing and longitudinal shower distribution provide a handle on BIB in ECAL





Various BIB mitigation approaches for ECAL can be studied

- possibly adding a preshower for absorbing the initial part of BIB in ECAL
- subtraction of BIB depositions using the hit time+depth information

Hadronic showers have longer development time → timing not critical

- the most straightforward approach: evaluate the average BIB energy deposition and consider only energy deposits above the BIB level

TF6 Calorimetry

- ✓ Timing and longitudinal shower distribution provide a handle on BIB in ECAL
- ✓ Readout energy is reduced by x3 when loose timing cuts are applied
- ✓ High granularity + precise timing of each channel would allow to use sophisticated BIB subtraction at the Particle Flow reconstruction level
- ✓ Could be expensive : other technologies e.g. use Cherenkov calorimeter with PbF2 crystals read out by SiPMs. Good timing, flexible granularity, much cheaper

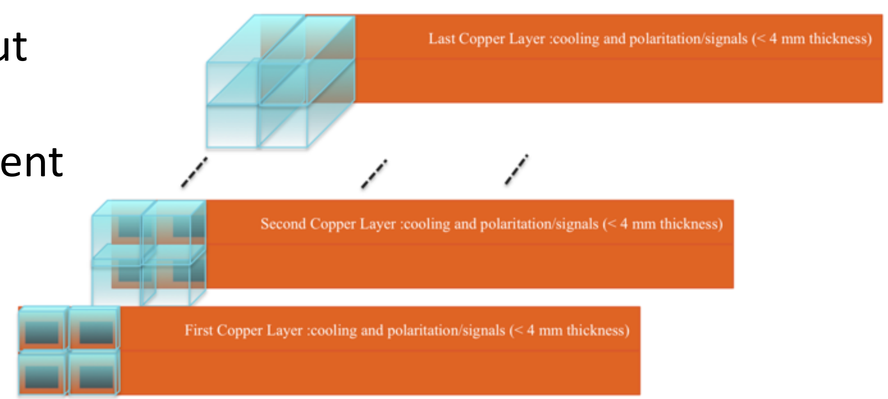
- R&D on Rad-hard fast crystals (PbF2, Ba2F, PbWO_4…)
- Synergy with KLEVER + LHCb….

Cherenkov light, semi-homogeneous calorimeter: PbF2 + copper + SiPM read-out

Design specific for Muon Collider experiment (Electromagnetic Calorimeter)

CRYLIN: CRYstal calorimeter with Longitudinal Information (idea by Ivano Sarra)

- Calorimeter Layout: **the calorimeter can be segmented longitudinally** as a function of the energy of the particles and the background level.

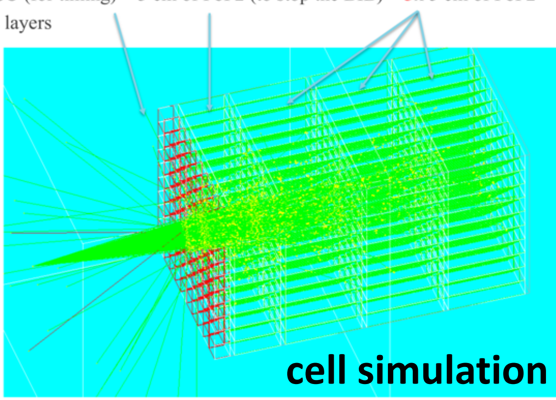


- A reduced first layer used as active pre-shower for timing → PbF2 or LYSO (5÷10 mm).

New materials and technologies

- A first layer of LYSO could be used for time measurement, then PbF_2 layer to absorb the BIB
- PbF_2 has good light yield (3 pe/MeV), fast signal (300 ps for muons 50 ps for pions), radiation hard, relatively cheap

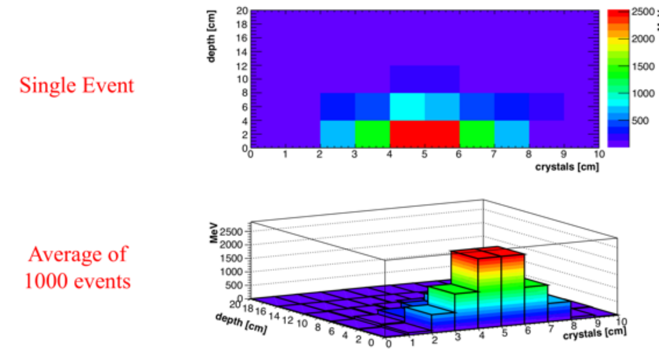
1 cm of LYSO (for timing) + 3 cm of PbF2 (to stop the BIB) + 3x 5 cm of PbF2 + 5x3 mm copper bias layers



cell simulation with Geant

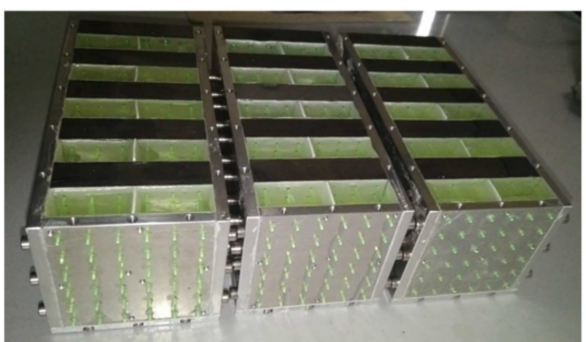
Most of BIB photons are absorbed in the first layer

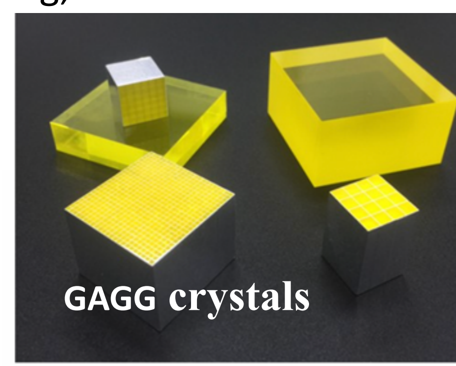
BIB parametrized as 1.7 MeV photons – 300 particles/cm² per event



→ cerium-doped GAGG: fast scintillation light (100 ps and 50 ns of rise and decay time), high light yield (50k photons/MeV)

→ Polysiloxane: lightweight, fast response, reduced cost and ease of manufacturing, although they display reduced light output with respect to inorganic crystals





Polysiloxane calorimeter [*J. Phys.: Conf. Ser.* **1162 012032**]

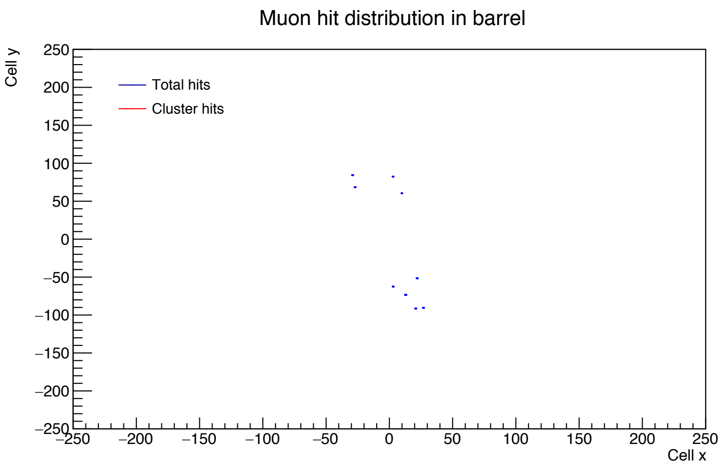
TF4 Photon Detectors and Particle Identification Detectors

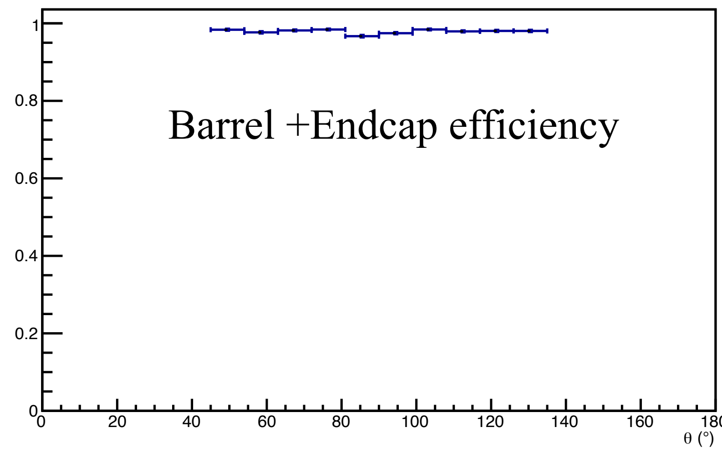
- The need to solve the fat jet substructure favors the design of finely segmented calorimeters
- However there is the need to have high temporal resolutions for signal events even at low energy deposits: in example, due to the passage of high-pulse muons
- PROPOSAL: a semi-homogeneous calorimeter based on Lead Fluoride (PbF2) Crystals with surface mounted UV extended Silicon Photomultipliers (SiPMs)
- Other rad-hard and fast material?
- Level of radiation on sensors and SiPM
- Rad hardness up to 10^{12} n(1MeVeq) /100 krad at SiPM level (1 Mrad on crystals)

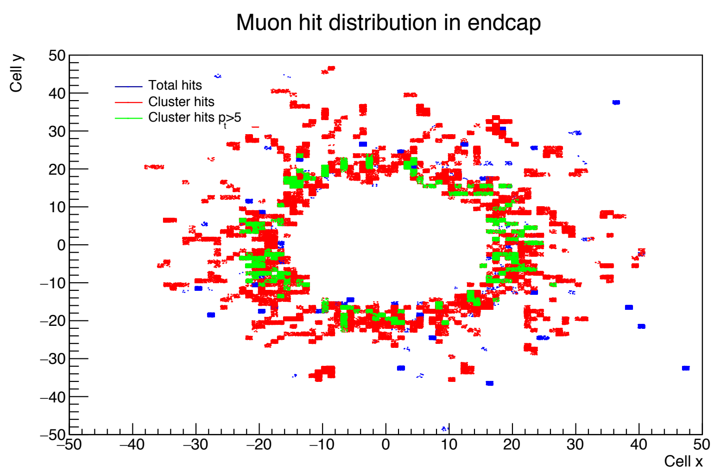
Muon reconstruction @ 1.5 TeV

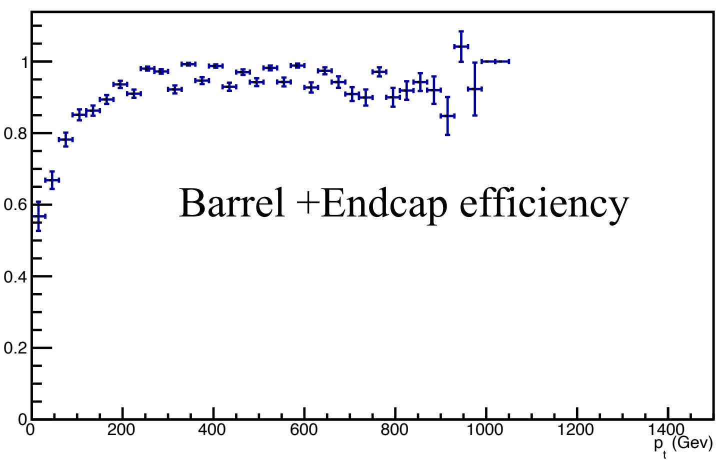
BIB in muon detectors

Central detector low occupancy









Backward/Forward detector
sizeable occupancy close to nozzle

Hadronic calorimeter features

- High longitudinal and transversal granularity (~1cm^2)
  - to distinguish the jet constituents from the BIB
  - to solve the substructures that are necessary for the fat jet identification
- High time resolution (few hundred of ps) to measure the time of arrival of particles to remove the BIB. Jet time resolution of the order of tens of picoseconds
- Excellent energy resolution (5%) to properly exploit the jet sub-structure in the fat-jet reconstruction algorithm.
- High radiation hardness
- Development of new HV power supplies with high sampling rate
- Further development of Front-End electronics specific for time and energy measurement

Options considered for active layers:

- plastic scintillator+SiPMs (exploited in the CMS HGCAL),
- RPCs, GEM and Micromegas.

➔R&D of gas-based detector as active layer to a new MPGD detector, optimized for fast timing, and based on the GEM detector concept: Fast Timing MPGD (FTM) (https://arxiv.org/abs/1503.05330) and the related readout electronics.

Gaseous Detectors are naturally rad-hard and can be designed for high rate capability and high spatial resolution

Gaseous Detectors can economically instrument large areas

Can measure Energy & Timing. Can send digital data out of the detector

TF1 Gaseous Detectors

MPGDs or also improved RPCs, ... for readout of high-granularity hadronic calorimeters and for muon detectors in high rate areas where high precision is required (eg endcaps, first station in barrel,…)

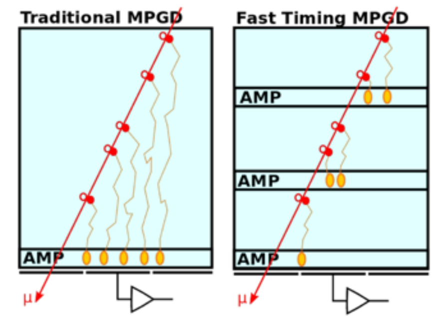
GOAL:

1. **First Muon Station(s**) with rad-hard, high spatial, time resolution and high rate-capability and two-track separation capable detectors; instrument large areas
2. **Instrumentation of active areas in sampling** (high-granularity) **Hadron Calorimeter**

- Study of hadronic shower interaction (absorber) with readout by gaseous detector as active detector
- Develop new calorimetric schemes (e.g. crystal absorber + photo-detection by MPGD)
- New gasmixtures for optimized operation and detection

FTM Concept, design, performance

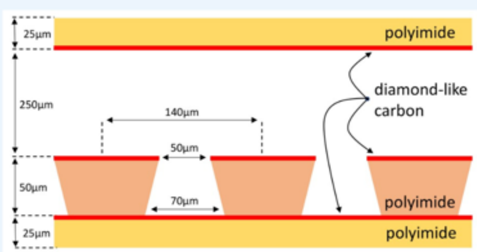
- Purpose of the fast timing MPGD (FTM): Improving on the time resolution of traditional MPGDs (~5ns) for MIP signals to ~500ps
- Jet energy resolution will scale 1/sqrt(number of jet particles)
- Working principle: Competition of arrival time of independent signals generated by fully decoupled drift+amplification layers



$$\sigma_{\mathrm{FTM}} = \frac{\sigma_{\mathrm{layer}}}{N_{\mathrm{layers}}}$$

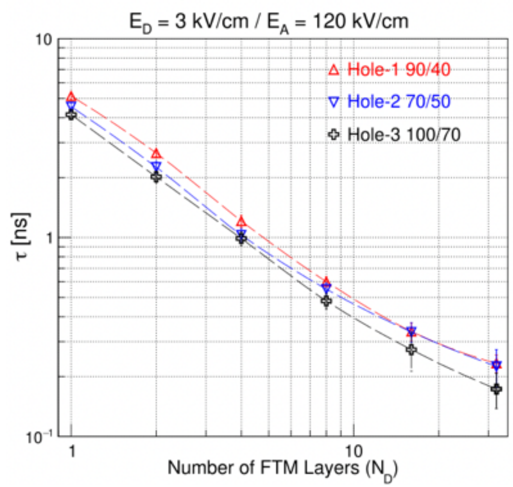
$N_{\mathrm{layers}} = 12 \rightarrow \sigma \sim 400\mathrm{ps}$

Signal pick-up by **external R/O electrodes**
→ **fully resistive** detector structure

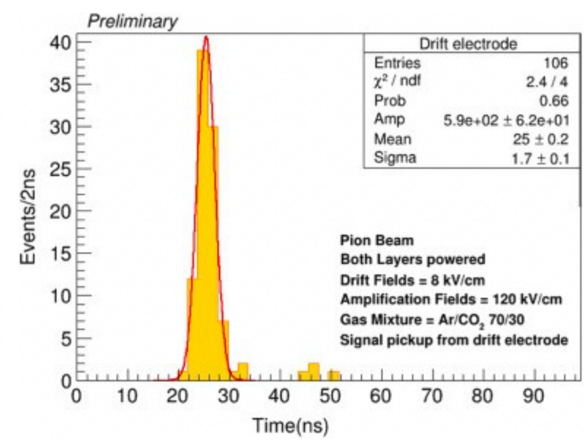


Structure of a single FTM layer

Prototypes undergoing tests in Bari, Pavia (Italy), Ghent (Belgium)



Simulated FTM time resolution for different n. of layers



Measured two-layer time resolution at test beam

Read-out considerations

- Per module, occupancy is significantly higher in the inner tracker layers than at the HL-LHC

➔ Requires on-detector logic (timing, double-layers) or higher bandwidth (more material, power)

- Total data rates at 1.5 TeV assumed to be tracker dominated and are ~30 Tb with **1 ns readout window (conservative)**
- Similar to total bandwidth of the LHCb triggerless DAQ. LHCb has smaller per event data volumes (~8800 5Gbps links) but operates at 40MHz (vs **100kHz for the Muon Collider**)
- Triggerless readout could probably work for this configuration. Total data rates do not look crazy even with today's commercial technology
- Studies are needed to understand system requirements at higher collider energies (different BIB) and larger readout windows (if needed for slow, heavy particles)

➔ Feasibility of triggerless readout for such scenarios need to be investigated.

Note, time between bunch crossings is very important

- Data => bandwidth => power

Read-out considerations

- Assuming module size of 20 cm^2
- With 50x50 microns pixel size, get ~800k pixels per module
- With 1% occupancy, this is 8k hits per module
- 32 bits to encode x/y/amp/time
- Data rates: 8000 * 32 bit * 100 kHz * 2(safety factor) ~ 50 Gbps
- This number is factor of ~5-10 higher than HL-LHC
- Not obvious that the technology will get us there in ~10-20 years
- More handles should be explored:

Data compression, some front-end clustering, pT-module based suppression (preliminary estimates indicate more than x5)

TF7 Electronics - On-detector Processing

- Extremely crucial

TF8 Integration

- Microchannel cooling – SiPM cooling
- Electronics power load
- Large data bandwidth transmission

TF9 Training

- Challenges are opportunities to grow next generation

Final remarks

- ✓ Main effort by International Design Study of Muon Collider:

  @ multi-TeV energy region: 3 TeV – 10+ TeV
- ✓ **Synergies with already proposed R&D and developing reconstruction software**
- ✓ Beam Induced Background (BIB) is a unique feature ➔ not originating from IP
- ✓ Detectors require carefully design with both physics goals and BIB in mind
- ✓ Detailed studies @ $\sqrt{s}$ = 1.5 TeV, easy to extend at 3 TeV,

  but 10 TeV need dedicated studies and R&Ds

Estimated time to simulate a basic machine design @ 10 TeV ➔ 1-2 year

- ✓ General detector requirements: rad hardness, high granularity, high time resolution
- ✓ Using special and time information is crucial for on-detector filtering in order to reduce bandwidth and power requirements to a manageable level
- ✓ Trigger-less readout is probably the way to go
- ✓ Additional considerations should be given to special cases, for example very high energy muons, displaced tracking, slow particles

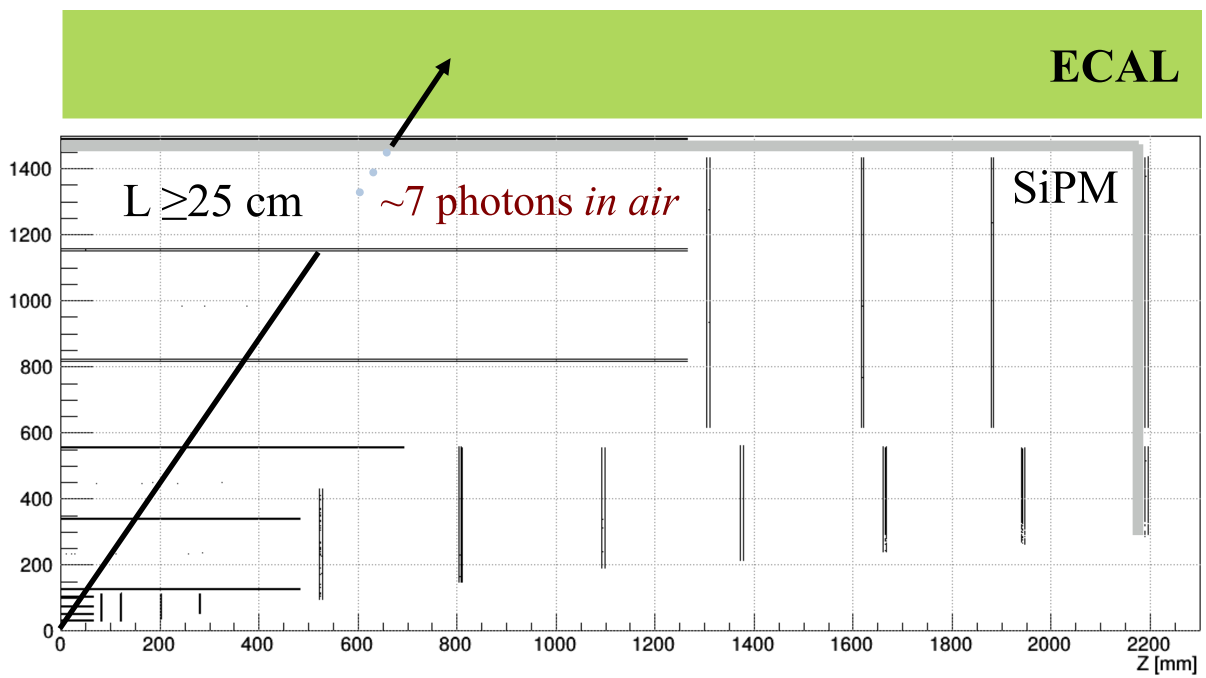
New idea: BIB kinematics to be exploited

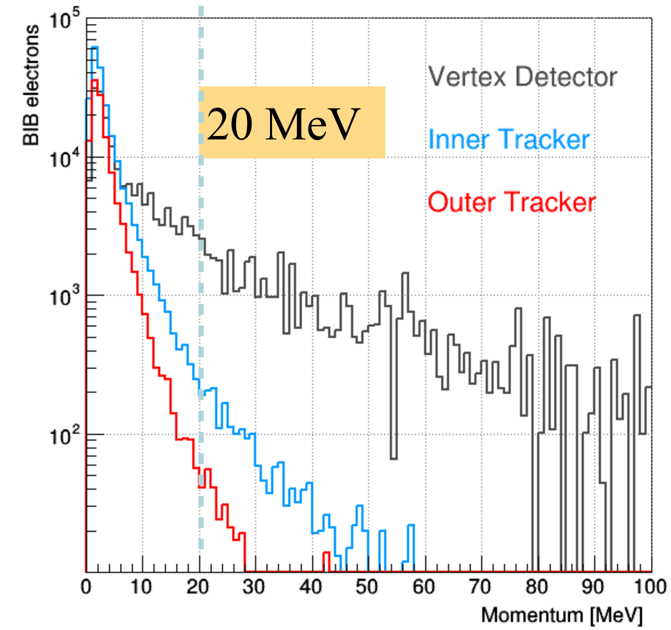
Cherenkov threshold in gas might be used for having 1-2 layers of BIB-free hits

- gas composition/pressure tuned for the needed threshold: γ > 40 *(electrons)*
- resolution limited by photosensor size (SiPM?)
- high time resolution (~50ps)

Detect only charged particles above the Cherenkov threshold at the outermost layers

- clean seed for the efficient inward track search





+ BIB-free time tagging of ECAL showers from charged particles

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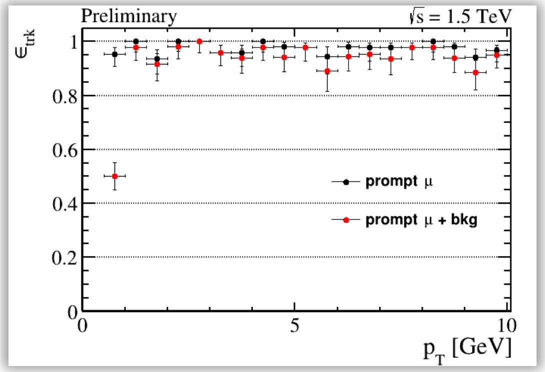
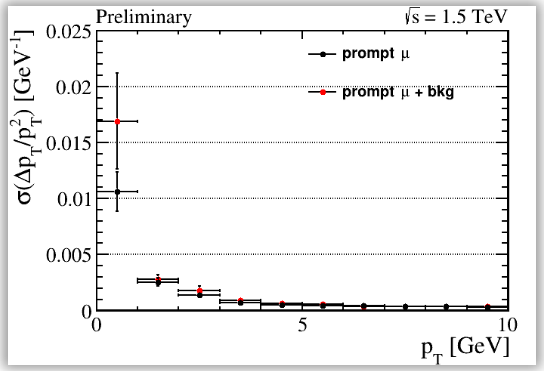
Francesco Collamati
Camilla Curatolo
Paola Sala
MDI

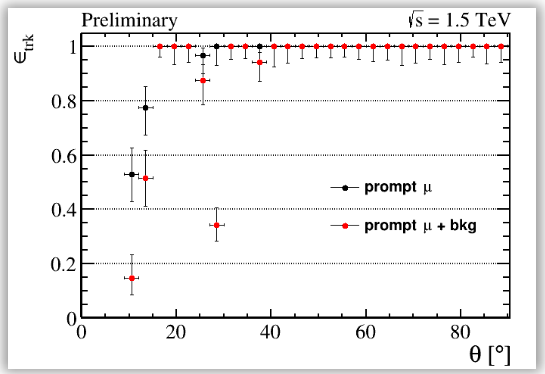
+ many others

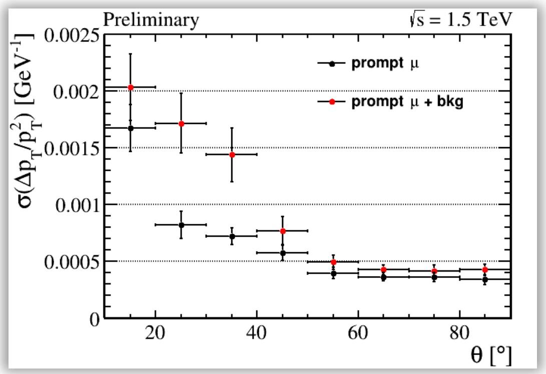
extras

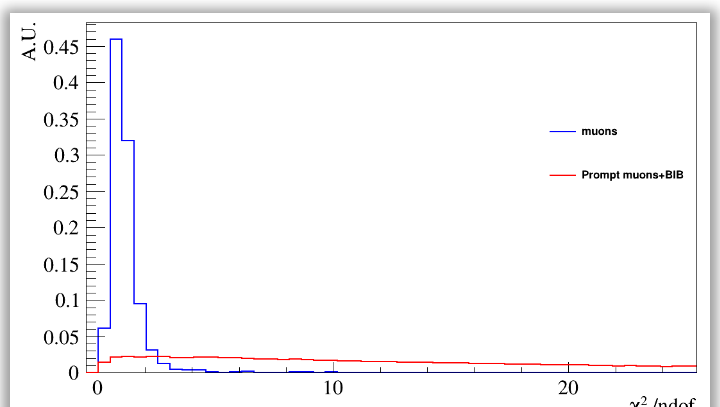
Tracking @ 1.5 TeV – present design

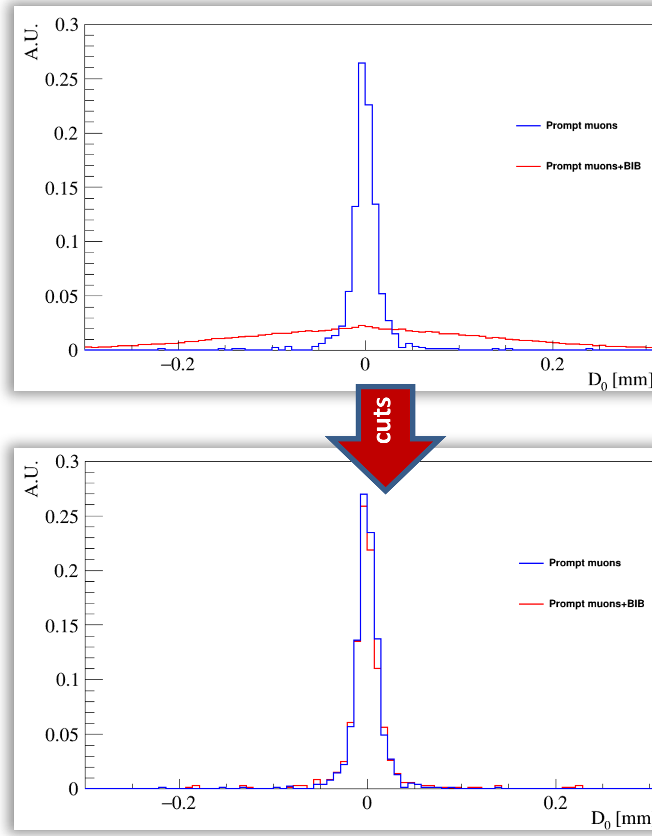




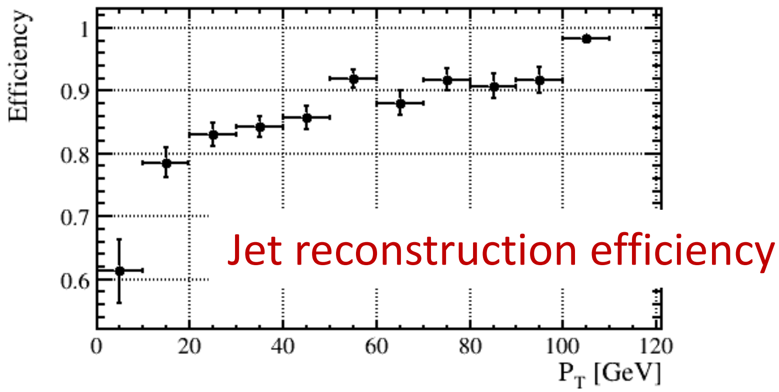


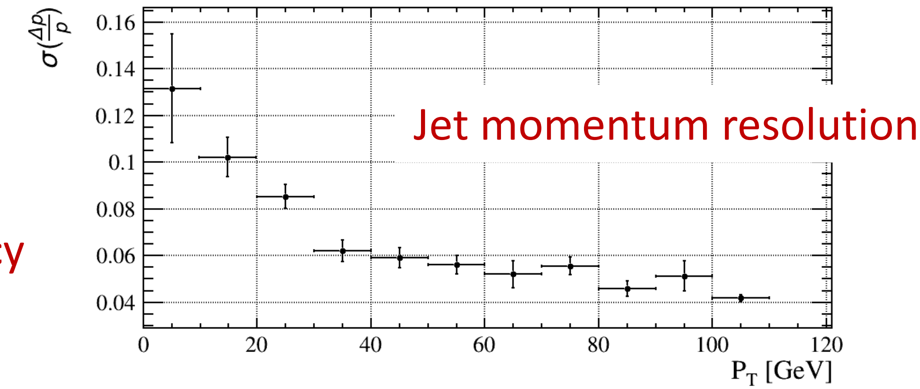




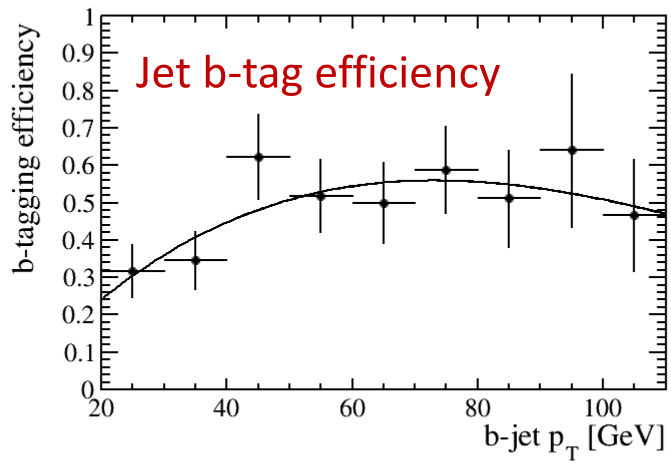


Calorimeter performance





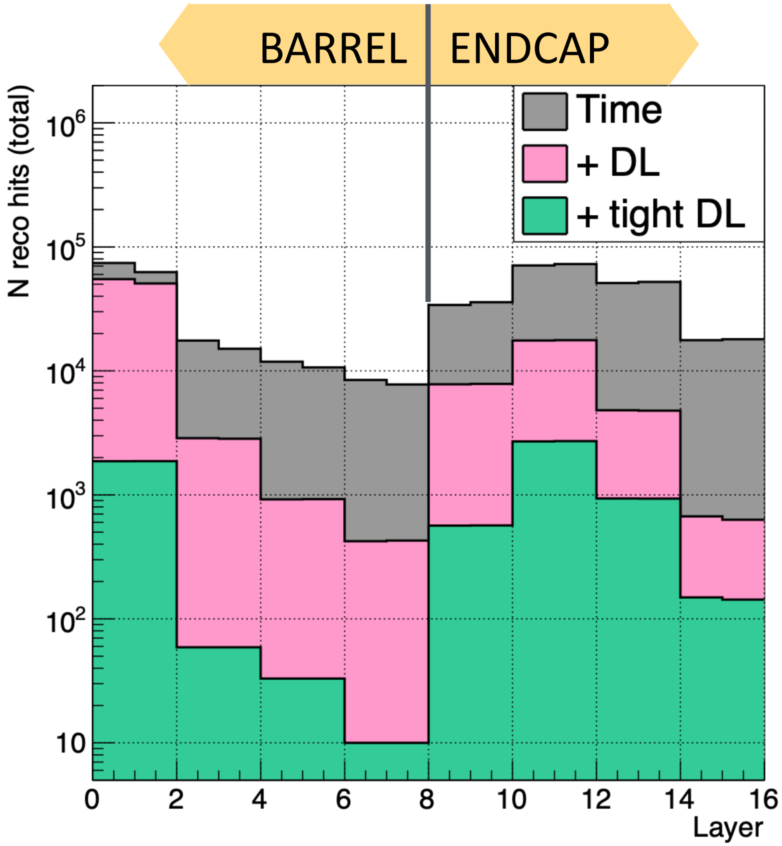
Jet ParticleFlow reconstruction algorithm under optimization.



b-jet identification very simple, based on secondary vertices

Determined with the “MAP” detector with dual-readout calorimeter and very “rough” jet reconstruction and b-tag algorithms

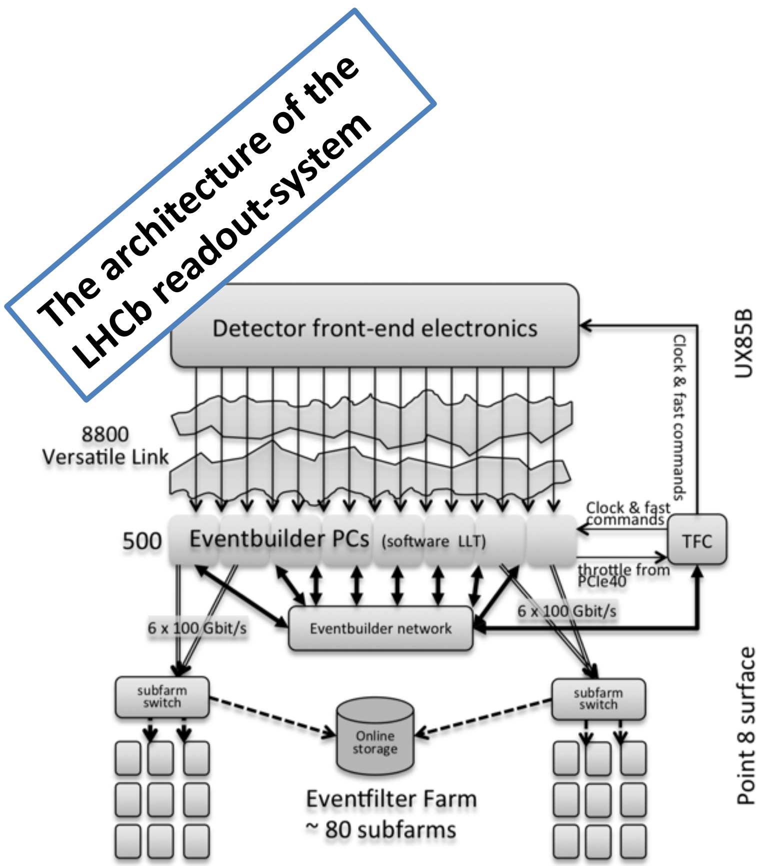
Tracking doublets selection



Tight angular selection of doublets reduces tracking time from 2 days → 3 minutes

Estimation of precise vertex position before the full track reconstruction is very valuable

Trigger/read-out considerations



- Assume data volume is tracker dominated
- Total number of hits per event ~10M (less with timing-based filtering)
- Total tracker data rate: 10M*32bits*100 kHz ~ 30 Tbps
- E.g. tracker readout system could consist of <100 readout boards running 25G Links
  - Similar to total bandwidth for LHCb triggerless DAQ
- LHCb has smaller data volumes (~8800 5Gbps links) but operates at 40MHz (vs 100kHz)
  - Does not look crazy even with today's commercial technology.
- Time between collision is very important