FCC-hh Workshop: 26-28 May Introduction

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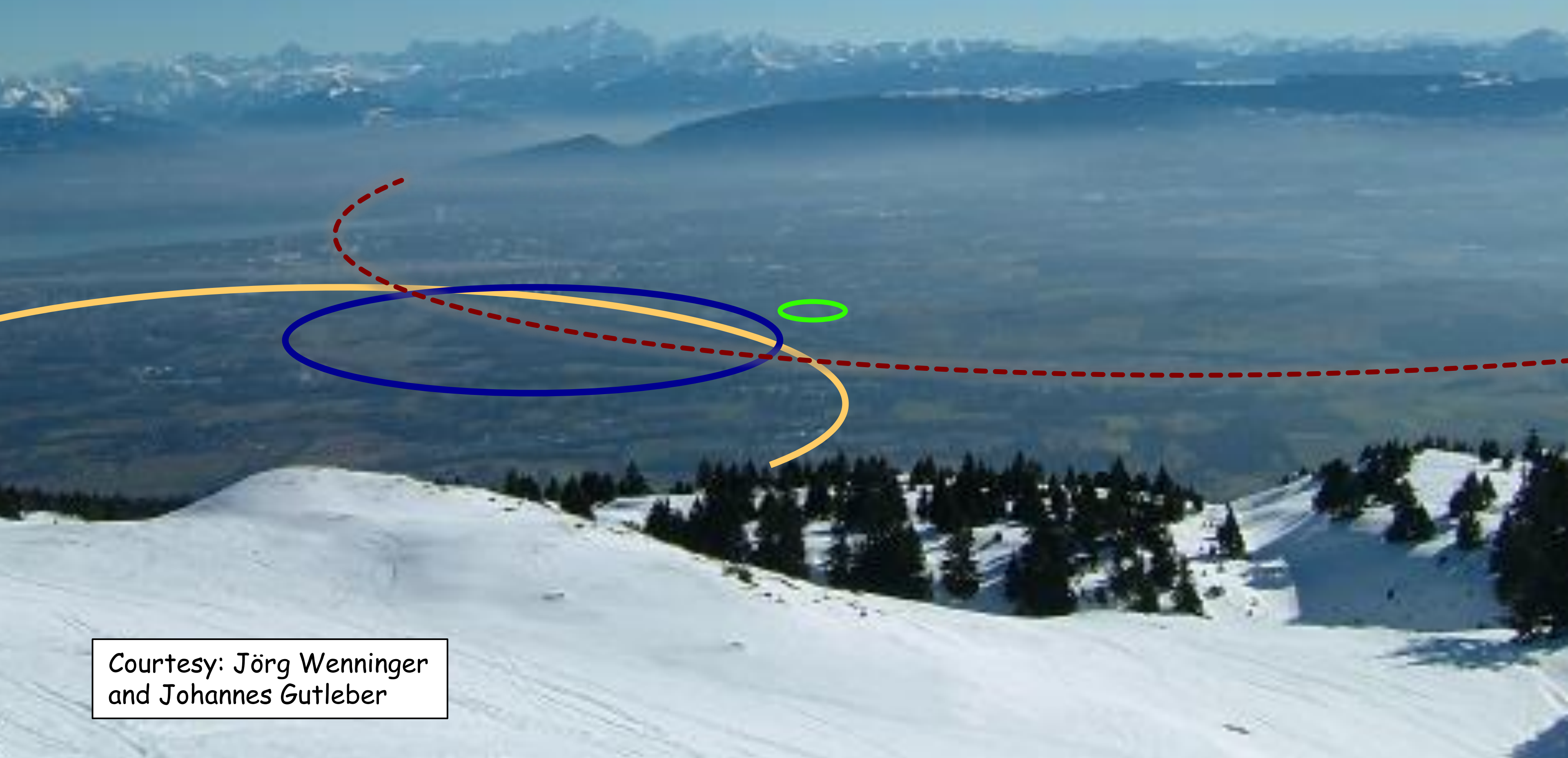


Courtesy: Jörg Wenninger and Johannes Gutleber

Following a recommendation of the European Strategy report, in Fall 2013 CERN Management set up the FCC project, with the main goal of preparing a Conceptual Design Report by the time of the next ES (~2018)

CDR main scope: physics motivations, technical feasibility (e.g. tunneling, magnets), design (machine, experiments, ..), cost

FCC kick-off meeting took place on 12-15 February 2014 at University of Geneva
http://indico.cern.ch/event/282344/timetable/#20140212.detailed
Very successful, almost 350 participants, strong international interest

Links established with similar studies in China and in the US

China:

- Future High-Energy Circular Colliders WS, Bejing, 16-17 December 2013: http://indico.ihep.ac.cn/conferenceDisplay.py?confId=3813
- 1st CFHEP (= Center for Future High Energy Physics) Symposium on Circular Collider Physics, Beijing, 23-25 February 2014: http://cfhep.ihep.ac.cn

US:

- Physics at a 100 TeV Collider, SLAC, 23-25 April 2014: https://indico.fnal.gov/conferenceDisplay.py?confId=7633
- Next steps in the Energy Frontier: Hadron Colliders, FNAL, 25-28 August 2014 https://indico.fnal.gov/conferenceDisplay.py?confId=7864

See talk by M.Benedikt's

Main areas for design study

Preparatory group for a kick-off meeting => Steering committee

Machines and infrastructure conceptual designs	Technologies R&D activities Planning	Physics experiments detectors
Infrastructure	High-field magnets	Hadron physics experiments interface, integration
Hadron collider conceptual design	Superconducting RF systems	$e^+ e^-$ coll. physics experiments interface, integration
Hadron injectors	Cryogenics	e^- - p physics and integration aspects
Lepton collider conceptual design	Specific technologies	
Safety, operation, energy management environmental aspects	Planning	

PP-131007-MBE_FCC Design Study

- ❑ Work started in November 2013
- ❑ ~ 250 people subscribed FCC-hh mailing list → hope efforts will continue to ramp up

Work outline - I

2	**Physics and experiments**
2.1	**Hadron collider physics**
2.1.1	**Exploration of EW Symmetry Breaking**
2.1.1.1	High-mass WW scattering, high mass HH production
2.1.1.2	Rare Higgs production/decays and precision studies of Higgs properties
2.1.1.3	Additional BSM Higgs bosons: discovery reach and precision physics programme
2.1.1.4	New handles on the study of non-SM EWSB dynamics
2.1.2	**Exploration of BSM phenomena**
2.1.2.1	Discovery reach for various scenarios
2.1.2.2	Theoretical implications of discovery/non-discovery of BSM scenarios
2.1.3	**Continued exploration of SM particles**
2.1.3.1	Physics of the top quark
2.1.3.2	Physics of the bottom quark
2.1.3.3	Physics of the tau lepton
2.1.3.4	W/Z physics
2.1.3.5	QCD dynamics
2.1.4	**Opportunities other than pp physics**
2.1.4.1	Heavy Ion Collisions
2.1.4.2	Fixed target experiments
2.1.4.3	Smaller-size experiments for dedicated purposes
2.1.5	**Theoretical tools for the study of 100 TeV collisions**
2.1.5.1	Parton Distribution Function
2.1.5.2	MC generators
2.1.5.3	N^nLO calculations

Main physics goals

High-precision studies, may require dedicated experiments

FCC-hh may be a very versatile facility
→ room for ideas for experiments of different types (collider, fixed target), size and scope (precise measurements, dedicated searches, …)
→ important to maintain flexibility in e.g. injector system

Work outline - II

2.2	**Hadron collider experiments**
2.2.1	**Detector performance**
2.2.1.1	Rapidity coverage for tracking, leptons, jets
2.2.1.2	Forward tracking and b-tag vs pile-up density
2.2.1.3	Electromagnetic calorimeter: dynamic range, forward granularity
2.2.1.4	Forward jet tagging
2.2.1.5	Muon resolution in the O(10 TeV) region
2.2.1.6	Optimisation of the bunch spacing (trigger and readout vs pile-up)
2.2.2	**Technical systems**
2.2.2.1	Technologies that require R&D
2.2.2.2	Detector technologies
2.2.2.3	Radiation effects
2.2.2.4	Shielding
2.2.2.5	ECAL
2.2.2.6	HCAL
2.2.2.7	Magnet system
2.2.2.8	Muon detection
2.2.2.9	Inner detector
2.2.2.10	Tracking
2.2.2.11	Trigger system
2.2.2.12	Data acquisition, detector controls and detector safety
2.2.3	**Detector machine Interface**
2.2.3.1	L*, TAS, TAN locations and specifications
2.2.3.2	Bunch structure, luminous region and crossing angle
2.2.3.3	Beam pipe and vacuum design
2.2.3.4	Fluencies, shielding, dose rates, activation, and radiological dose minimization
2.2.3.5	Physics and detector protection instrumentation in the long straight section

Performance requirements and experimental challenges

Detectors layout, R&D and technologies
→ important to maintain flexibility at this stage
→ synergies with FCC-ee, ILC and CLIC being established

Detector-machine interface issues

Present organization of FCC-hh

For the time being, one working group (plus Heavy Ion group):
- ❑ until now we benefitted from discussions in one forum
- ❑ we wanted to give opportunity to more people to join and give their input before defining a WG structure and assigning coordination roles

Meetings: typically every 3 weeks at fixed time slot: Thursday at 3:30PM

- ❑ Meeting page: http://indico.cern.ch/category/5258/
- ❑ Mailing list: fcc-experiments-hadron@cern.ch

To join the mailing list for communications on the activities of the Future Hadron Collider group, go to https://e-groups.cern.ch/e-groups/, search for the "fcc-experiments-hadron" e-group and subscribe.

Main goals of this Workshop

- ❑ Review progress since Feb kick-off meeting: physics, detectors, software, etc.
- ❑ Discuss future plans and milestones
- ❑ Organization: set up a WG structure (approximately mapping work plan), starting with macro-groups and increasing granularity with time
  → discussion on Wednesday

Main milestones of the FCC project

See talk by M.Benedikt's

Phase 1 → ends Spring 2015: "Exploration phase":
- ❑ explore all options and potential studies
- ❑ identify requirements and constraints

Phase 2 → September 2016: "Analysis phase":
conceptual study of chosen baseline(s) → relative merits and costs assessed

Phase 3 → End 2017: "Consolidation phase":
- ❑ consolidation of baseline (cost ..), physics scope in light also of LHC Run-2 results, …
- ❑ preparation of CDR

At the end of each phase:
- ❑ a workshop, followed by a review to indicate directions of next phase
- ❑ interim written reports

→ Spring 2015 is natural milestone for a first document covering ongoing studies of physics goals/potential and preliminary ideas about experiments and their layout

One highlight since the kick-off meeting

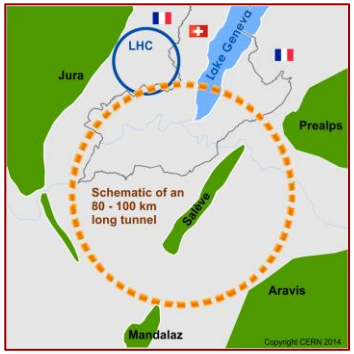
On the experimental side, work has focused on SW developments:

- detector studies reached level where (detailed) simulations needed to make progress
- physics studies need to go beyond MC generator level

- common effort of the full FCC project (hh, ee, eh)
- synergies also with CLIC/ILC work

- short-term goal (weeks):
  - -- develop a light framework (GaudiHive based)
  - -- ROOT-based EDM
  - -- interface to HepMC and various flavours of simulations (including DELPHES for detector parameterization, G4, etc.)
  - -- use existing tools (from LHC, CLIC, ..) as much as possible

→See talks by B. Hegner and C.Helsens



Why joining the FCC-hh efforts now ?

Intellectually very stimulating and exciting activity:

- establish the physics potential of a very powerful collider
- conceive challenging experiments at a challenging machine from scratch
- develop/improve (new) detector technologies

For the more senior people (including myself):
it is our duty to prepare the future for the younger generations, as our predecessors made for us with the LHC

SPARES

Parameters of a ~ 100 TeV pp collider

Version 1.0 (2014-02-11) — Preliminary, in progress !	LHC	HL-LHC	FHC-hh
c.m. Energy [TeV]	14	14	100
Circumference C [km]	26.7	26.7	100 (83)
Dipole field [T]	8.33	8.33	16 (20)
Peak luminosity [10^{34} $cm^{-2}s^{-1}$]	1.0	5.0	5.0
Peak no. of inelastic events / crossing at - 25 ns spacing - 5 ns spacing	27	135 (lev.)	171 34
Number of bunches at - 25 ns - 5 ns	2808	2808	10600 (8900) 53000 (44500)
Bunch population N_b [10^{11}] - 25 ns - 5 ns	1.15	2.2	1.0 0.2
Nominal transverse normalized emittance [mm] - 25 ns - 5 ns	3.75	2.5	2.2 0.44
IP beta function [m]	0.55	0.15 (min)	1.1
RMS IP spot size [mm] - 25 ns - 5 ns	16.7	7.1 (min)	6.8 [illegible]
Stored beam energy [GJ]	0.392	0.694	8.4 (7.0)

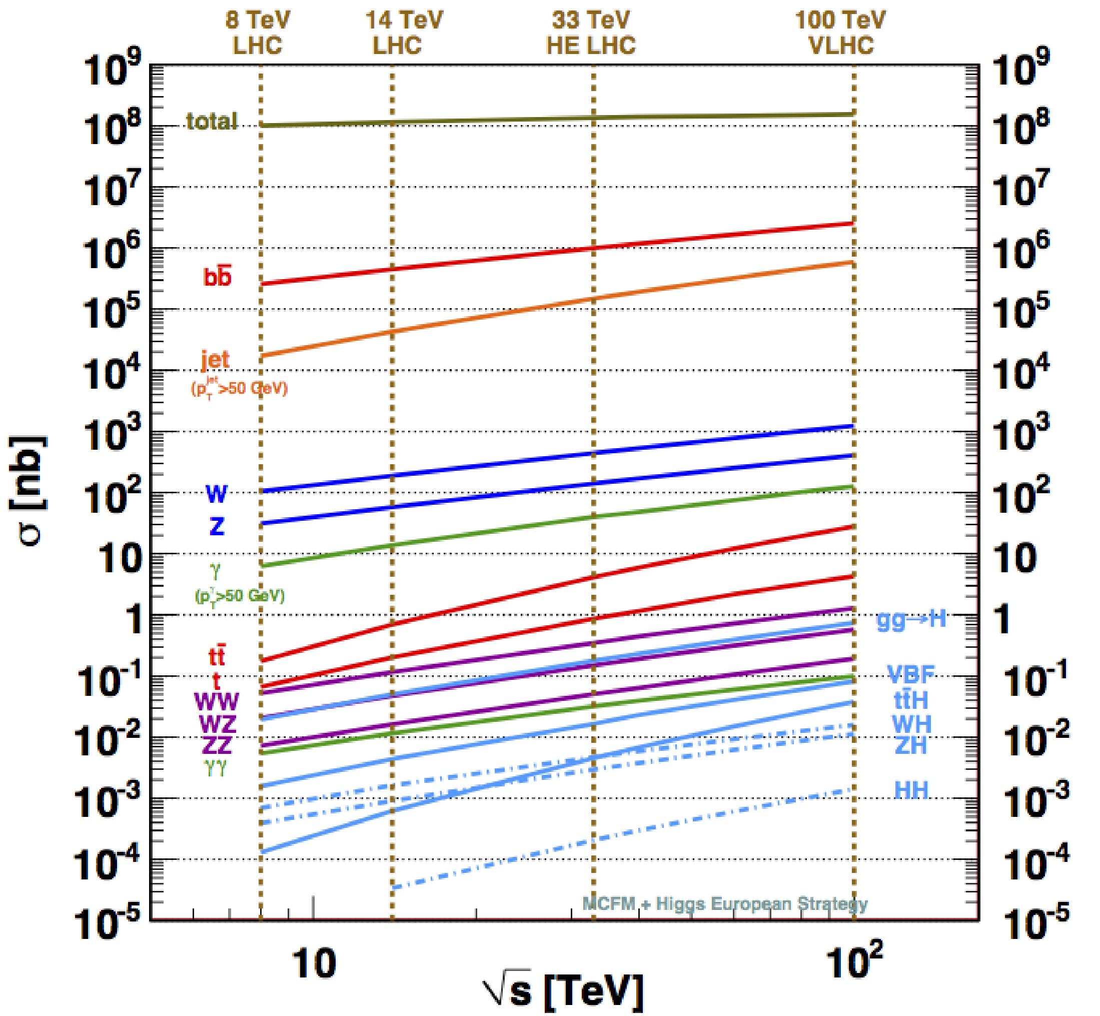
Nb_3Sn ok up to 16 T;
20 T needs HTS

Largest integrated luminosity needed for heavy physics
→ $L=10^{35}$ may be reached
→ bunch-spacing 5 ns to mitigate pile-up and e-cloud

25 x LHC !

Cross sections vs √s

Snowmass report: arXiv:1310.5189

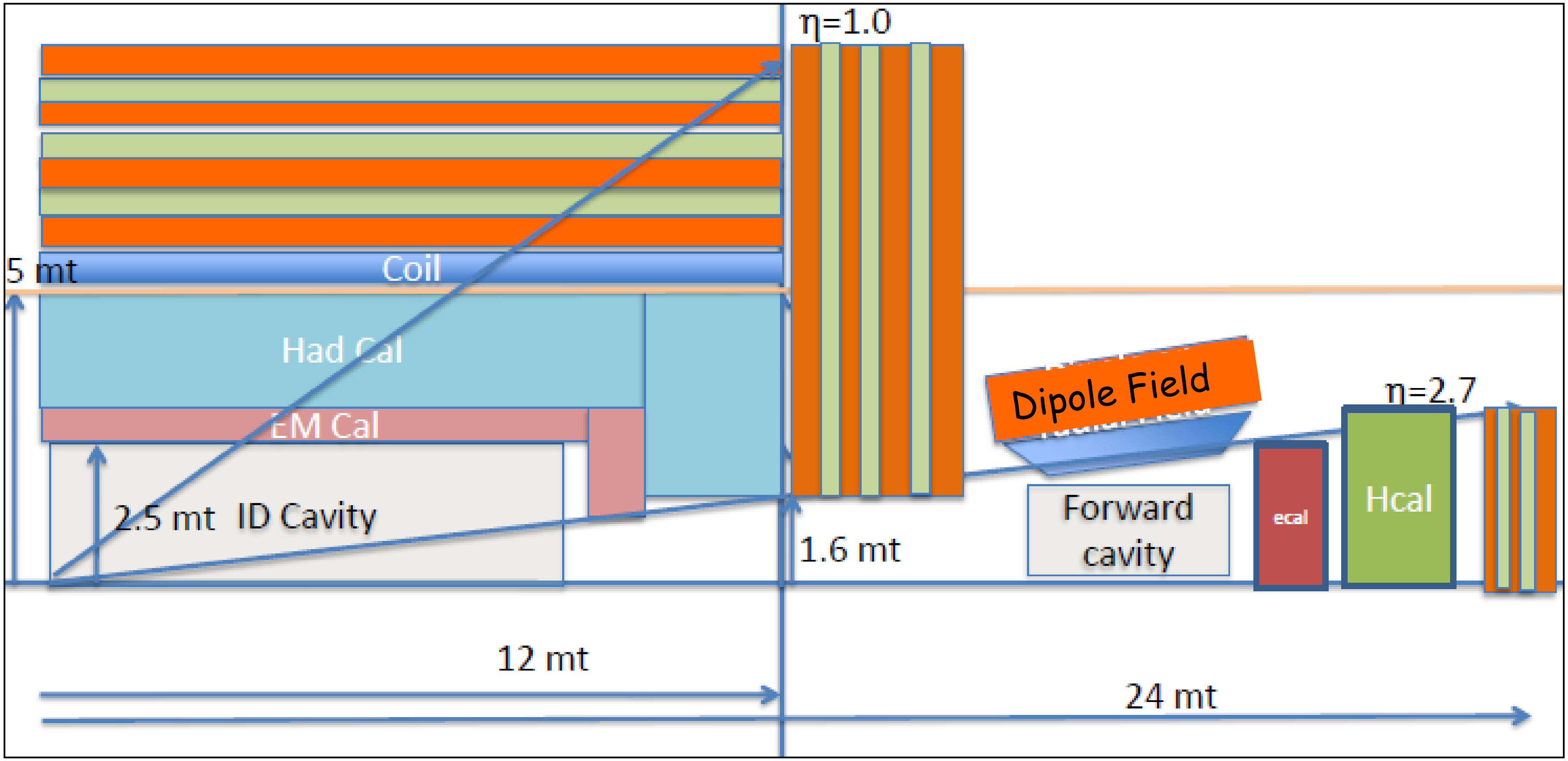


Process	σ (100 TeV)/σ (14 TeV)
Total pp	1.25(*)
W	~7
Z	~7
WW	~10
ZZ	~10
tt	~30
H	~15 (ttH ~60)
HH	~40
stop (m=1 TeV)	~10^3

(*) Note: radiation doses only x2 LHC for same integrated luminosity

Studies will be made vs √s:
- comparison with HE-LHC
- if cost forces machine staging

First ideas about detector layout: solenoid option



- ❑ Need BL^2 ~10 x ATLAS/CMS to achieve 10% muon momentum resolution at 10-20 TeV
- ❑ Solenoid: B=5T, R_{in}=5-6m, L=24m → size is x2 CMS. Stored energy: ~ 50 GJ
- ❑ > 5000 m^3 of Fe in return joke → alternative: thin (twin) lower-B solenoid at larger R to capture return flux of main solenoid
- ❑ Forward dipole à la LHCb: B~10 Tm
- ❑ Calorimetry: ≥ 12 λ for shower containment; W takes less space but requires 50ns integration for slow neutrons; speed advantageous for 5ns option (→ Si active medium ?)