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Muon Collider:

Requirements for experiment and detectors

- 3 TeV and 10 TeV (or above)
- At each energy, beam parameters and bunch intensity will define the design of the machine optics and lattice in the vicinity of the Machine Detector Interface (MDI).
- Each configuration will determine for each BIB's particle its direction, timing, momentum, defining the occupancy as a function of the radius r from the beam pipe inside the experiment and the distance z from the collision point.

➔ see LoI on BIB distributions as MDI and machine lattice/optics design

- The experiment must be designed to be capable to mitigate and cope with BIB through cutting-edge detector technologies and a dedicated geometry.
- Each detector design requires an optimised design, high granularity, timing information. Pattern reconstruction and physical objects identification require new Artificial Intelligence algorithm.

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Machine parameters

Center of mass energy $\sqrt{s}$ (TeV)	.126	3	14
Circumference (km)	0.3	4.5	14
Interaction points	1	2	2
Average luminosity (10^{34} cm^{-2} s^{-1})	0.008	1.8	40
Integrated luminosity/detector (ab^{-1}/year)	0.001	0.18	4
Time between collisions (μs)	1	15	47
Cycle repetition rate (Hz)	1	5	5
Energy spread (rms, %)	0.004	0.1	0.1
Bunch length (rms, mm)	63	5	1
IP beam size (μm)	75	3.0	0.6
Dipole design field (T)	10	10	15
Proton driver beam power (MW)	4	4	1
Beam power in collider (MW)	0.08	5.3	20.2

Experiment required performances

The experiment performances must be tuned with the choice of physics benchmarks at each machine center of mass energy:

1) identification of charged tracks (electrons, muons)
2) identification of showers (electrons, gammas, hadrons)
3) rejection of out of time or pointing outside collision region
4) displaced vertexes
5) c-b tagging
6) neutron rejection
7) missing energy

Experiment layout

So far the experiment layout has been taken with some modification from a CLIC (ILC) standard design.

➔ Some work has to be dedicated to each detector volume, mainly the tracker, where barrel layers and endcap disks should be oriented according to BIB rates.

➔ The acceptance is limited along by the nozzles that was tuned to shield up to 10 degree in polar angles at center of mass energy 1.5 TeV. For events of interest like H(bb)H(bb) show losses due to the acceptance reduction at higher energies.

- The tracker volume design requires to be developed to minimise occupancy due to BIB.
- The interface between barrel and endcap as well as the tracker and calorimeter has to be carefully studied on benchmark channels.
- The choice of the magnetic field matches the momentum resolution requirements and define the volume for the muon detectors.

Detectors R&D

The harsher background is coming out of time and not pointing to the collision area.

The measurement of shower shapes in the calorimeters together with timing can improve background power rejection.

New R&D are mainly required for:

- **silicon tracker**

to achieve at the same time the best combined spatial and timing resolution (4D tracking) with a sufficient radiation hardness and high rate/occupancy capability

exploring: AC-LGAD (RSD) sensors (30 ps and 10 microns), CMOS-based DMAPS technology with 28 nm ASIC technology for analogue and digital read-out

- **calorimeter**

to achieve high granularity and timing in the inner layers, 5D imaging

exploring solutions where different active materials could provide PID, 4D tracking in the inner layers and fast scintillating crystalsto be compared to high granularity calorimeter as for CMS-Phase2 and dual read out solutions

extras

Instrumentation & computation Frontier

Understand the impact of detector designs on physics

- **We have to prepare requirement we would like to reach at an experiment at Muon Collider,mainly on:**
  - **Trackers – sensors with timing and electronics**
  - **Calorimeter – high granularity and timing required**
  - **Software tools**
  - **AI/ML applications**

Instrumentation ➔ see at links: https://indico.fnal.gov/event/43730/

Computational ➔ to come soon at links: https://indico.fnal.gov/event/43829/