



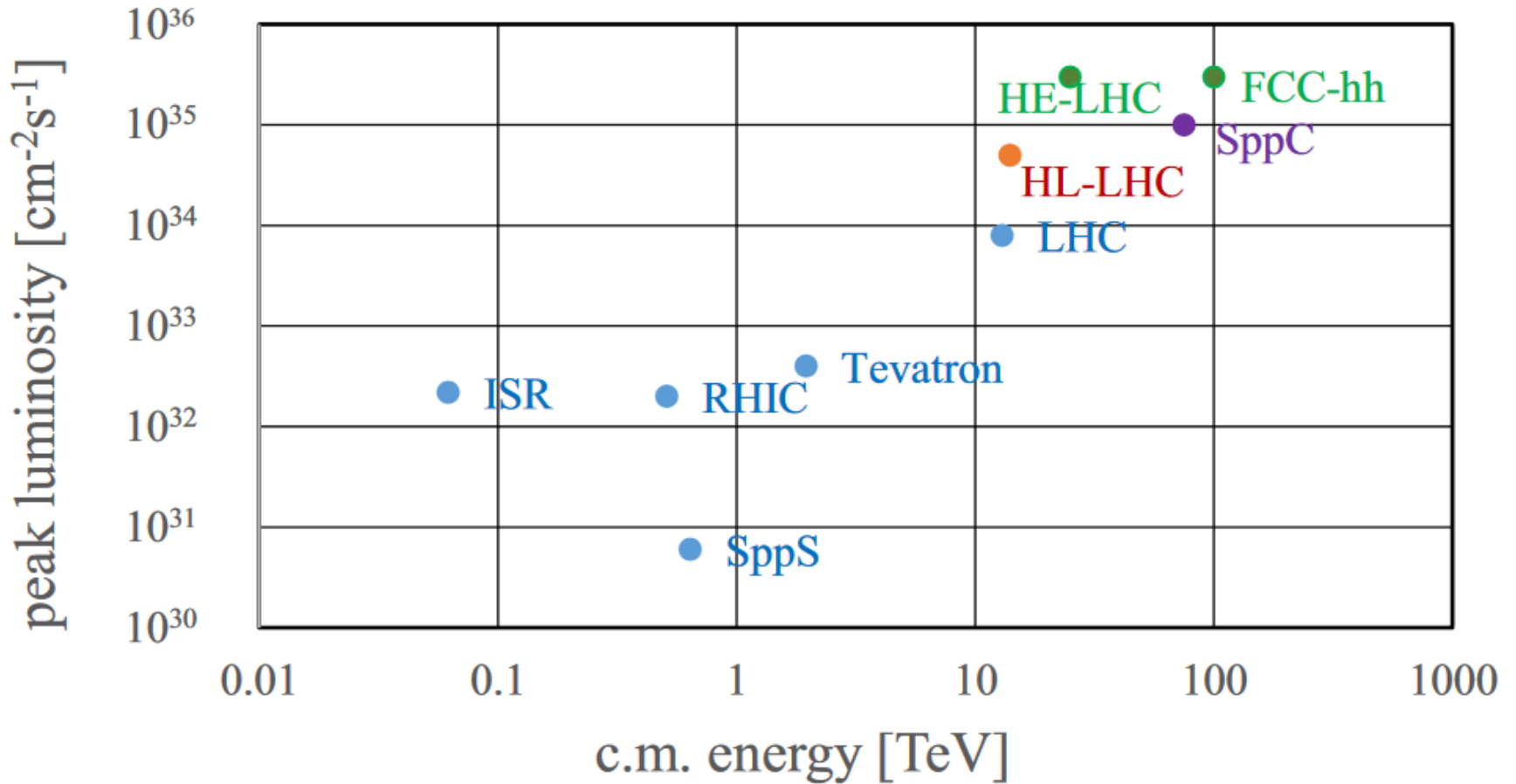
FCC and High-Energy LHC: Accelerator Physics Challenges

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Energy Frontier (EF) working group meeting

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Luminosity vs E_{cm}



hadron collider parameters - 1

parameter	FCC-hh		HE-LHC	(HL) LHC
collision energy cms [TeV]	100		27	14
dipole field [T]	16		16	8.33
circumference [km]	100		27	27
straight section length [m]	1400		528	528
# IP	2 main & 2		2 & 2	2 & 2
beam current [A]	0.5		1.12	(1.12) 0.58
bunch intensity [10^{11}]	1	1 (0.2)	2.2 (0.44)	(2.2) 1.15
bunch spacing [ns]	25	25 (5)	25 (5)	25
rms bunch length [cm]	7.55		7.55	(8.1) 7.55
peak luminosity [$10^{34} \text{ cm}^{-2}\text{s}^{-1}$]	5	30	25	(5) 1
events/bunch crossing	170	1k (200)	~800 (160)	(135) 27
stored energy/beam [GJ]	8.4		1.3	(0.7) 0.36
beta* [m]	1.1-0.3		0.25	(0.20) 0.55
norm. emittance [μm]	2.2 (0.4)		2.5 (0.5)	(2.5) 3.75

Challenges FCC:

- Cost of 100 km magnets and civil
- 16 T magnets
- ~1000 pileup
- Collimation/protection

Challenges HE-LHC:

- Cost of 27 km magnets
- 16 T magnets
- ~800 pileup
- High current



hadron collider parameters - 2

parameter	FCC-hh	HE-LHC	(HL) LHC
rms IP beam size [μm]	6.7 (3) – 3.5 (1.5)	6.6 (3.0)	(8.2) 16.7
half crossing angle [μrad]	37 - 70	131 (60)	(255) 143
Piwinski angle	0.42 – 1.51	1.50 (1.50)	(2.52) 0.65
crab cavities needed	NO - YES	YES (YES)	(YES) NO
synchr. rad. power / ring [kW]	2400	101	(7.3) 3.6
beam-screen half aperture [mm]	13.2	13.2 or 14	17
beam-screen temperature [K]	50	20 or 50	20
SR power / length [W/m/ap.]	28.4	4.6	(0.33) 0.17
ΔE / turn [keV]	4600	93	6.7
long. emit. damping time [h]	0.54	1.8	12.9
initial beam lifetime [h]	18 3	3	(15) 40
total / inelastic cross section [mbarn]	156 / 109	125 / 91	112 / 82
injection energy [TeV]	3.3	1.3	0.45
hor.,vert. arc half aperture [mm]	15,13.2	15, 13.2 (19, 14)	22, 17

Challenges FCC:

- Need new 3.3 TeV injector
- x100 LHC radiation power /meter

Challenges HE-LHC:

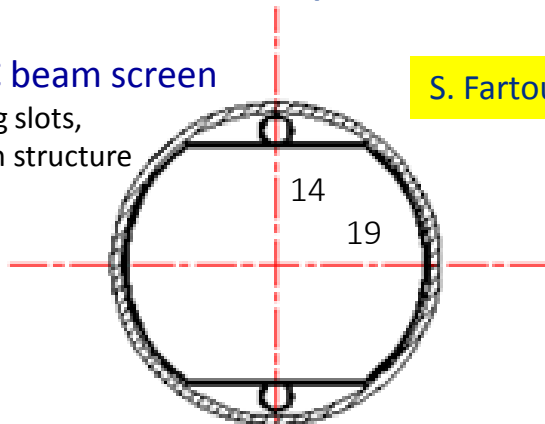
- Need new 1.3 TeV injector/beamlines
- x15 LHC radiation power /meter

Common Challenge : Beampipe

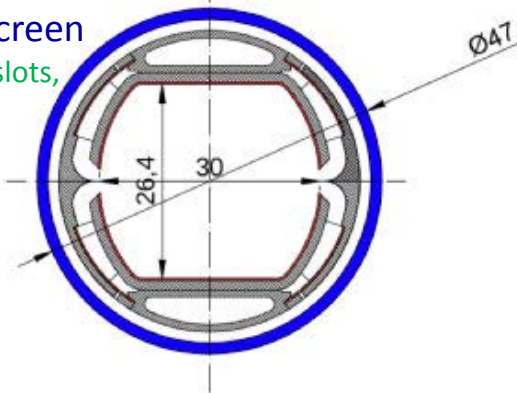
arc beam-screen options

scaled LHC beam screen
with pumping slots,
and sawtooth structure

S. Fartoukh



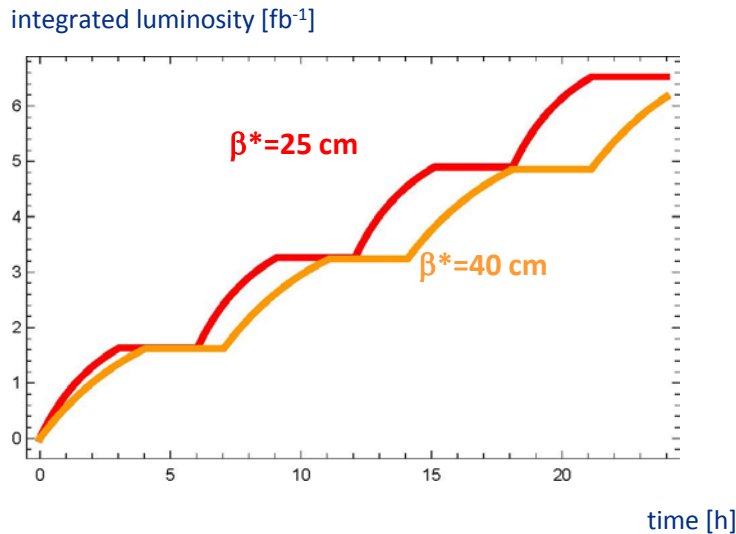
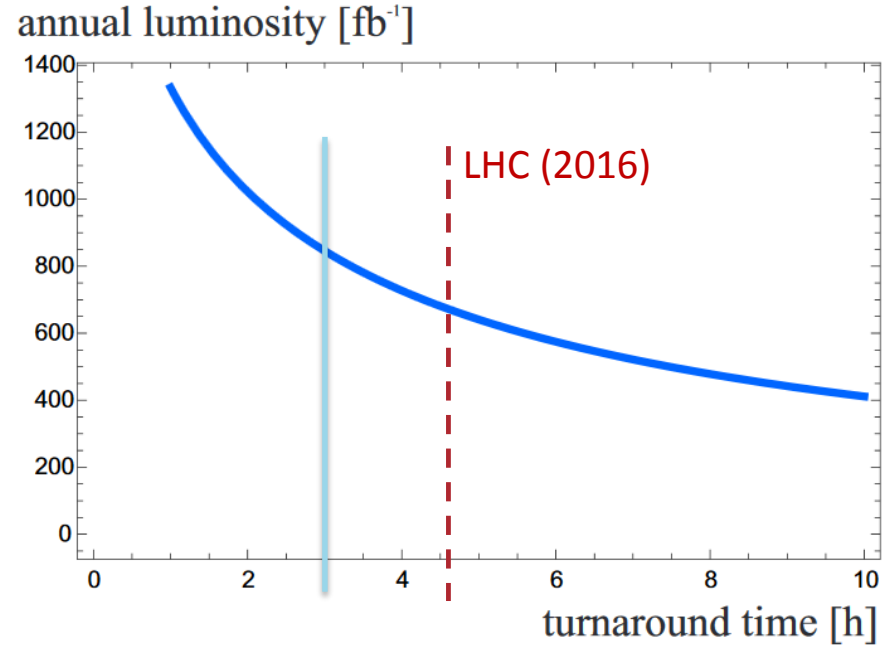
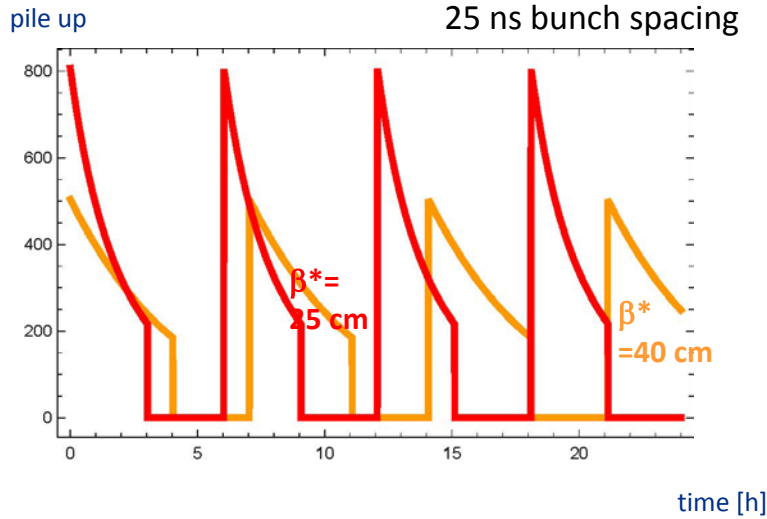
FCC-hh beam screen
shielded pumping slots,
less electron cloud



✓ choice

accelerator	450 GeV	1.3 TeV
LHC w LHC tolerances	n1= 6.7	-
HL-LHC w HL-LHC tol's	13.5	-
HE-LHC 24x60 degree	8.2	13.9
HE-LHC 18x60 degree	4.7	7.9

Common Challenge : 3 h Turnaround Time



with 160 days of physics,
70% availability, 3 h turnaround time

$\beta^* = 25 \text{ cm}$: $820 \text{ fb}^{-1}/\text{year}$

$\beta^* = 40 \text{ cm}$: $700 \text{ fb}^{-1}/\text{year}$

HE-LHC design goals and basic choices

physics goals:

- 2x LHC collision energy with FCC-hh magnet technology
- c.m. energy = 27 TeV \sim 14 TeV x 16 T/8.33T
- target luminosity \geq 4 x HL-LHC (cross section $\propto 1/E^2$)

key technologies:

- FCC-hh magnets (**curved!**) & FCC-hh vacuum system
- HL-LHC crab cavities & electron lenses

beam:

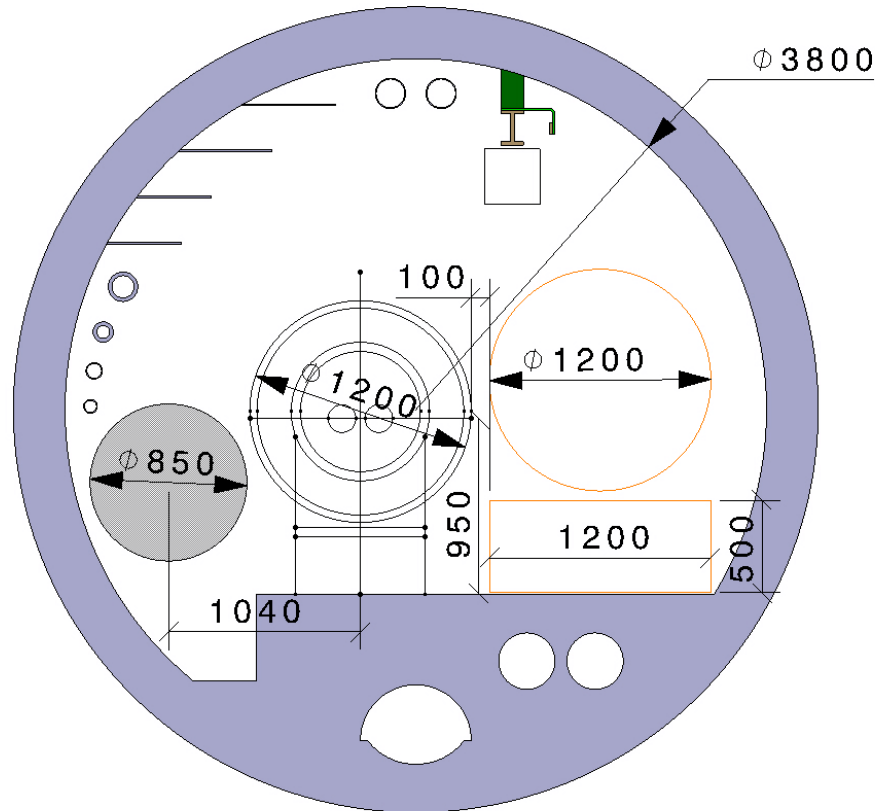
- HL-LHC/LIU parameters (25 ns baseline, also 5 ns option)

Extra challenge: Integrating HE-LHC in the LHC tunnel

tunnel diameter 3.8 m much smaller than FCC-hh's 6.0 m

use existing LHC tunnel
without tunnel
enlargement;
→ push for “compact”
16 T magnets (magnetic
cryostats?)

QRL diameter: 850 mm
(LHC 750 mm), max.
outer magnet cryostat
size: 1200-1250 mm



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Cost Estimate (2016 B\$ TPC)

