Si Sensors for 5D Calorimeters

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Key Parameters of Future Colliders

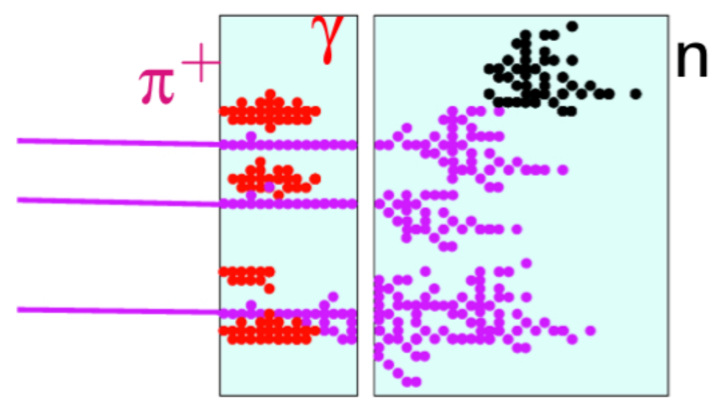
Table 7.1: Key numbers relating the detector challenges at the different accelerators.

Parameter	Unit	LHC	HL-LHC	HE-LHC	FCC-hh
E_{cm}	TeV	14	14	27	100
Circumference	km	26.7	26.7	26.7	97.8
Peak $\mathcal{L}$, nominal (ultimate)	$10^{34}\text{cm}^{-2}\text{s}^{-1}$	1 (2)	5 (7.5)	16	30
Bunch spacing	ns	25	25	25	25
Number of bunches		2808	2760	2808	10600
Goal $\int \mathcal{L}$	ab^{-1}	0.3	3	10	30
σ_{inel} [331]	mb	80	80	86	103
σ_{tot} [331]	mb	108	108	120	150
BC rate	MHz	31.6	31.0	31.6	32.5
Peak pp collision rate	GHz	0.8	4	14	31
Peak av. PU events/BC, nominal (ultimate)		25 (50)	130 (200)	435	950
Rms luminous region σ_z	mm	45	57	57	49
Line PU density	mm^{-1}	0.2	1.0	3.2	8.1
Time PU density	ps^{-1}	0.1	0.29	0.97	2.43
$dN_{ch}/d\eta\vert_{\eta=0}$ [331]		6.0	6.0	7.2	10.2
Charged tracks per collision N_{ch} [331]		70	70	85	122
Rate of charged tracks	GHz	59	297	1234	3942
$<p_T>$ [331]	GeV/c	0.56	0.56	0.6	0.7
Bending radius for $<p_T>$ at B=4 T	cm	47	47	49	59

- **FCC-hh wrt HL-LHC:**
  - 5-7x higher pile-up, ~1000 interaction per bunch crossing!
  - 8x time pile-up
  - 10x more Int. Lumi and radiation dose / fluencies

Calorimetry Requirements for Future Colliders

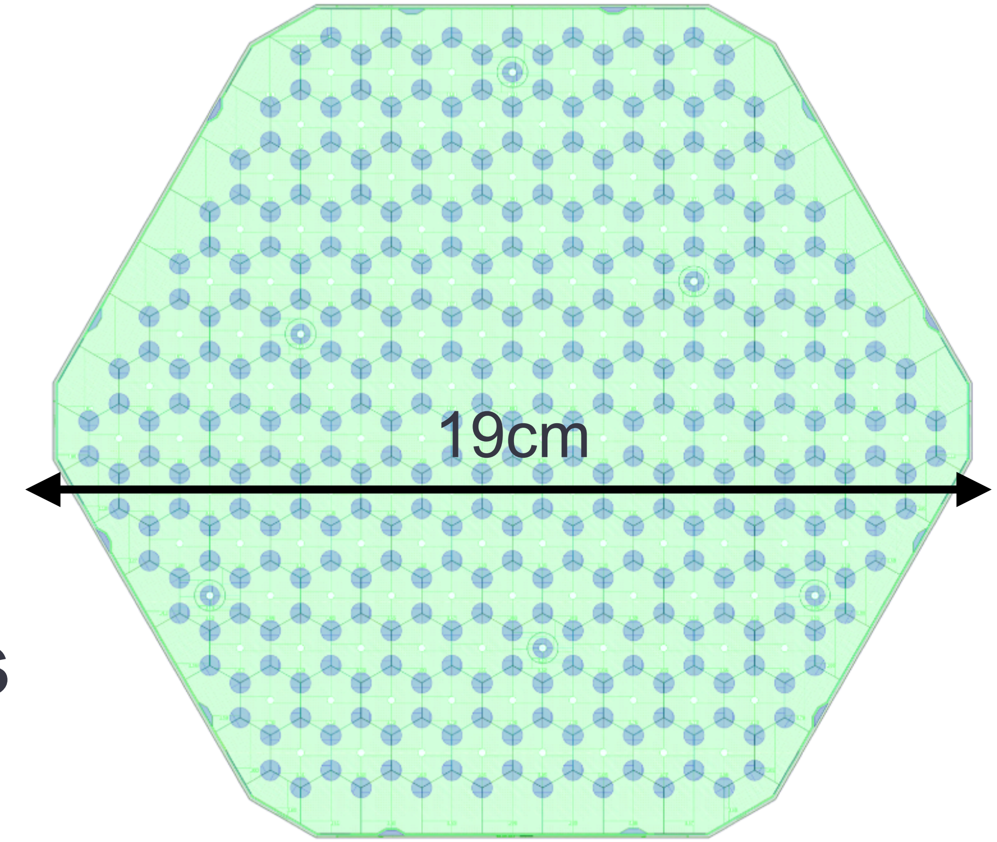
- **Large dynamic range for energy measurement 0.1-1e5 MIPs (6 orders of magnitude)**
- **High pile-up environment requires high spatial granularity imaging calorimeters**
- **High temporal pile-up requires good timing resolution (~10ps)**
- **Good separation of showers will support the particle flow algorithm**

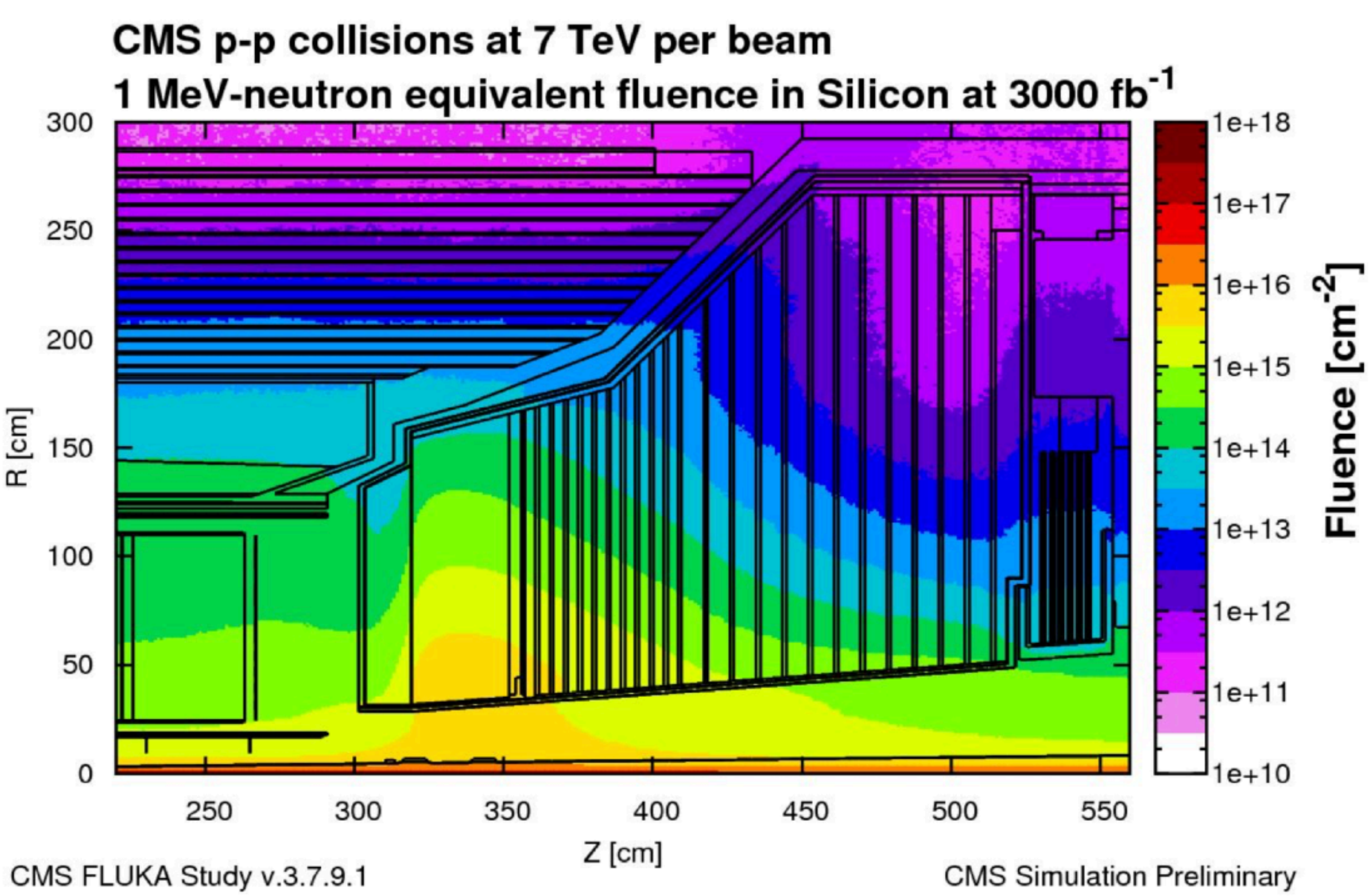


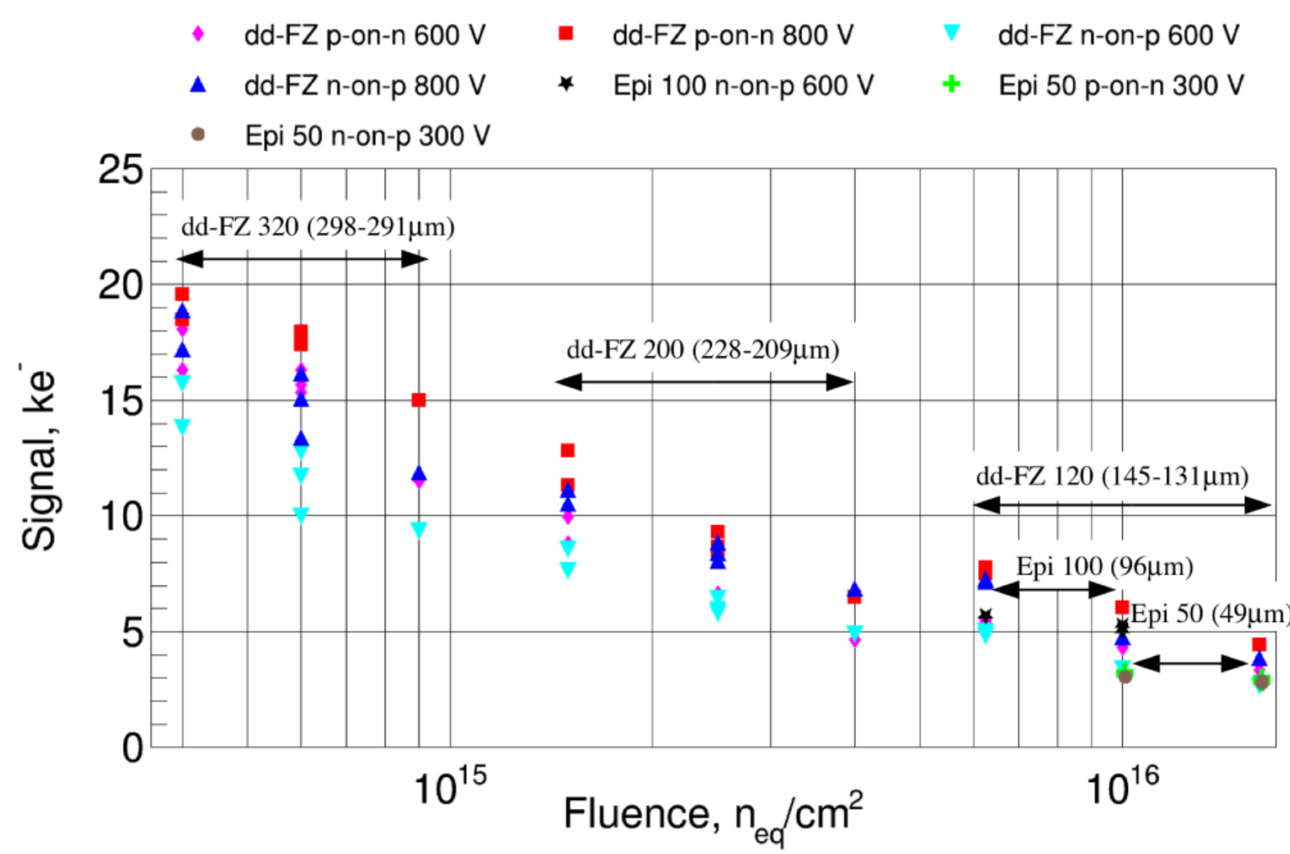
- **Also radiation hard detector for fluencies up to 1e17 neq/cm2**

CMS HGCal for HL-LHC

- **Sampling calorimeter based on full 8” wafer sensors in the high radiation areas**
- **25,000 sensors, 600m2 area**
- **0.5-1cm2 hexagonal cells, n-on-p**
- **300um, 200um and 120um thicknesses**







Beyond HGCal

- **To further improve radiation tolerance of silicon sensors, consider prototyping thinner (~50um) sensors with potentially smaller area 0.25cm2 area to keep capacitance low**
- **Use Fermilab facilities to characterize the sensor on probe station and test beam: leakage current, CCE, timing performance, etc…**
- **Use the ITA facility to study radiation hardness with protons**
- **Fermilab team: Ron Lipton, Maral Alyari and Zoltan Gecse**
  - Currently, actively contributing to the design, simulation and characterization of the HGCal sensors
- **A white paper can be submitted on the characterization results**
  - Requires resources to procure prototype sensors