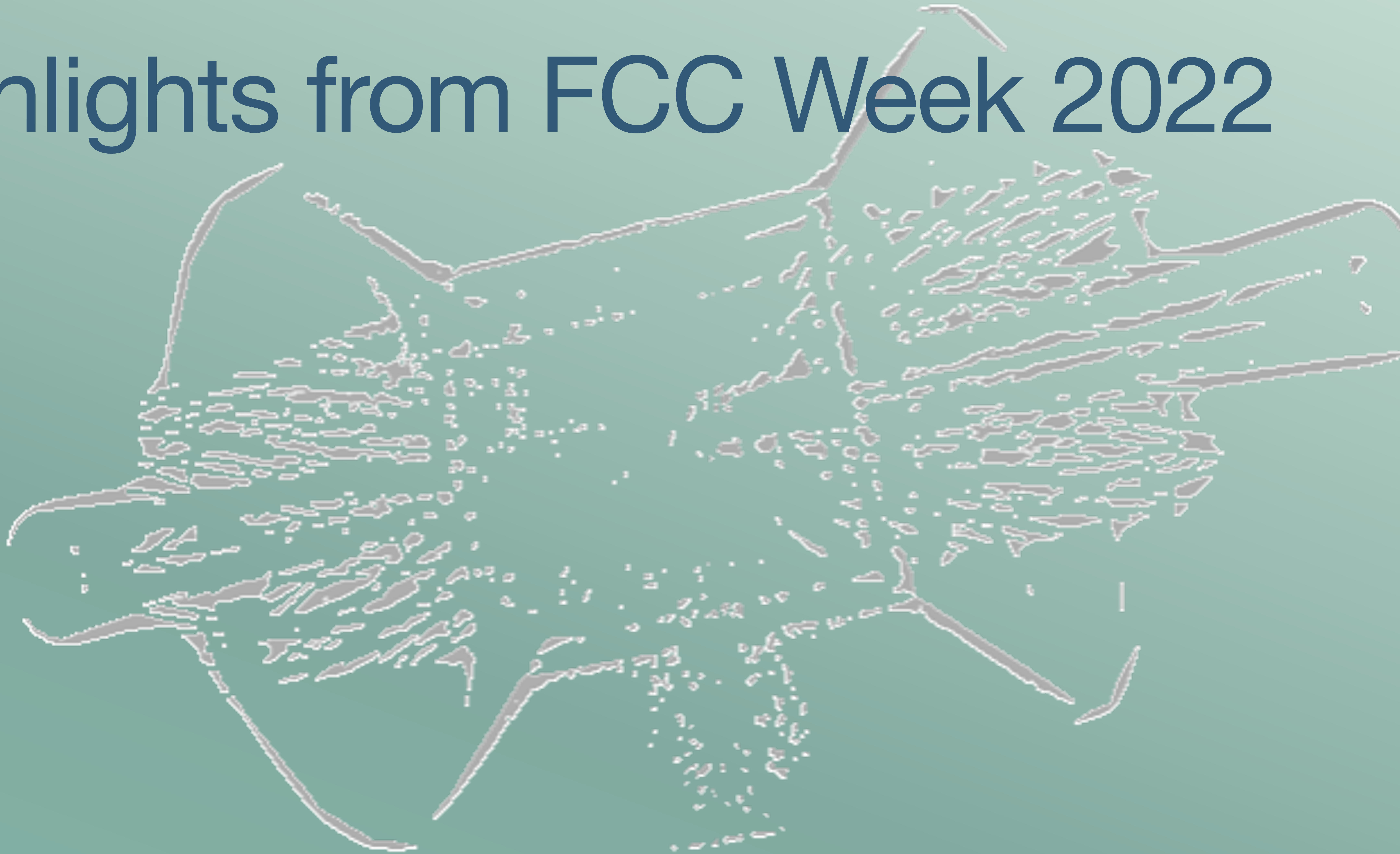
Selected highlights from FCC Week 2022

ETP weekly meeting
June 20, 2022



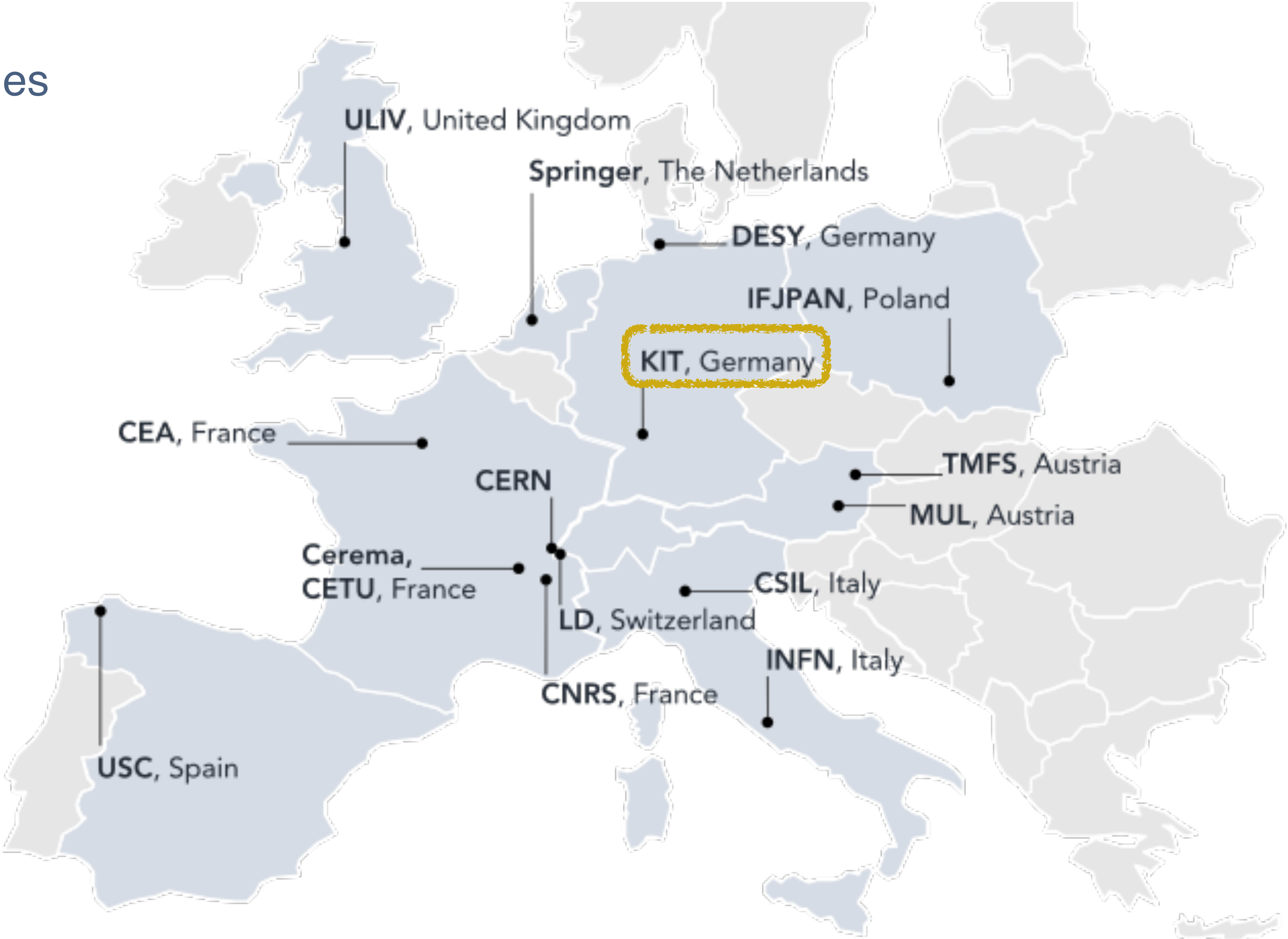
Xunwu Zuo

FCC

91 km ring near CERN for ee and hh collision (and maybe more) experiments

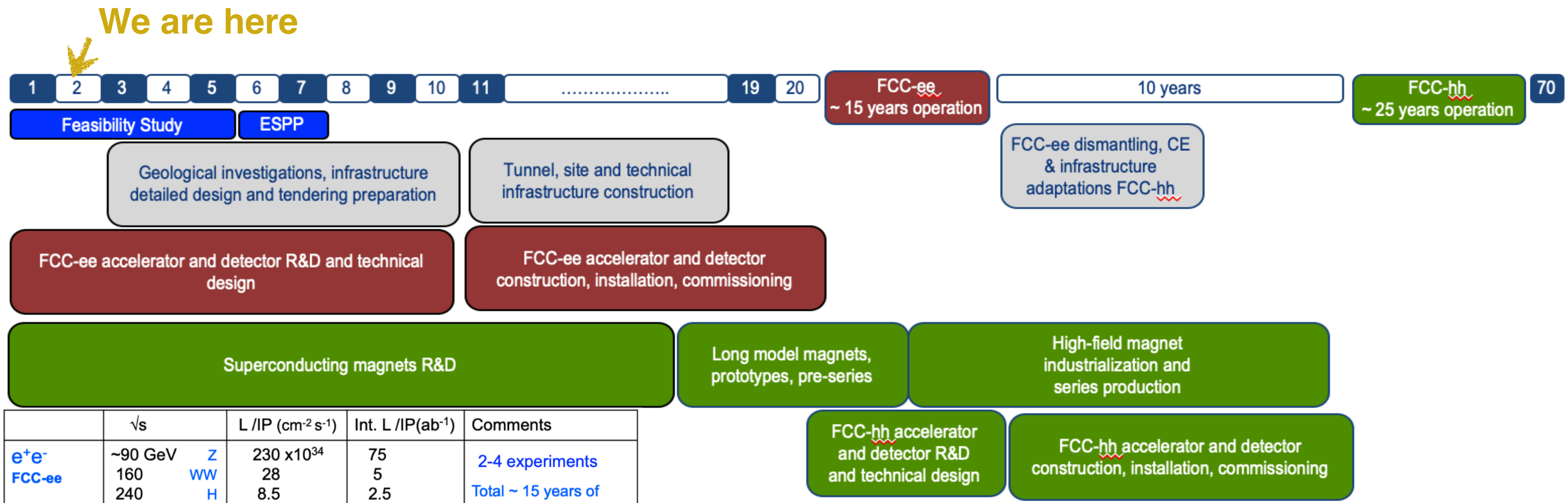
(Some of) current FCC collaborators

- Showing EC H2020 beneficiaries



Planned timeline

We are here



	$\sqrt{s}$	L /IP ($cm^{-2} s^{-1}$)	Int. L /IP(ab^{-1})	Comments
e^+e^- FCC-ee	~90 GeV Z 160 WW 240 H ~365 top	230 $\times 10^{34}$ 28 8.5 1.5	75 5 2.5 0.8	2-4 experiments Total ~ 15 years of operation
pp FCC-hh	100 TeV	5 x 10^{34} 30	20-30	2+2 experiments Total ~ 25 years of operation
PbPb FCC-hh	$\sqrt{s_{NN}}$ = 39TeV	3 x 10^{29}	100 nb^{-1}/run	1 run = 1 month operation
ep Fcc-eh	3.5 TeV	1.5 10^{34}	2 ab^{-1}	60 GeV e- from ERL Concurrent operation with pp for ~ 20 years
e-Pb Fcc-eh	$\sqrt{s_{eN}}$ = 2.2 TeV	0.5 10^{34}	1 fb^{-1}	60 GeV e- from ERL Concurrent operation with PbPb

- ❑ Feasibility Study: 2021-2025
- ❑ If project approved before end of decade → construction can start beginning 2030s
- ❑ FCC-ee operation ~2045-2060
- ❑ FCC-hh operation ~2070-2090++

Feasibility study

- **Total CERN funding for the Feasibility Study 2021 - 2025: 100 MCHF material & personnel**
- **H2020 FCCIS Design Study**
- **Swiss CHART programme**
- **FCC collaboration resources**

FCC week 2022

Review status on

- Infrastructure & civil engineering
- Accelerator technology & design
- **Physics, experiment, and detector**
  - Physics performance
  - Detector technology & design
  - Software infrastructure

Also, after two years of remotely working, for people in the community to catch up/get familiar with each other

FCC Week

Version: 0.19 Date: 30.05.2022

Day	Monday	Tuesday				Wednesday			Thursday				Friday	Time
Room	Plenary	Parallel 1	Parallel 2	Parallel 3	Parralel 4	Parallel 1	Parallel 2	Parallel 3	Parallel 1	Parallel 2	Parallel 3	Parallel 4	Plenary	Room
	Campus Cordeliers	CICSU Jussieu				Campus Cordeliers		Réfectoire Cordeliers	Campus Cordeliers			Réfectoire Cordeliers	Campus Cordeliers	
Time	FARABOEUF	Room 105	Room 107	Room 109	Room 116	ROUSSY	PASQUIER		FARABOEUF	PASQUIER	ROUSSY		FARABOEUF	Time
09:00-09:30		FCCee accelerator FCCIS WP2	Phy Programme/ Performance	FCCIS WP4 Socio Econom		FCC hh accelerator	PED: EPOL	FCCIS WP3 Placement	PED/ACC: FCCee EPOL	RF Points for FCC-ee	Technology		Summaries	09:00-09:30
09:30-10:00	Plenary session													09:30-10:00
10:00-10:30		T. Raubenheimer	S. Jadach			G. Apollinari	E. Gianfelice	F. Eder	F. Willeke	J. P. Tock	R. Losito		A.M. Valente	10:00-10:30
10:30-11:00	L. Rivkin	*Coffee break*				*Coffee break*			*Coffee break*				*Coffee break*	10:30-11:00
11:00-11:30	*Coffee break*	FCCee accelerator FCCIS WP2	Phy Programme/ Performance	SRF Directions for R&D		Technology	PED: Detector Concepts	Civil Engineering	PED/ACC: FCCee MDI	Electricity and Cooling	Technology		Summaries	11:00-11:30
11:30-12:00	*Plenary session*													11:30-12:00
12:00-12:30	B. Heinemann	M. Minty	F. Blekman	O. Brunner			S. Eno	F. Bordry	M. Chamizo Llatas	I. Ruehl	T. Pieloni		R. Aleksan	12:00-12:30
12:30-14:00	*Lunch break*	*Lunch break*				*Lunch break*			*Lunch break*					12:30-13:00
14:00-14:30		FCCee injector FEB	Phy Programme/ Performance	Technology SRF	ISC meeting CLOSED	FCCee accelerator	PED: Detector Concepts	FCCIS WP5 Collaboration	PED/ACC: FCCee MDI	Transport & logistics, Safety				14:00-14:30
14:30-15:00	Plenary session													14:30-15:00
15:00-15:30		A. Grudiev	G. Cacciapaglia	A.M. Valente	F. Gianotti	A. Faus-Golfe	F. Gaede	M. Chrzaszcz	K. Oide	C. Prasse				15:00-15:30
15:30-16:00	J. Mnich	*Coffee break*				*Coffee break*			*Coffee break*					15:30-16:00
16:00-16:30	*Coffee break*	FCCee injector FEB	Phy Programme/ Performance	Technology SRF	ISC meeting CLOSED	FCCee accelerator	TI Geodesy and survey	FCCIS WP5 Communication				France, special session		16:00-16:30
16:30-17:00	Plenary session													16:30-17:00
17:00-17:30		I. Chaikovska	M. Chamizo Llatas	T. Proslier	F. Gianotti	F. Carlier	A. Wieser							17:00-17:30
17:30-18:00	M. Lamont					Early Career Researchers	ICB meeting CLOSED	M. Chalmers				Poster session & DRINK		17:30-18:00
18:00-18:30														18:00-18:30
18:30-19:00	*WELCOME RECEPTION*					E. Rabinovici	P. Chomaz							18:30-19:00
19:00-19:30												Public event		19:00-19:30
19:30-20:00														19:30-20:00
20:00-20:30	*(Réfectoire Cordeliers)*					*CONFERENCE DINNER*						*VERRE DE L'AMITIE*		20:00-20:30
20:30-21:00														20:30-21:00

List of selected highlights

Main dishes

(Physics opportunities)

- Electroweak physics
  - m_W measurement
- Flavor physics
  - $B^0 \to K^* \tau^+ \tau^-$
  - $B^+ / B_c^+ \to \tau^+ \nu_\tau$
- QCD measurements
- Higgs physics
  - Higgs self-coupling
  - Higgs mass

Drinks

(Experiment setups)

- Detector concepts
- Beam energy calibration
- Flavor tagging
- Software framework

Desserts

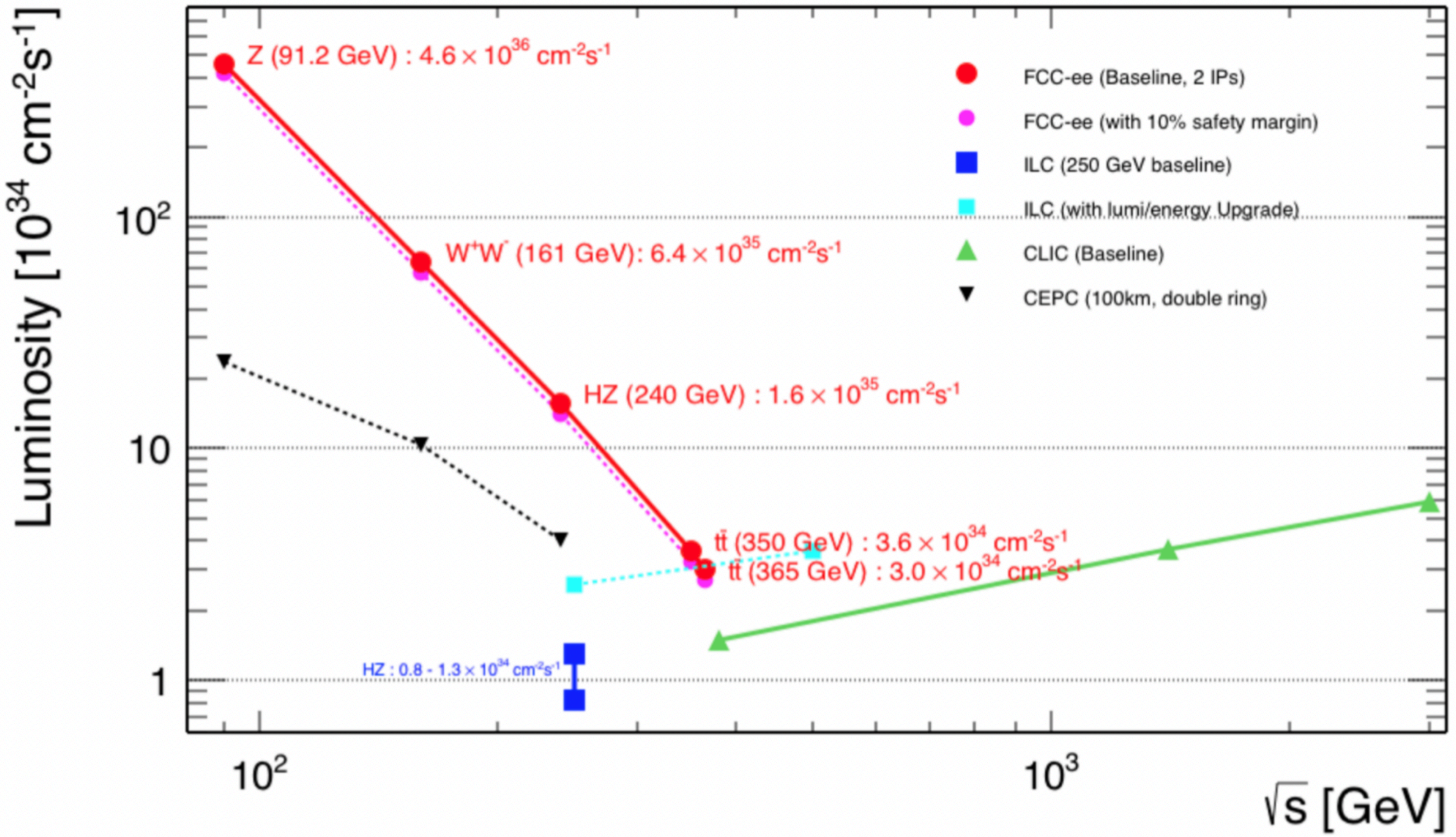
(Civil engineering and logistics)

N.B. the menu does not reflect the importance of these projects, but rather the structure of this talk

FCC-ee dataset

Much more than just “H-factory”

- Splendid datasets expected with a plethora of physics opportunities
  - EW precision measurement (Z, W, H, t)
  - QCD precision measurement (α_s)
  - Flavor physics (b, c, τ)
  - Rare decay searches
  - BSM particles (ALPs, dark photons, LLPs)
- Meanwhile, experimental challenges-opportunities for tracking, vertexing, PID, jet tagging, etc.



Dataset	Operation	Events	$\sigma(E_{CM})$
Z	4 years	5×10^{12}	0.1 MeV
WW	2 years	$> 10^{8}$	0.3 MeV
ZH	3 years	$> 10^{6}$	1 MeV
tt	5 years	1×10^{6}	2 MeV

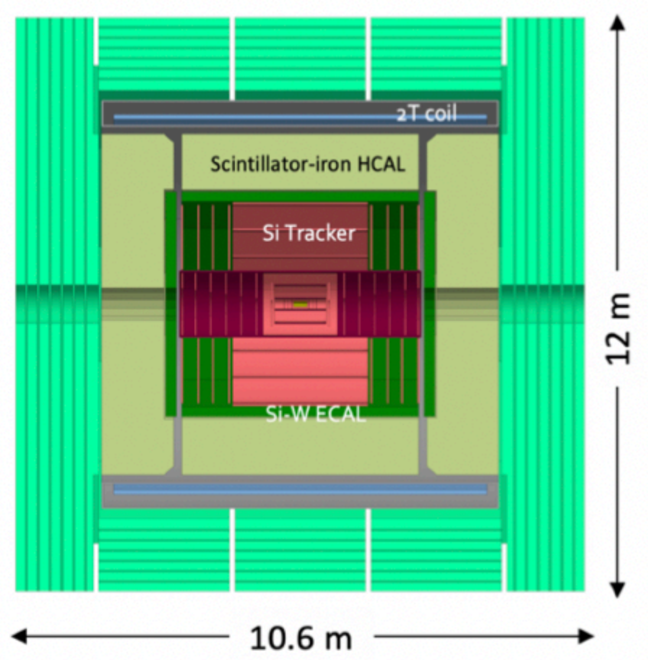
Detector concepts

Requirements:

- Higgs and top: lepton momentum, flavor tagging (with PID)
- Z: extremely accurate acceptance, stable B field, lepton momentum
- W: jet angular calibration
- Flavor: vertex precision, PID
- LLP: far reach of tracking capability

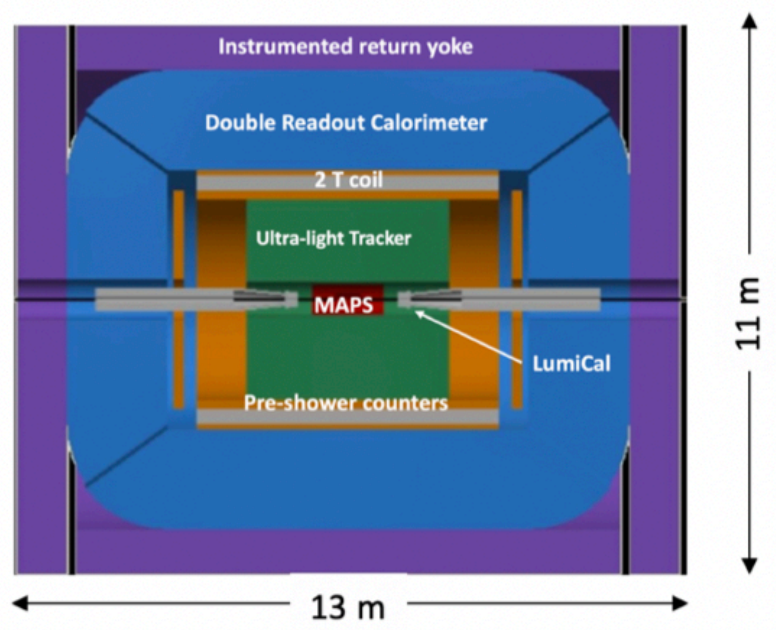
Mogens Dam at FCC Week

CLD



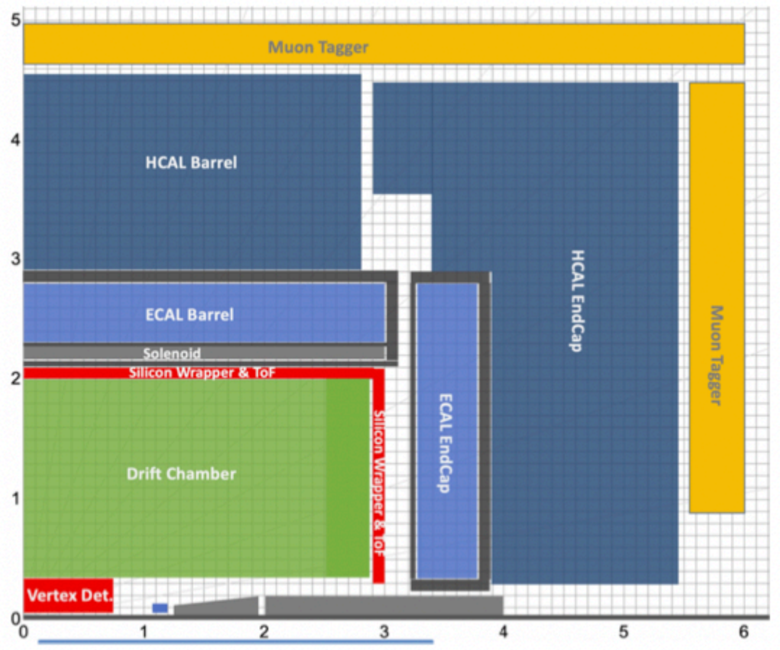
- Well established design
  - ILC -> CLIC detector -> CLD
- Engineering needed to make able to operate with continous beam (no pulsing)
  - Cooling of Si-sensors & calorimeters
- Possible detector optimizations?
  - σ_p/p, σ_E/E
  - PID ($\mathcal{O}$(10 ps) timing and/or RICH)?
  - …
- Robust software stack
  - Now ported (wrapped) to FCCSW

IDEA



- Less established design
  - But still ~15y history: 4th Concept
- Developed by very active community
  - Prototype construction / test beam compains
  - Italy, Korea,…
- Is IDEA really two concepts? Or will it be?
  - w, w/o crystals
- Software under active development
  - Being ported to FCCSW

Noble Liquid ECAL based



- A design in its infancy
- High granul Noble Liquid ECAL is the core
- Very active Noble Liquid R&D team
  - Readout electrodes, feed-throughs, electronics, light cryostat, …
  - Software & performance studies
- Full simulation of ECAL available in FCCSW

Electroweak physics

Paradigm shift:

Before the LHC, people had a clear “plan” for discovering new physics.

After 10 years of the LHC, no hint of specific BSM models.

Instead of direct searches for various signatures, examine SM very precisely to understand: what kind of new physics to expect, and at what energy scale.

Unparalleled opportunity:

The “ultimate” Z dataset (5×10^{12}) in our era (likely also for the far future).

The cleanest possible way to measure W and t properties.

Bring humans’ knowledge of EW physics to a completely new level.

Electroweak physics

- O(10-100) times more precise than the current best measurements
  - Expected to be sensitive to new physics described by dim 6 operators up to $\Lambda \sim 70$ TeV.
  - Clues for what to expect / not to expect at FCC-hh
- In many cases, $\sigma_{syst} \gg \sigma_{stat}$
  - Fundamental improvements to be done in experimental techniques and theoretical calculations.

arxiv:2106.13885

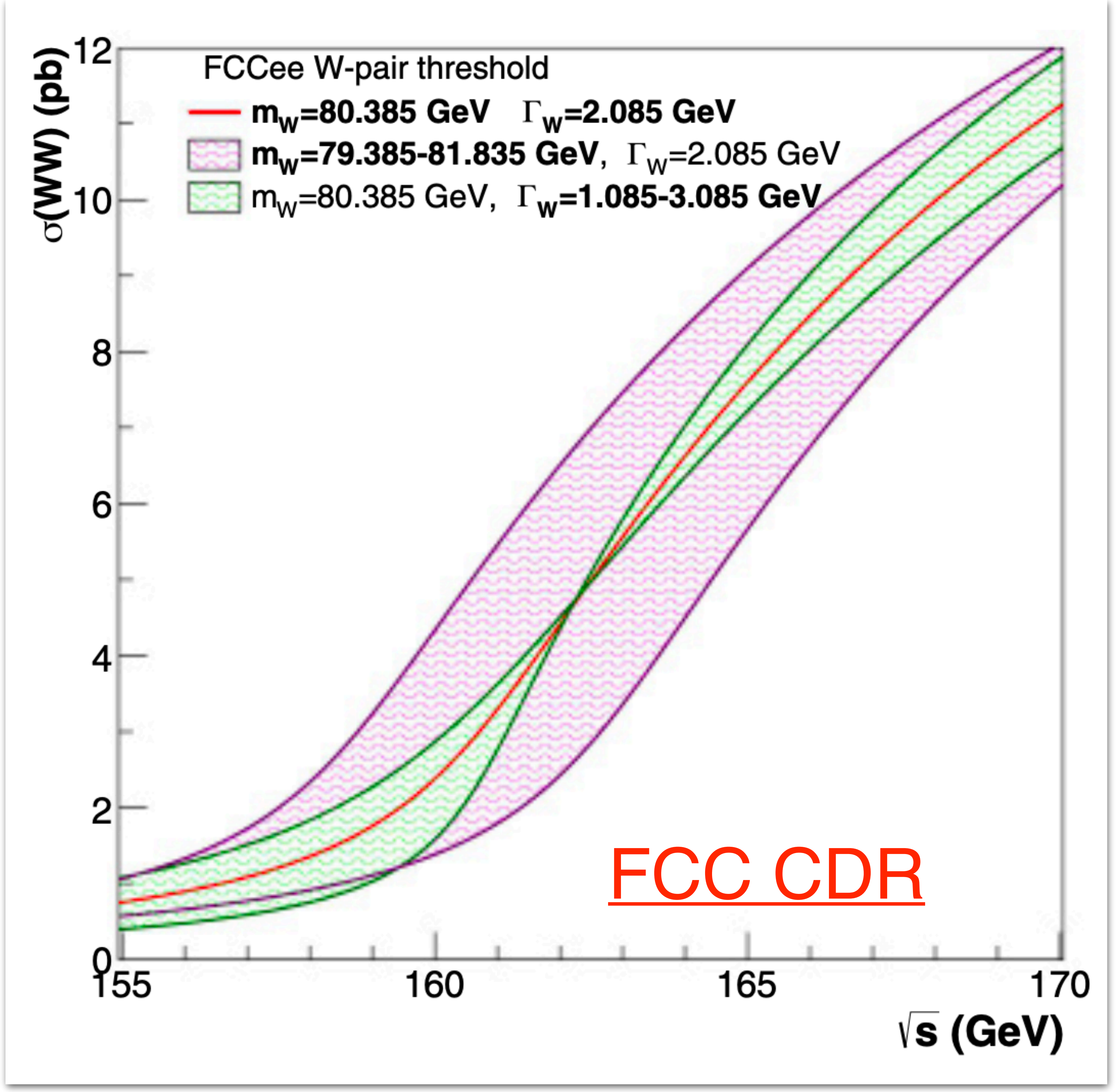
Observable	present value ± error	FCC-ee **Stat.**	FCC-ee Syst.	Comment and leading exp. error
m_Z (keV)	91186700 ± 2200	**4**	100	From Z line shape scan Beam energy calibration
Γ_Z (keV)	2495200 ± 2300	**4**	25	From Z line shape scan Beam energy calibration
$\sin^2\theta_W^{eff}(\times 10^6)$	231480 ± 160	**2**	2.4	from $A_{FB}^{\mu\mu}$ at Z peak Beam energy calibration
$1/\alpha_{QED}(m_Z^2)(\times 10^3)$	128952 ± 14	**3**	small	from $A_{FB}^{\mu\mu}$ off peak QED&EW errors dominate
R_ℓ^Z $(\times 10^3)$	20767 ± 25	**0.06**	0.2-1	ratio of hadrons to leptons **acceptance for leptons**
$\alpha_s(m_Z^2)$ $(\times 10^4)$	1196 ± 30	**0.1**	0.4-1.6	from R_ℓ^Z above
σ_{had}^0 $(\times 10^3)$ (nb)	41541 ± 37	**0.1**	4	peak hadronic cross section luminosity measurement
$N_\nu(\times 10^3)$	2996 ± 7	**0.005**	1	Z peak cross sections Luminosity measurement
R_b $(\times 10^6)$	216290 ± 660	**0.3**	< 60	ratio of $b\bar{b}$ to hadrons stat. extrapol. from SLD
$A_{FB}^b, 0$ $(\times 10^4)$	992 ± 16	**0.02**	1-3	b-quark asymmetry at Z pole from jet charge
$A_{FB}^{pol,\tau}$ $(\times 10^4)$	1498 ± 49	**0.15**	<2	τ polarization asymmetry τ decay physics
τ lifetime (fs)	290.3 ± 0.5	**0.001**	0.04	radial alignment
τ mass (MeV)	1776.86 ± 0.12	**0.004**	0.04	momentum scale
τ leptonic $(\mu\nu_\mu\nu_\tau)$ B.R. (%)	17.38 ± 0.04	**0.0001**	0.003	e/μ/hadron separation
m_W (MeV)	80350 ± 15	**0.25**	0.3	From WW threshold scan Beam energy calibration
Γ_W (MeV)	2085 ± 42	1.2	0.3	From WW threshold scan Beam energy calibration
$\alpha_s(m_W^2)(\times 10^4)$	1170 ± 420	**3**	small	from R_ℓ^W
$N_\nu(\times 10^3)$	2920 ± 50	**0.8**	small	ratio of invis. to leptonic in radiative Z returns
m_{top} (MeV/c^2)	172740 ± 500	**17**	small	From $t\bar{t}$ threshold scan QCD errors dominate
Γ_{top} (MeV/c^2)	1410 ± 190	45	small	From $t\bar{t}$ threshold scan QCD errors dominate
$\lambda_{top}/\lambda_{top}^{SM}$	1.2 ± 0.3	**0.10**	small	From $t\bar{t}$ threshold scan QCD errors dominate
ttZ couplings	± 30%	0.5 – 1.5%	small	From $\sqrt{s} = 365$ GeV run

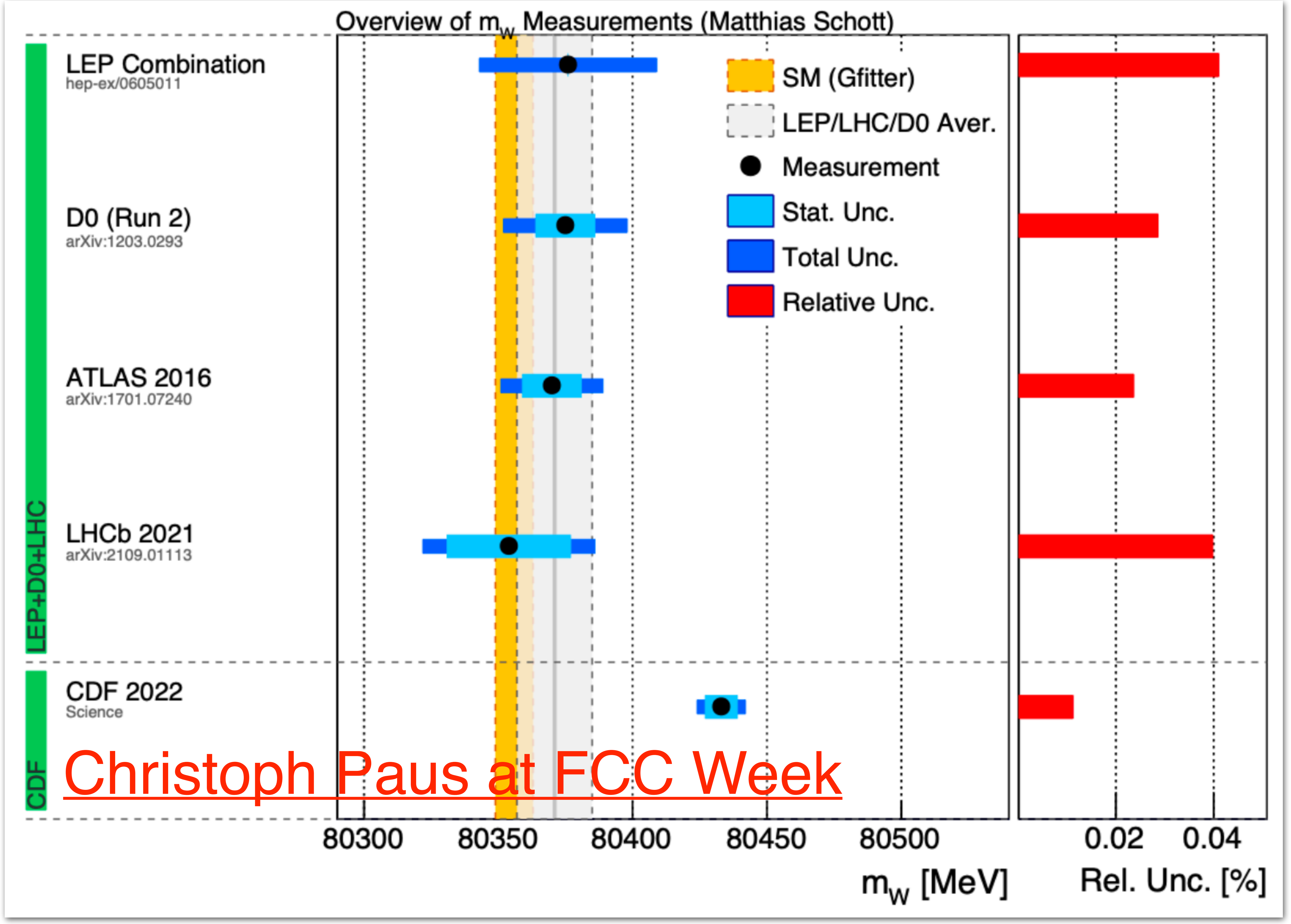
Electroweak case - m_W

Scan production threshold

- Clean and robust measurement

- SM $\sigma(m_W)$ = 6 MeV, CDF $\sigma(m_W)$ = 9 MeV
- Expect $\sigma(m_W)$ ~ 0.25 MeV at FCC-ee





Note: can also be measured from the reconstruction side at FCC-ee and used backward to examine the complex techniques developed in hadron experiments

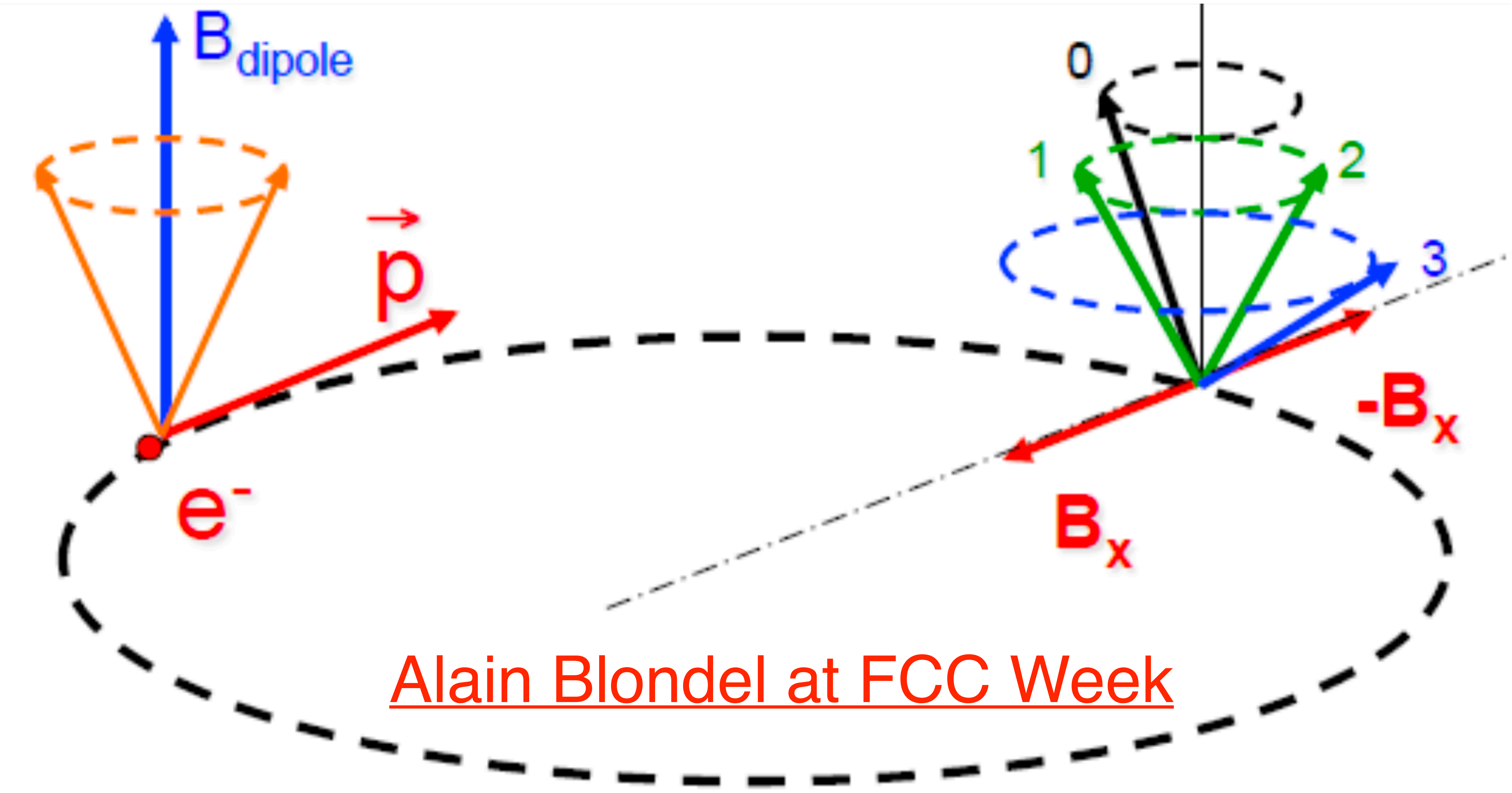
Beam energy calibration

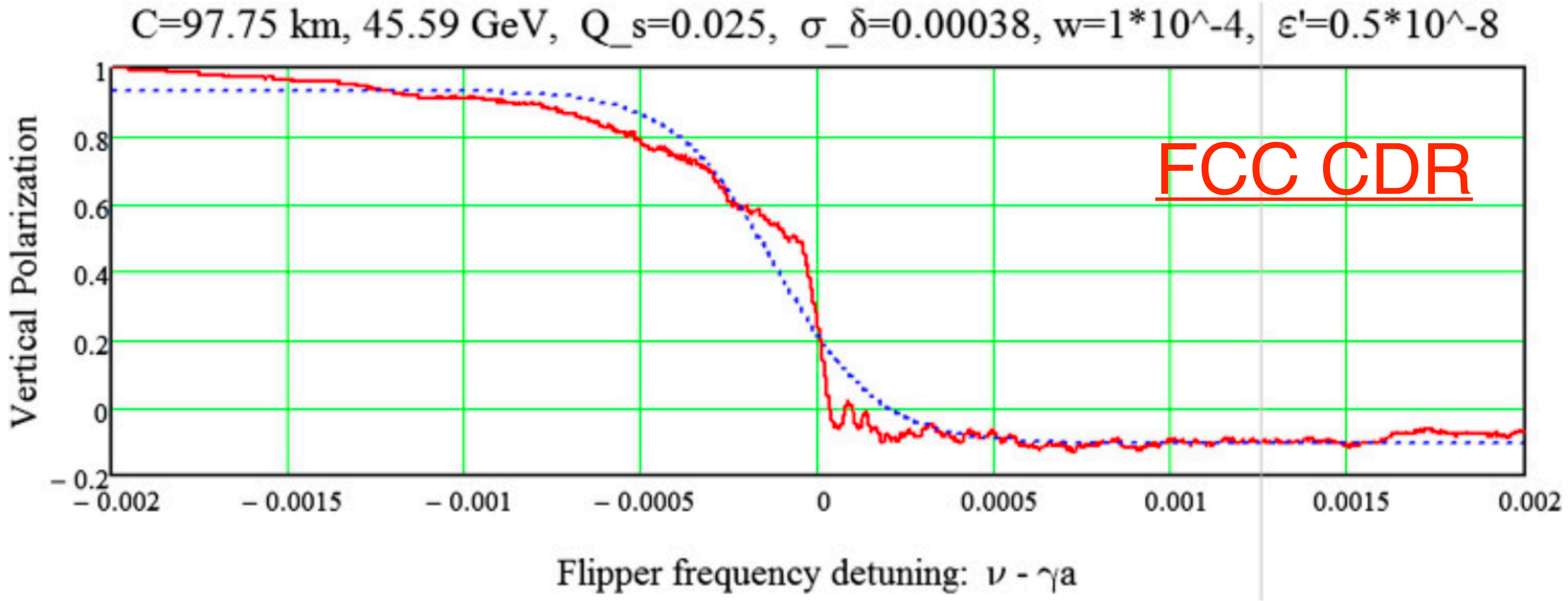
Calibration by resonant depolarization

- Precession frequency for polarized electrons is directly related to beam energy.
- Spin tune, the number of precession per tunnel-cycle defined as.

$$\nu = \frac{g_e - 2}{2}\frac{E_b}{m_e} = \frac{E_b \text{ (in GeV)}}{0.4406486(1)}$$

- The RF kicker synchronized with the precession frequency would gradually tilt the spin direction to the horizontal plane (vertical depolarization)





Flavor physics

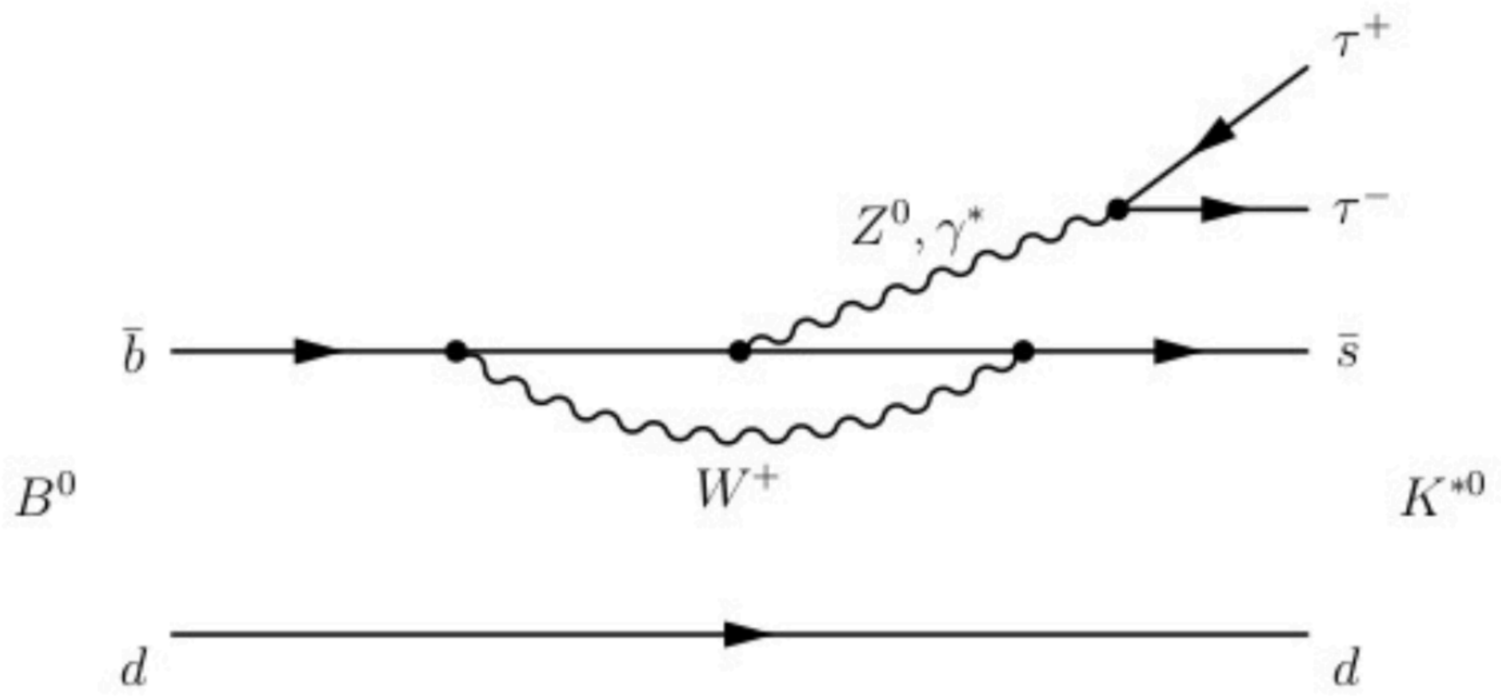
- With $\mathbf{5 \times 10^{12}}$ Z bosons
  - 10^{12} b quarks
    - about 13x as many B^0/B^+ as Belle II (50 ab^{-1})
    - All species of b-hadrons are produced
  - 10^{12} c quarks, 3.3×10^{11} τ leptons
    - about 10x as many c-hadrons as Belle II (50 ab^{-1}) Belle II physics book
    - about 8x as many τ as Super tau-charm factory STCF slides
  - Decay products significantly boosted
  - LFV $Z \to \tau\mu$, $Z \to \mu e$, $Z \to \tau e$ decays
- More opportunities in H-dataset (LFV decay) and WW-dataset (CKM measurements).

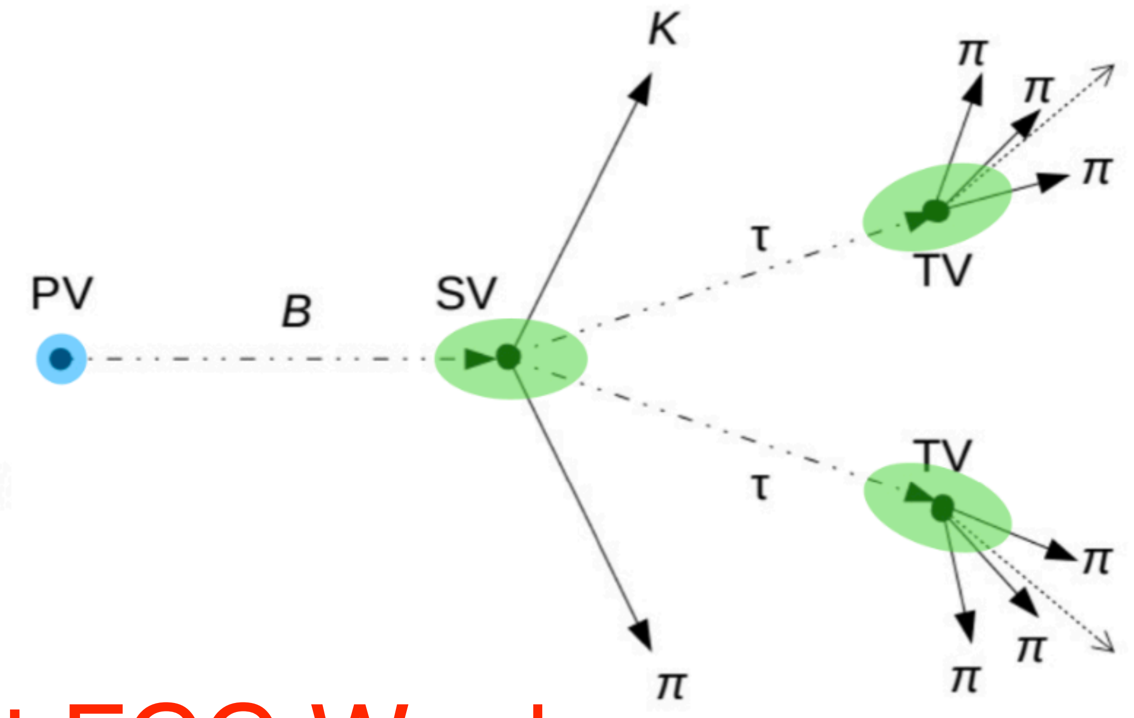
Attribute	$\Upsilon(4S)$	pp	Z^0
All hadron species		✓	✓
High boost		✓	✓
Enormous production cross-section		✓	
Negligible trigger losses	✓		✓
Low backgrounds	✓		✓
Initial energy constraint	✓		(✓)

Next-generation machine for all flavor physics

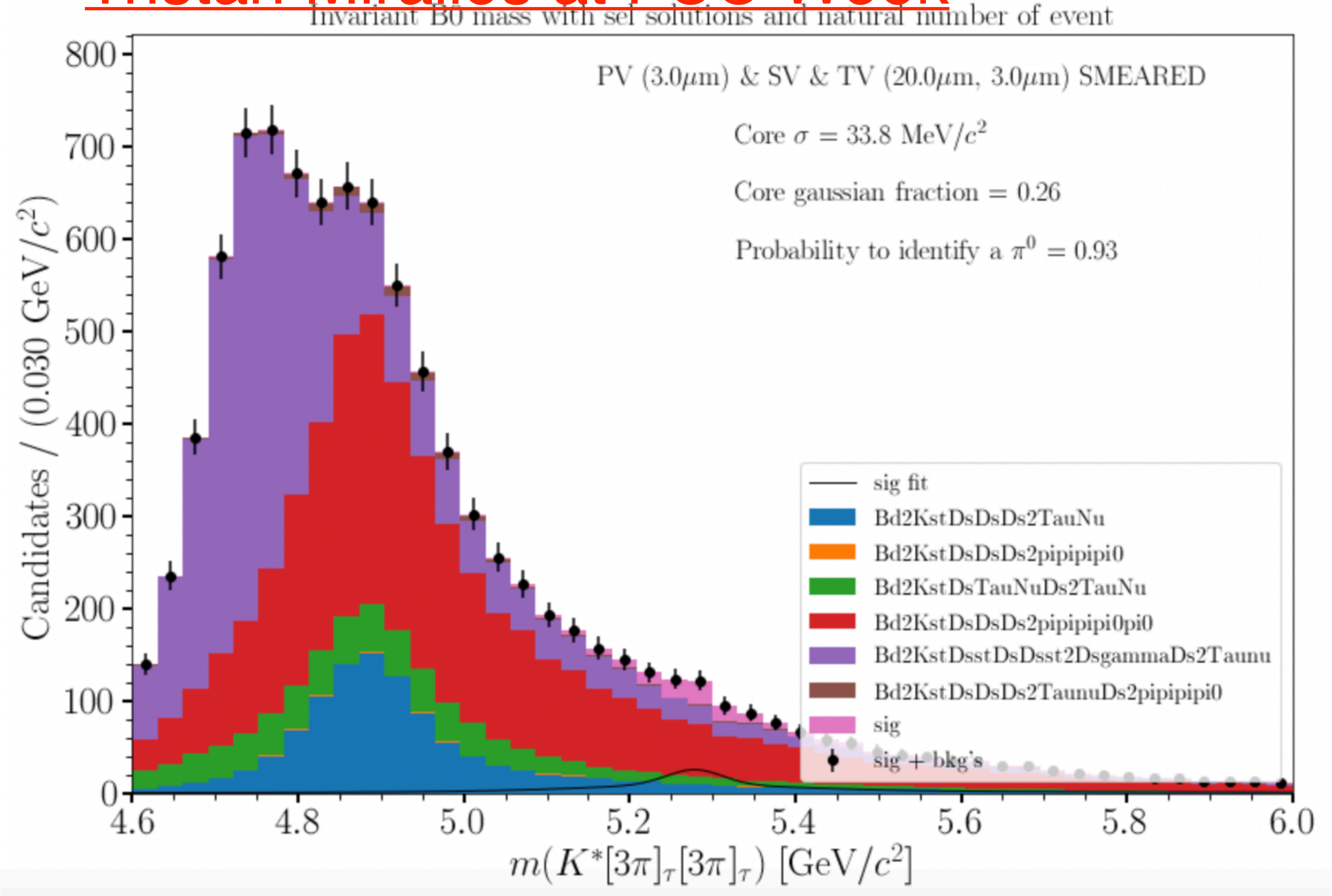
Flavor case - $B^0 \to K^* \tau^+ \tau^-$

- Compare with current LFV in $b \to s\ell\ell$ between e and μ
- Super rare decay $BR_{SM} \sim$ O(10^{-7})
  - Current limit at 10^{-3} (from BaBar)
- Highly sensitive to BSM enhancements
- Strong case to study/demand detector performance
- Backgrounds are overwhelming, but the signal is still visible
  - (WIP) significance ~ 3
  - To further reduce backgrounds



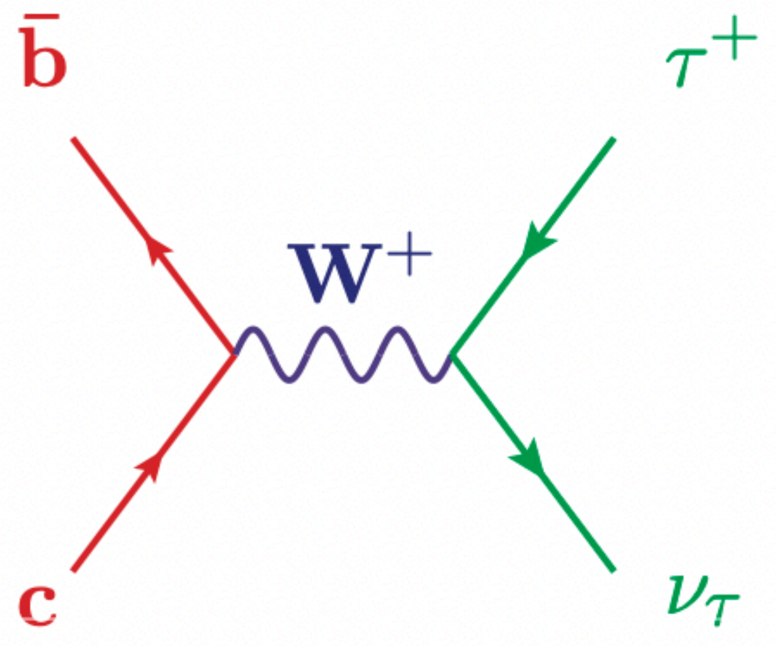


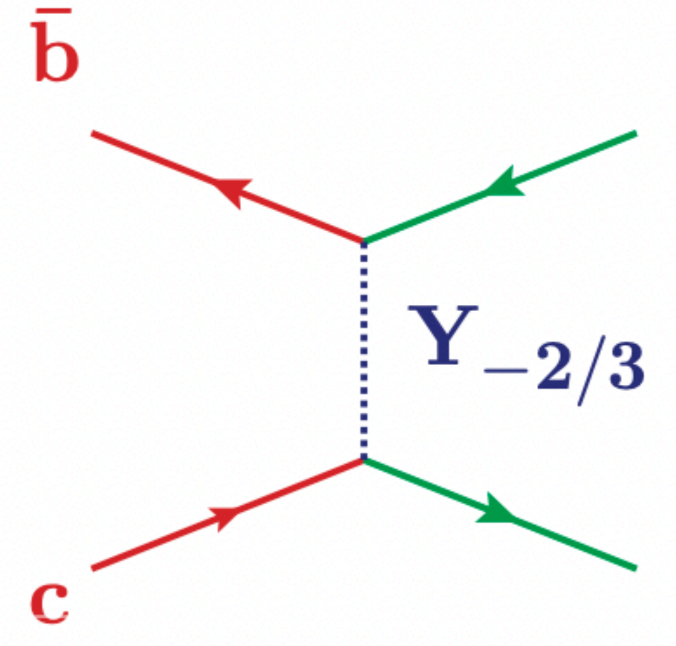
Tristan Miralles at FCC Week



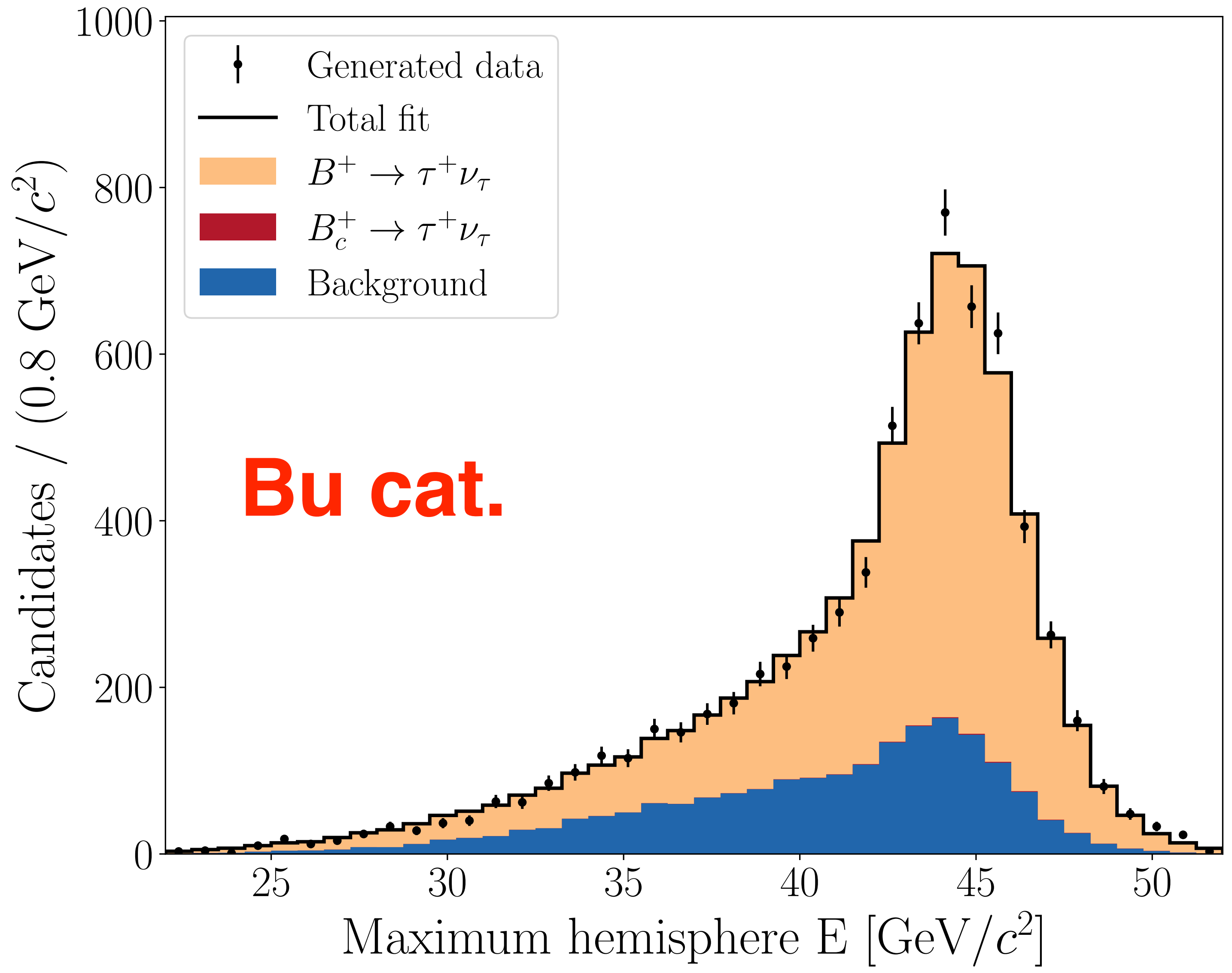
Flavor case - $B^+/B_c^+ \to \tau^+\nu_\tau$

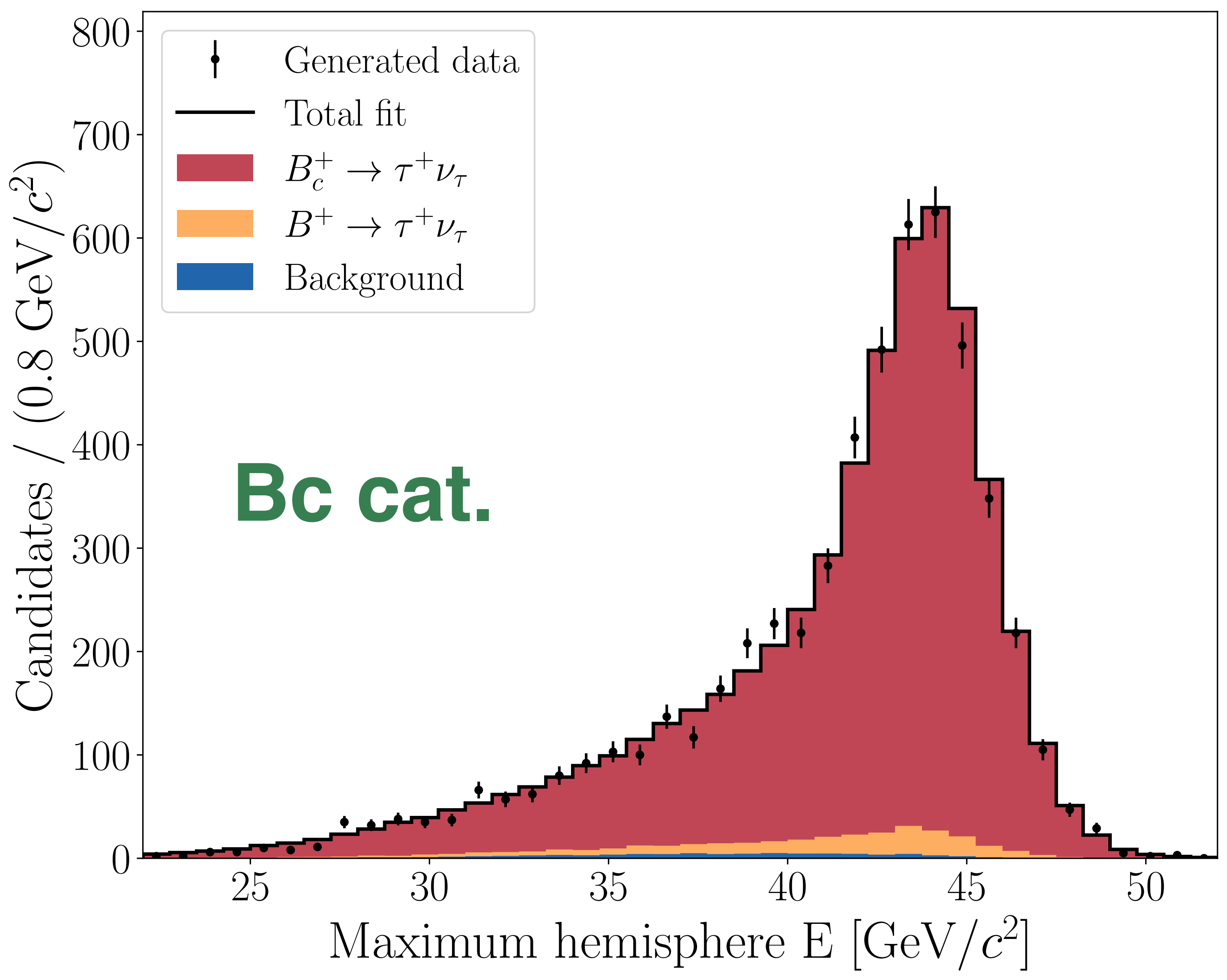
- Decays suppressed by CKM
  - Still, millions of signals at FCC-ee
- Efficient background rejection and little cross-contamination
- Measure $|V_{cb}|$ and $|V_{ub}|$, or constrain BSM models

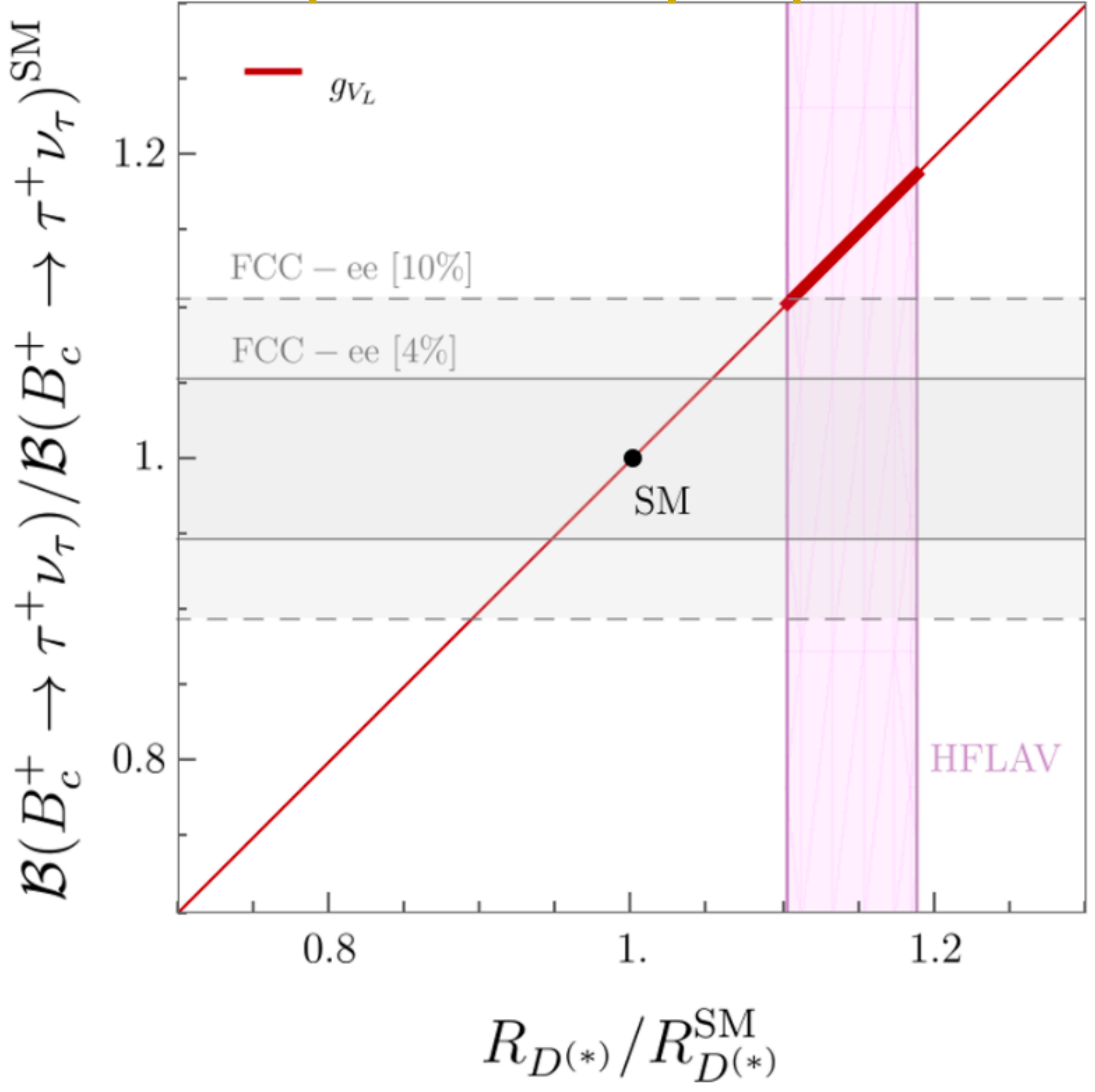




Interpreted with lepto-quark model

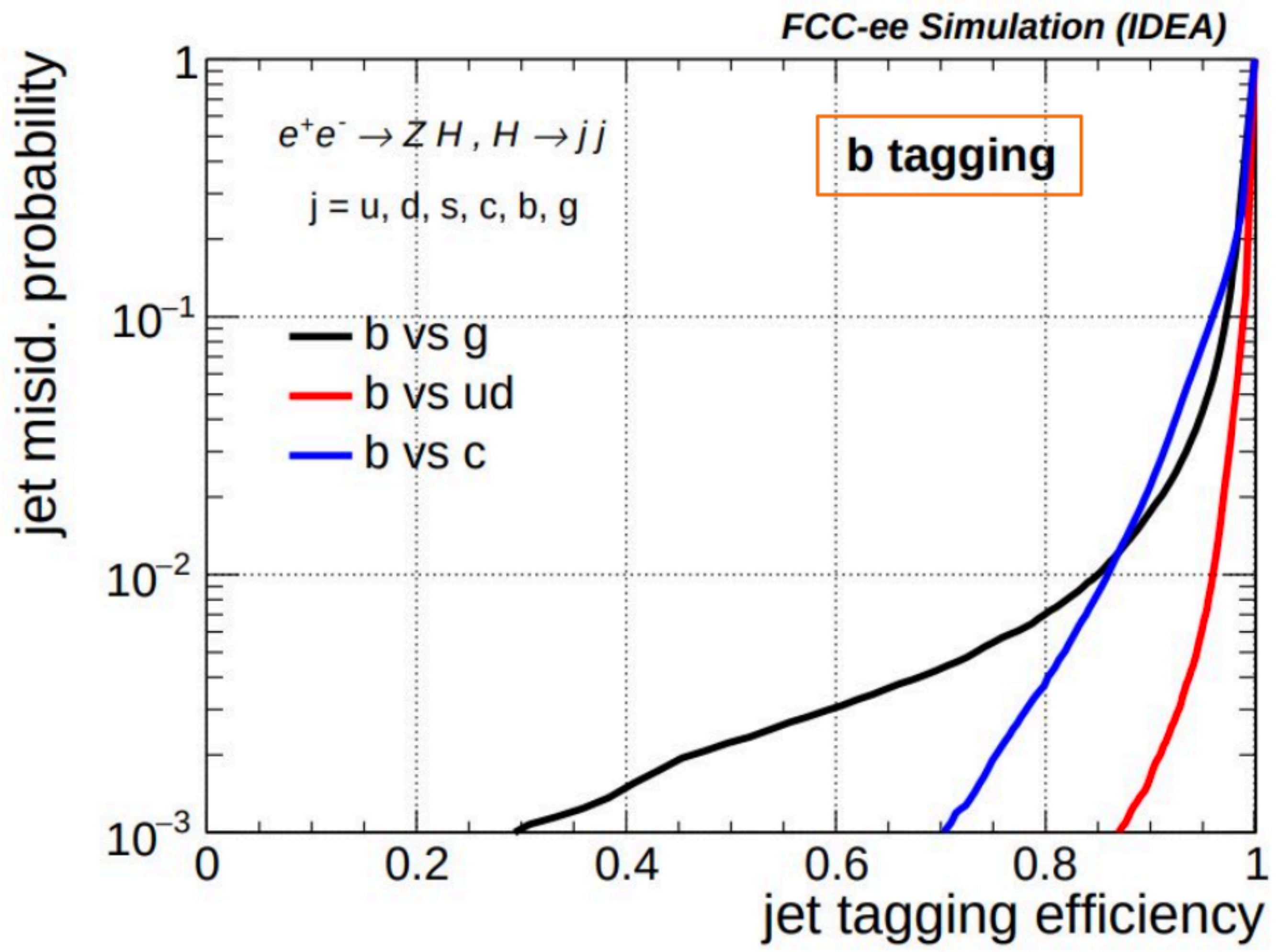


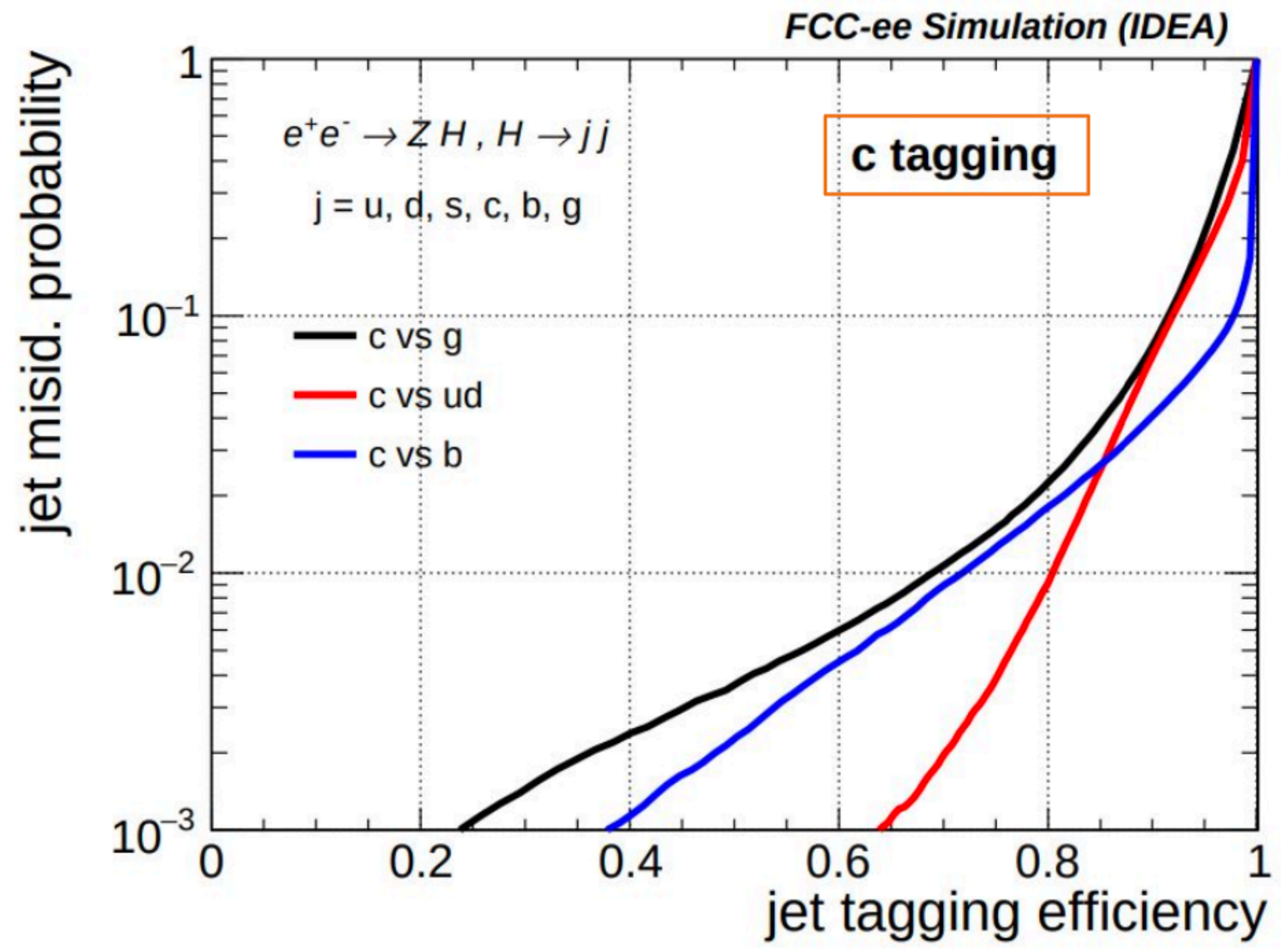




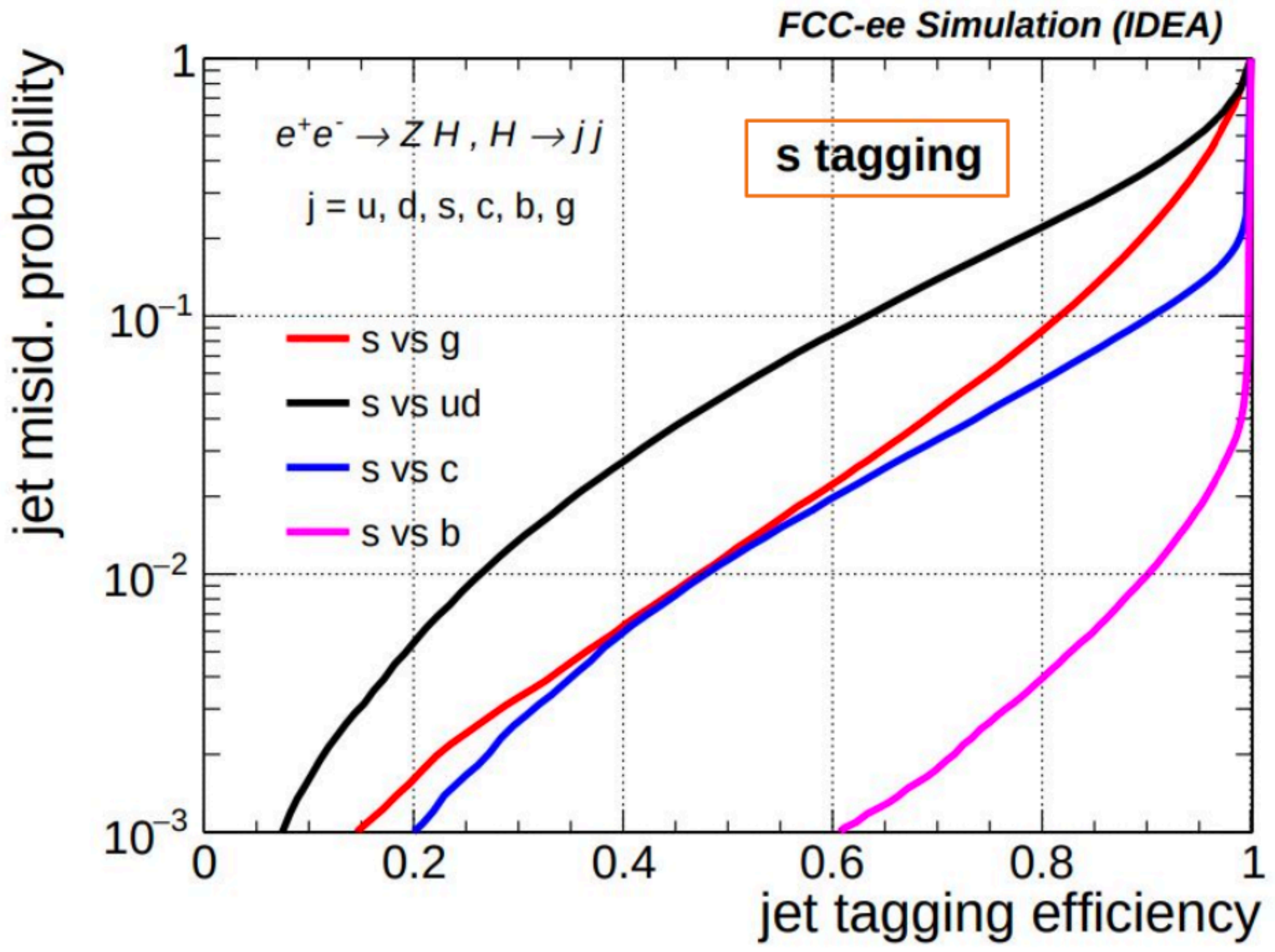
Flavor tagging

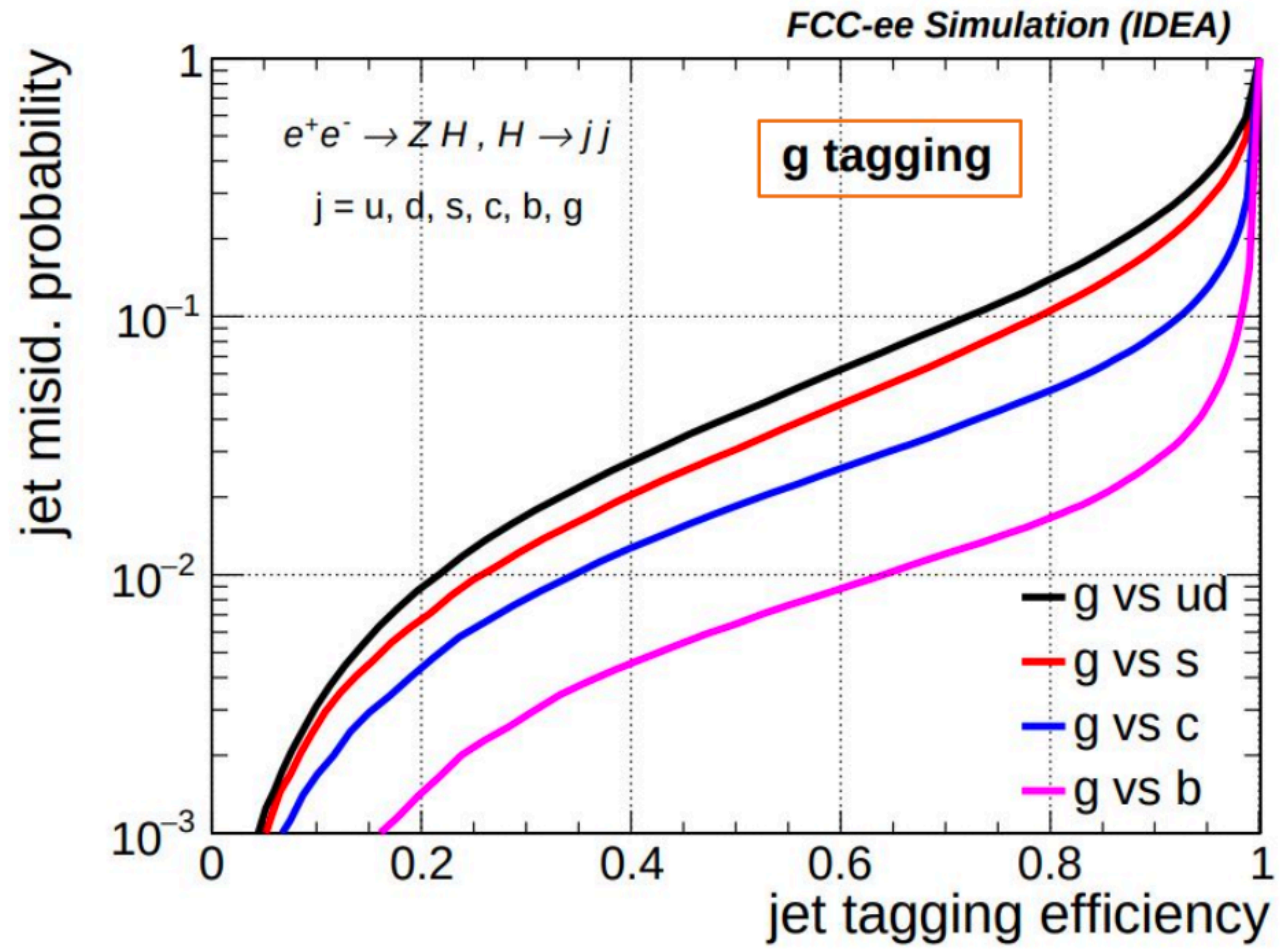
- Crucial to all studies with hadronic final states
- Benefit from excellent vertexing and PID performances.
- Additional (novel) opportunities for measurements in the strange sector
- Irreplaceable opportunities to study light q-jet vs g-jet properties with standard candles of $Z \to qq$ and $H \to gg$ samples





Kunal Gautam at FCC Week

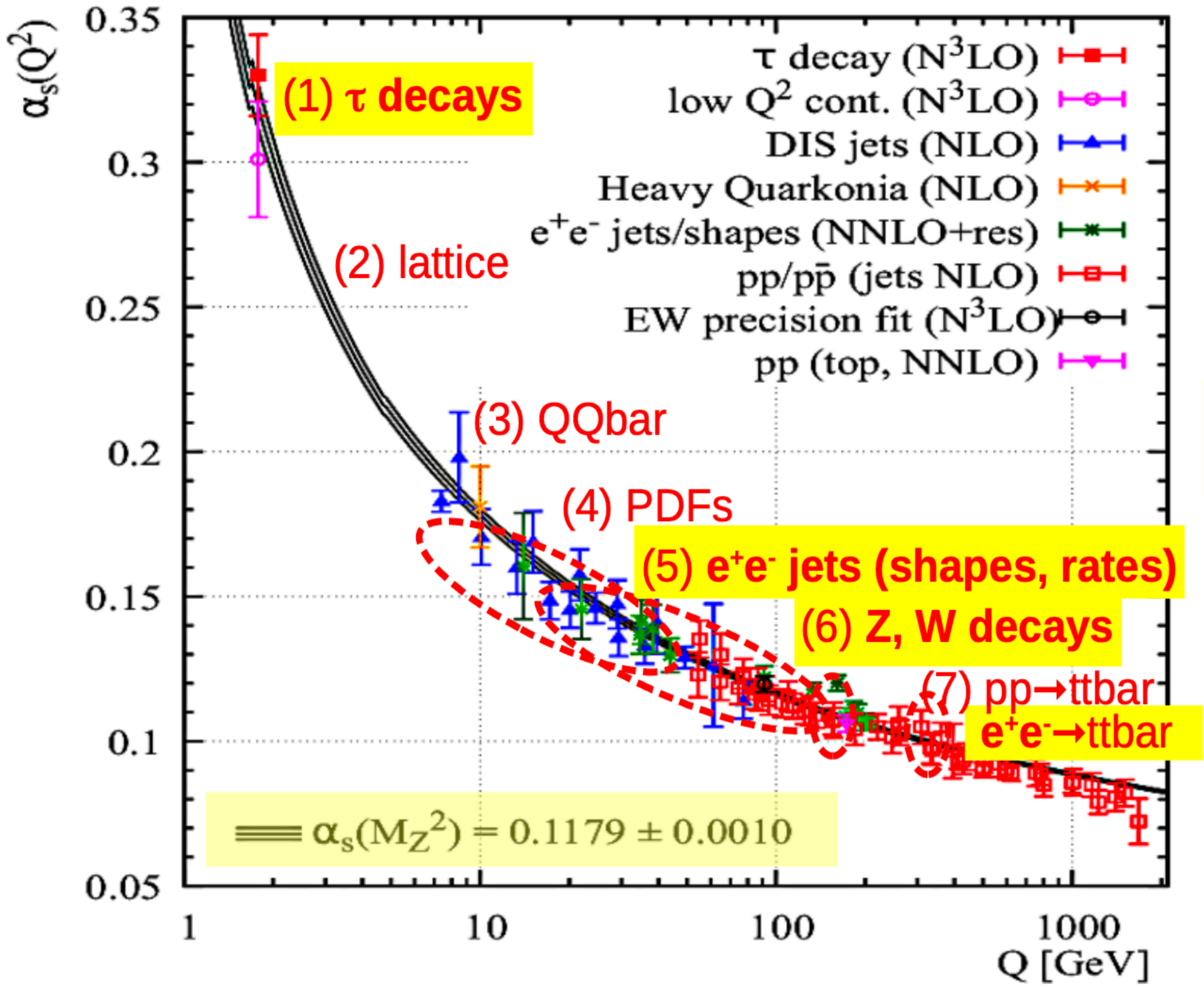




QCD

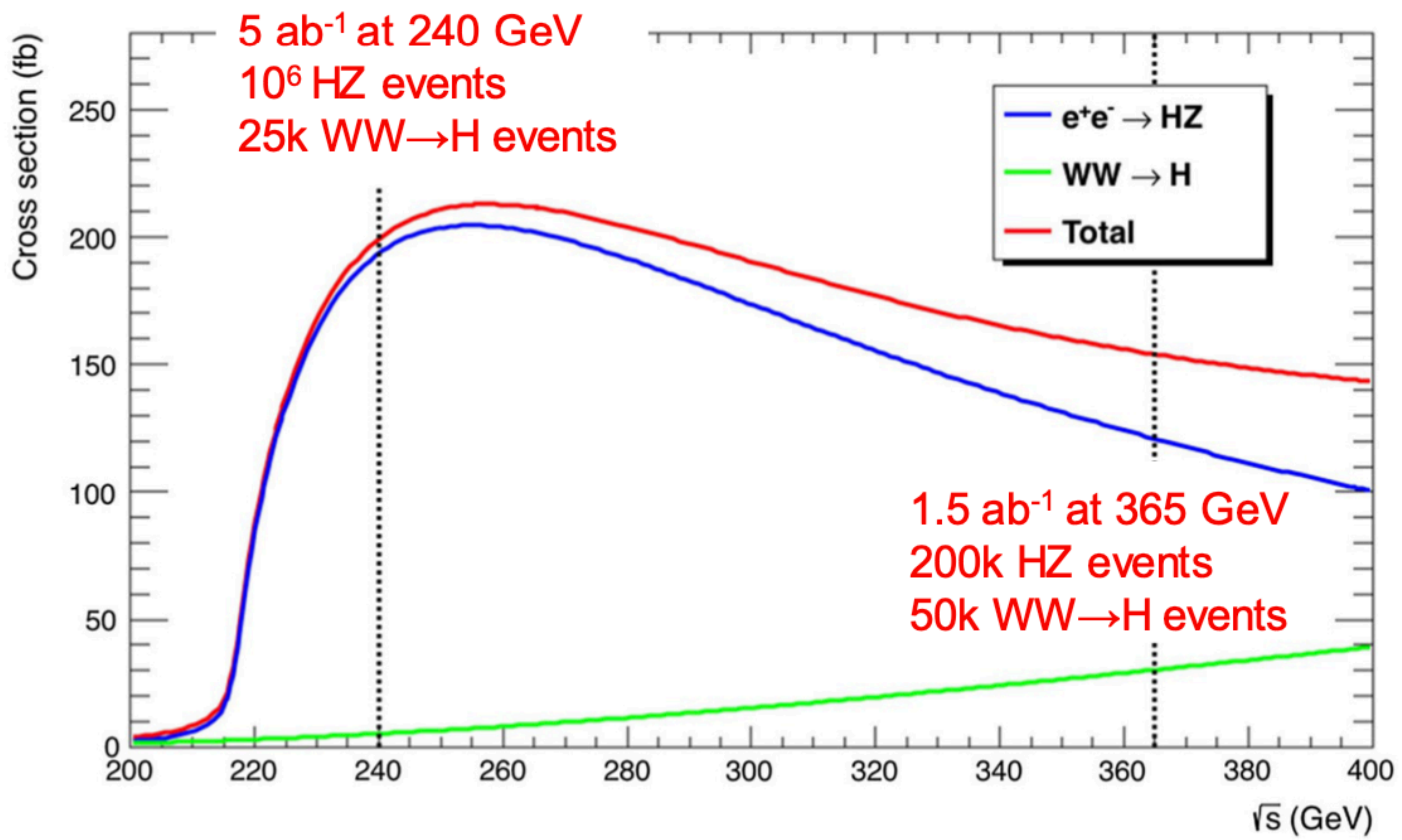
- α_s measurement matters for all decays
  - Many ways to measure α_s at FCC-ee
- Clean and abundant data events to study jet substructure, parton shower, and hadronization.
- High demands for QCD calculation
  - QCD syst is the leading uncertainty for some EW measurements
  - Improvements needed in high order calculation and resummation, and color reconnection

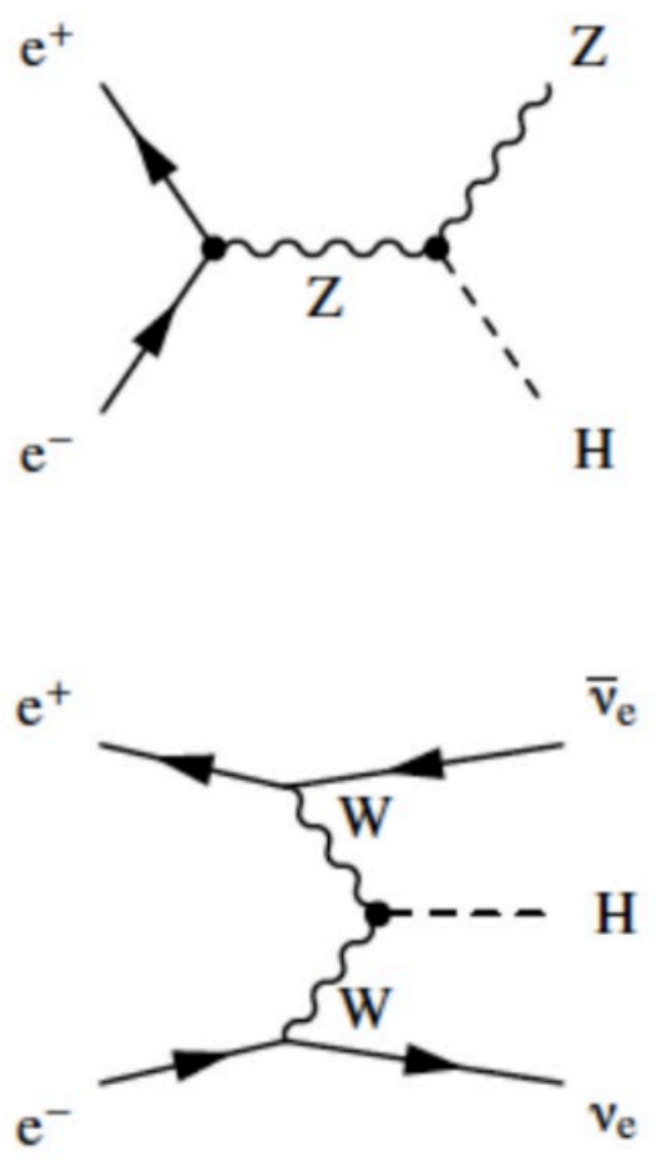
α_s measurements at FCC-ee



Higgs physics

Christophe Grojean at FCC week





Electricity bill per Higgs boson FCC Q&A

Collider	ILC_{250}	CLIC_{380}	$\mathrm{FCC\text{-}ee}_{240}$
Cost (Euros/Higgs)	7,000 to 12,000	2,000	255

- Complementary to Higgs programs at HL-LHC (4×10^8) and FCC-hh ($> 10^{10}$)
  - Higgs mass and width
  - Higgs to light quarks and gluons decay.
  - Higgs to invisible decay
  - $H - e$ coupling from direct production.
- Most cost-effective e^+e^- Higgs factory
  - Linear colliders are limited by luminosity

Higgs physics - experimental coverage

Karlsruher Institut für Technologie

- Unique opportunities in FCC-ee are under study
- Many more essential measurements to be covered

Ongoing activities

[performance meetings: Nov, March and May]
[more details in J. Eysermans' talk]

- ZH cross section and m_h (recoil of $Z \to \mu^+\mu^-$ and hadrons)
- $H \to b\bar{b}, c\bar{c}, gg$ and $s\bar{s}$ ($Z \to \ell^+\ell^-, \nu\bar{\nu}, jj$)
- $H \to \tau\tau$ (+ CPV + light scalars at Z pole)
- $H \to$ invisible ($Z \to e^+e^-, \mu^+\mu^-, b\bar{b}, q\bar{q}$)
- self-coupling through loops
  - recoil with $Z \to \mu^+\mu^-, q\bar{q}$ at 240 & 365 GeV
  - VFB $\nu\bar{\nu}H(b\bar{b})$ and $e^+e^-H(b\bar{b})$ at 365 GeV
  - combination with di-Higgs at FCC-*hh*
- differential $ZH \to 4f$ for anomalous couplings [Beneke, Boito, Wang '14] [Craig, Gu, Liu, Wang '15]
- $e^+e^- \to H$

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Exotica largely untouched

[see BSM talks this afternoon]

- CPV
  - $H \to \tau\tau$ (planned)
  - differential ZH
- Quark flavour violation
  - $H \to bs, bd, cu$ (extending $H \to$ hadrons analyses)
  - and four-body?
- Lepton flavour violation
  - $H \to \tau\mu, \tau e, \mu e$ (extending $H \to \tau\tau$ analysis)
  - and four-body?
- More exotic decay?
  - $H \to xx, Zx \to 4f$ [Curtin, Essig, Gori, Jaiswal, Katz et al. '13]
  - displaced, long-lived, invisible [Cepeda, Gori, Outschoorn, Shelton '21]

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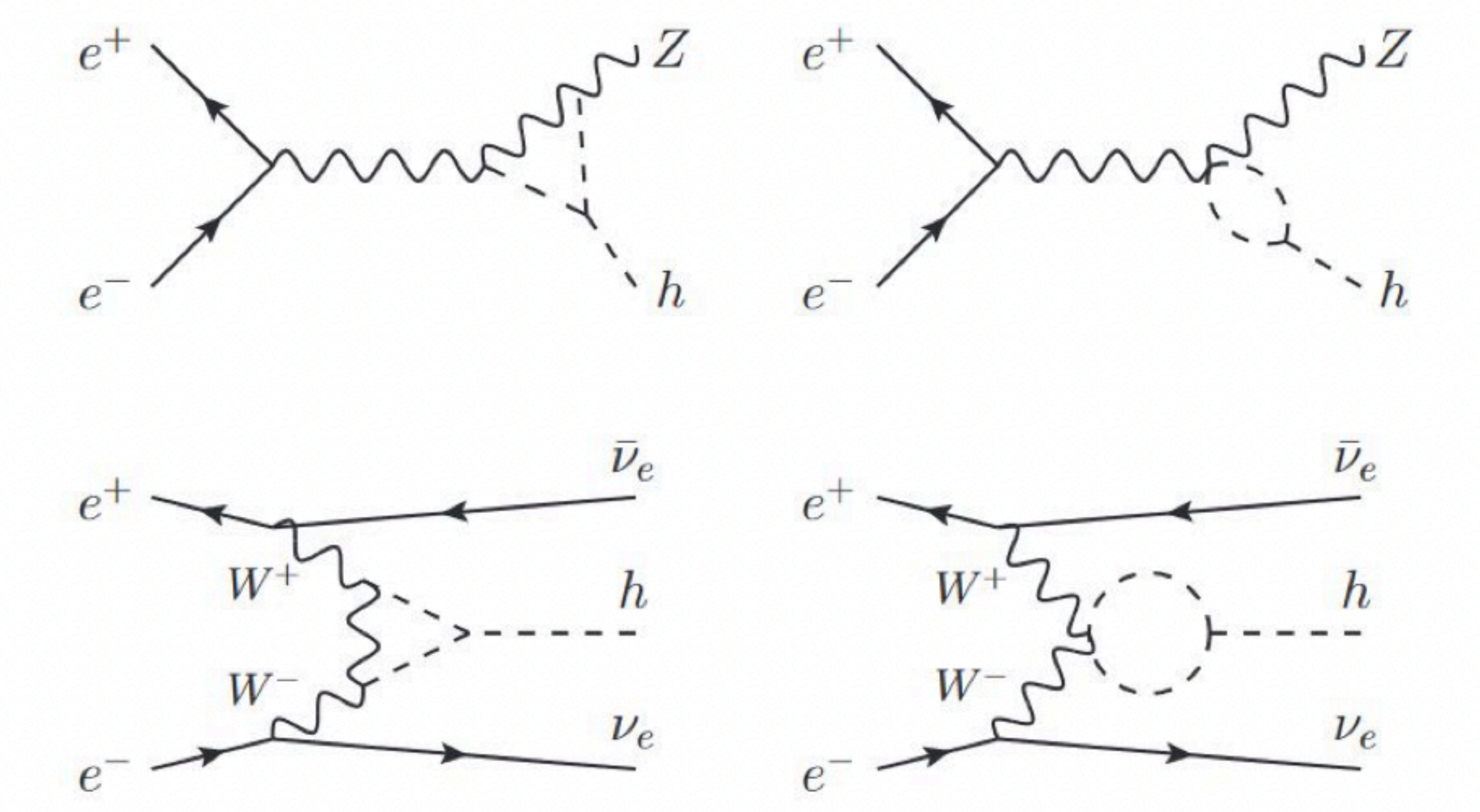
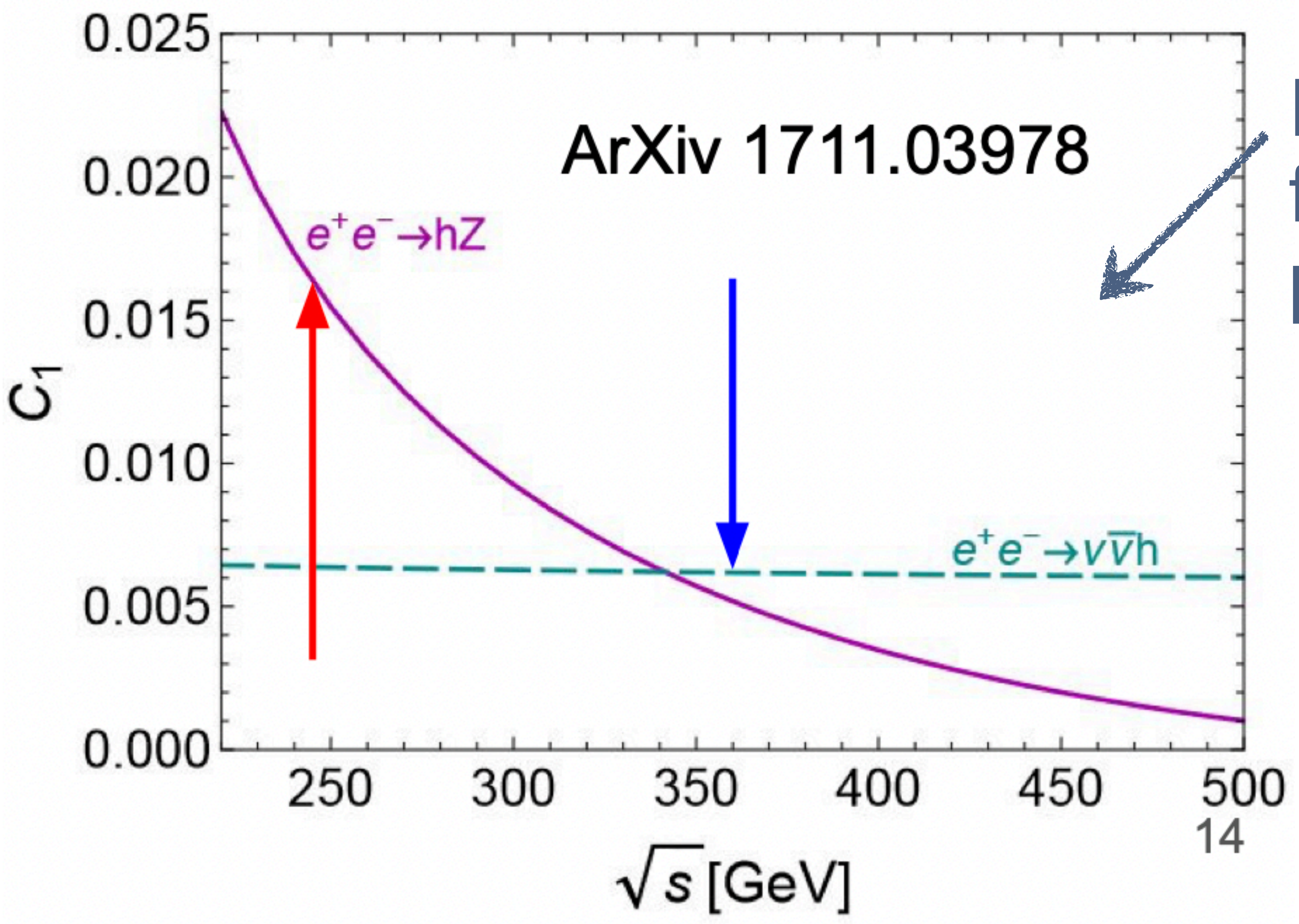
Gauthier Durieux at FCC week

Higgs case- Higgs self-coupling



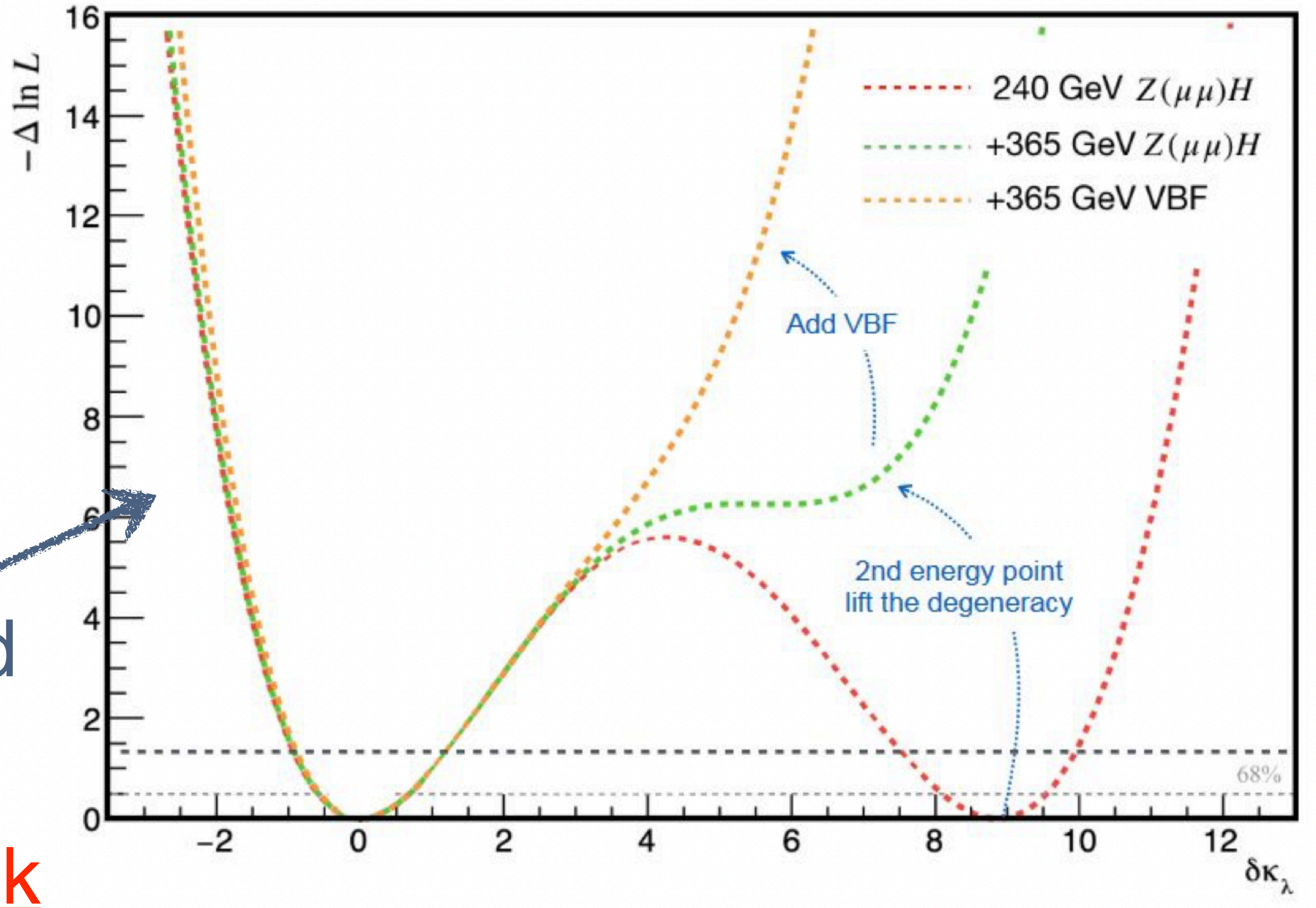
- Direct production of HH is very rare at FCC-ee
- Self-coupling indirectly probed through loop correction to ZH and VBF processes

$$\Sigma_{\mathrm{NLO}} = Z_H \Sigma_{\mathrm{LO}} (1 + \kappa_\lambda C_1) \qquad \kappa_\lambda \equiv \frac{\lambda_3}{\lambda_3^{\mathrm{SM}}}$$



Expect 1% - 2% deviation from LO (experimental precision at per-mille level)

Complementary measurements with different energies and production modes



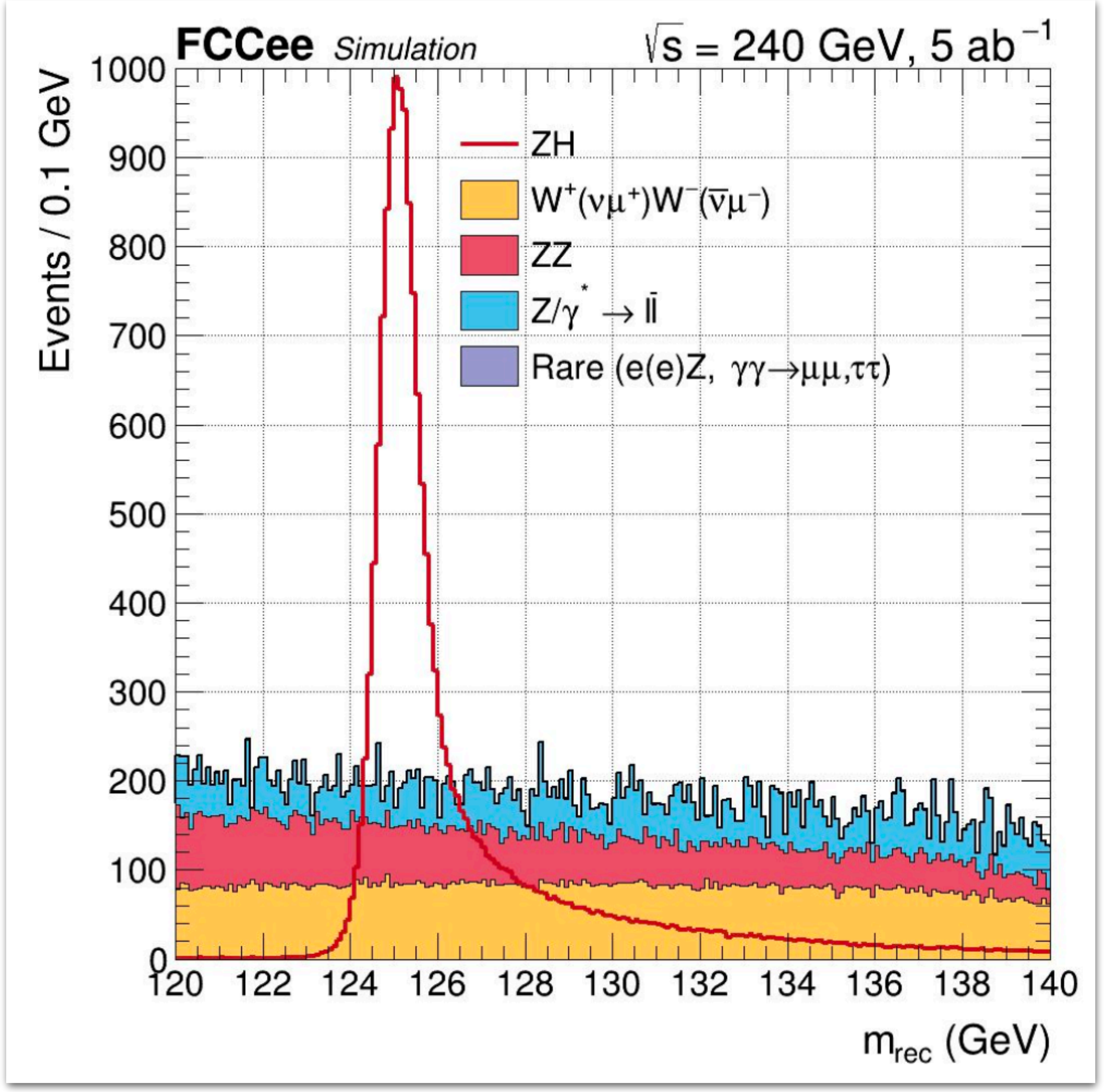
Jan Eysermans at FCC week

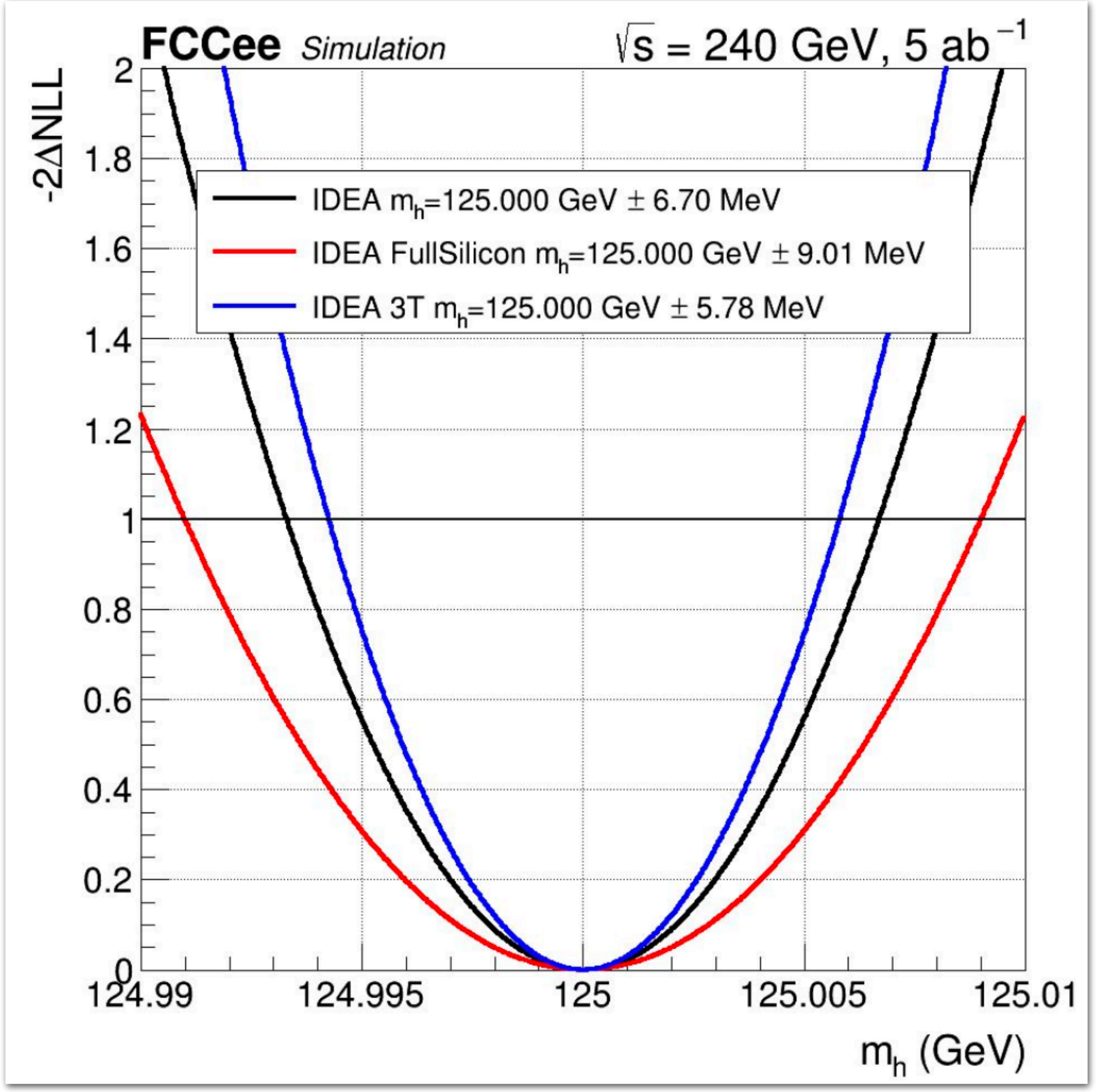
Higgs case - Higgs mass

- With ZH events, measure Higgs mass from the recoil of Z

$$m_H^2 \triangleq m_{recoil}^2 = (\sqrt{s} - E_Z)^2 - p_Z^2$$

- With $Z \to \mu\mu$ channel, $\sigma(m_H)$ = **6 - 9 MeV**, depending on detector resolution
- Compared to current LHC results, $\sigma_{tot}(m_H) > 100$ MeV, in which $\sigma_{syst}(m_H) \lesssim 100$ MeV
  - Possible to reach ~20 MeV at HL-LHC with significant amount of work





Jan Eysermans at FCC week

Higgs physics

- Higgs programs at lepton collisions and hadron collisions are complementary.
- Sub-percent precision for most measurements at FCC
  - Challenges for theory to match this precision

What theory precision? [Freitas, Heinemeyer, et al. '19]

- 2-loop *ZH* needed for $< 1\%$ unc. and possibly achievable
  off-shell *Z* effects?
- Partial 2-loop VBF possibly achievable and sufficient
- Off-shell *WW* production at 2-loop requiring significant effort
- Factorisable NNLO QCD to $H \to VV^* \to 4f$ decay achievable
- N^{4}LO $H \to gg$ and m_b dependence at N^{3}LO needed for $< 1\%$ unc. and possibly reachable
- One-loop SMEFT automation ongoing

[Degrande, GD, Maltoni, Mimasu, Vryonidou, Zhang '20]

Gauthier Durieux at FCC week

Gauthier Durieux – FCC Week – 31 May 2022 15

Mainly constrained by FCC-ee

Collider	HL-LHC	FCC-ee$_{240\to365}$	FCC-INT
Lumi (ab^{-1})	3	5 + 0.2 + 1.5	30
Years	10	3 + 1 + 4	25
g_{HZZ} (%)	1.5	0.18 / 0.17	0.17/0.16
g_{HWW} (%)	1.7	0.44 / 0.41	0.20/0.19
g_{Hbb} (%)	5.1	0.69 / 0.64	0.48/0.48
g_{Hcc} (%)	SM	1.3 / 1.3	0.96/0.96
g_{Hgg} (%)	2.5	1.0 / 0.89	0.52/0.5
$g_{\mathrm{H}\tau\tau}$ (%)	1.9	0.74 / 0.66	0.49/0.46
$g_{\mathrm{H}\mu\mu}$ (%)	4.4	8.9 / 3.9	0.43/0.43
$g_{\mathrm{H}\gamma\gamma}$ (%)	1.8	3.9 / 1.2	0.32/0.32
$g_{\mathrm{HZ}\gamma}$ (%)	11.	– / 10.	0.71/0.7
g_{Htt} (%)	3.4	10. / 3.1	1.0/0.95
g_{HHH} (%)	50.	44./33. 27./24.	3-4
Γ_{H} (%)	SM	1.1	0.91
$\mathrm{BR}_{\mathrm{inv}}$ (%)	1.9	0.19	0.024
$\mathrm{BR}_{\mathrm{EXO}}$ (%)	SM (0.0)	1.1	1

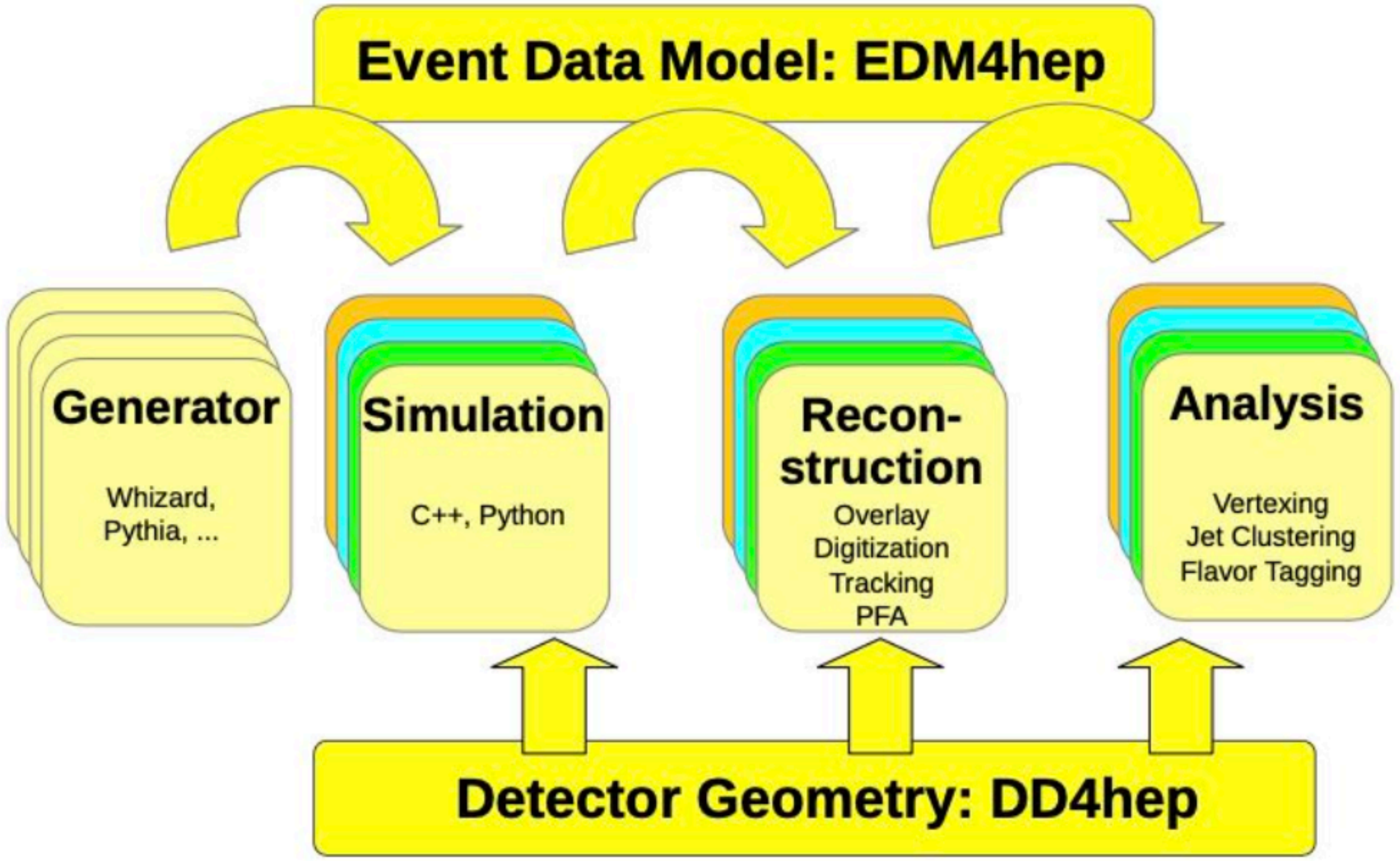
arxiv:2106.13885

Software tools - key4hep

Goal: create a software ecosystem integrating various tools and providing a standard workflow and data format for generic HEP experiments

- Complete set of tools for all steps in HEP experiments
- Ready to use, straightforward to learn, centrally maintained
- Synergy and unification across all major future collider experiments
  - FCC, CLIC, ILC, CEPC, and EIC
  - Led by a small core group at CERN

Gerardo Ganis at FCC week



* Software and computing co-convened by our own Clement Helsens

Software tools - analysis workflow

Common framework for all FCC analyses

Clement Helsens at FCC week

Data processing: https://github.com/HEP-FCC/FCCAnalyses

- With common utilities for object reconstruction and kinematic calculation

Specific studies: https://github.com/zuoxunwu/FCCeePhysicsPerformance

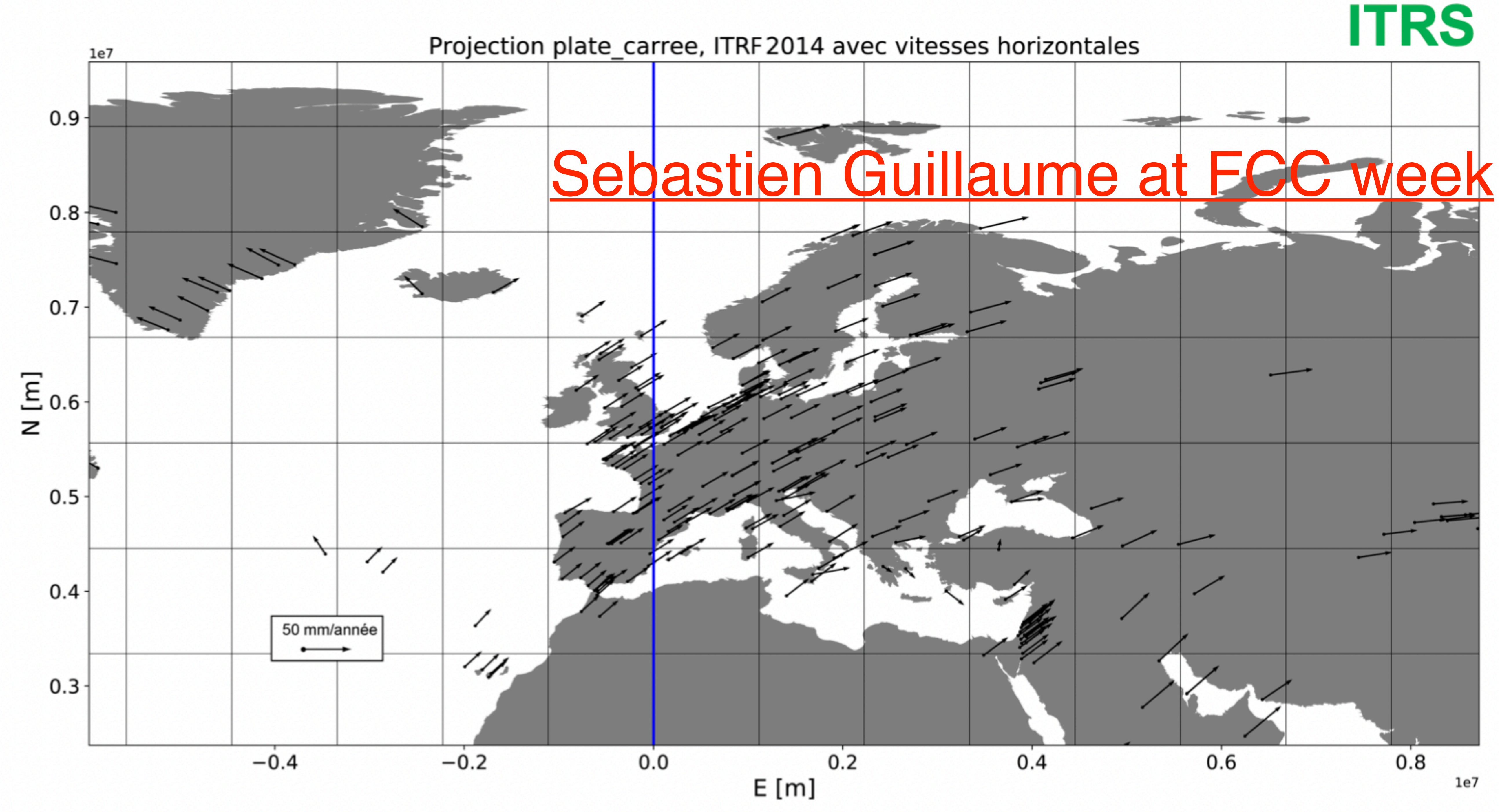
- With common utilities for usual analysis studies and plotting

Complete workflow can be run in 1-2 days

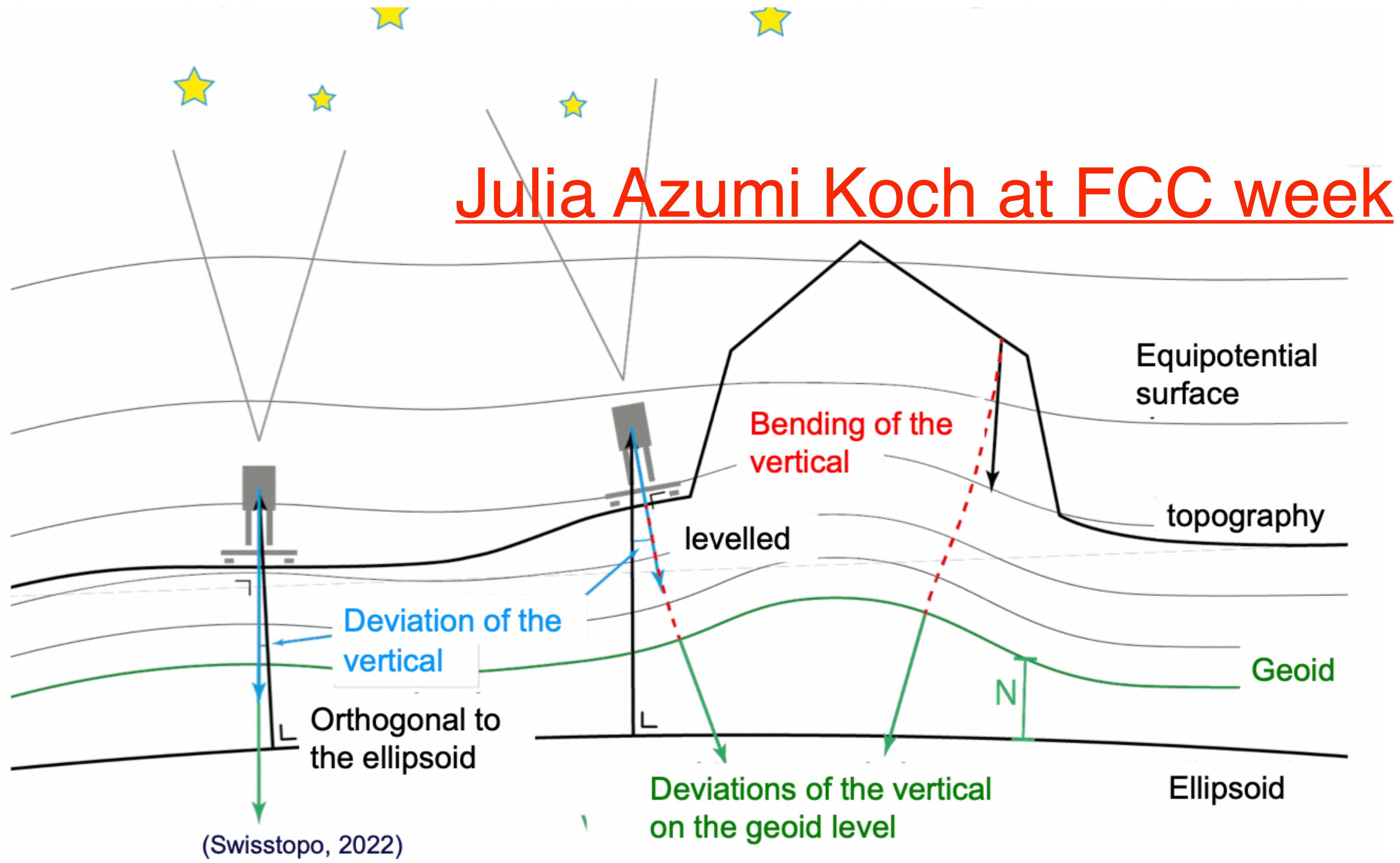
Civil engineering

- **Horizontal coordinate:** set coordinate reference
  - Fluid field of the land
  - Many different coordinate systems
  - Coordinate precision at mm level

- **Vertical coordinate:** gravity field and Geoid measurements
  - Definition of “vertical” varies point-by-point
  - Affects height measurement at cm level



Sebastien Guillaume at FCC week

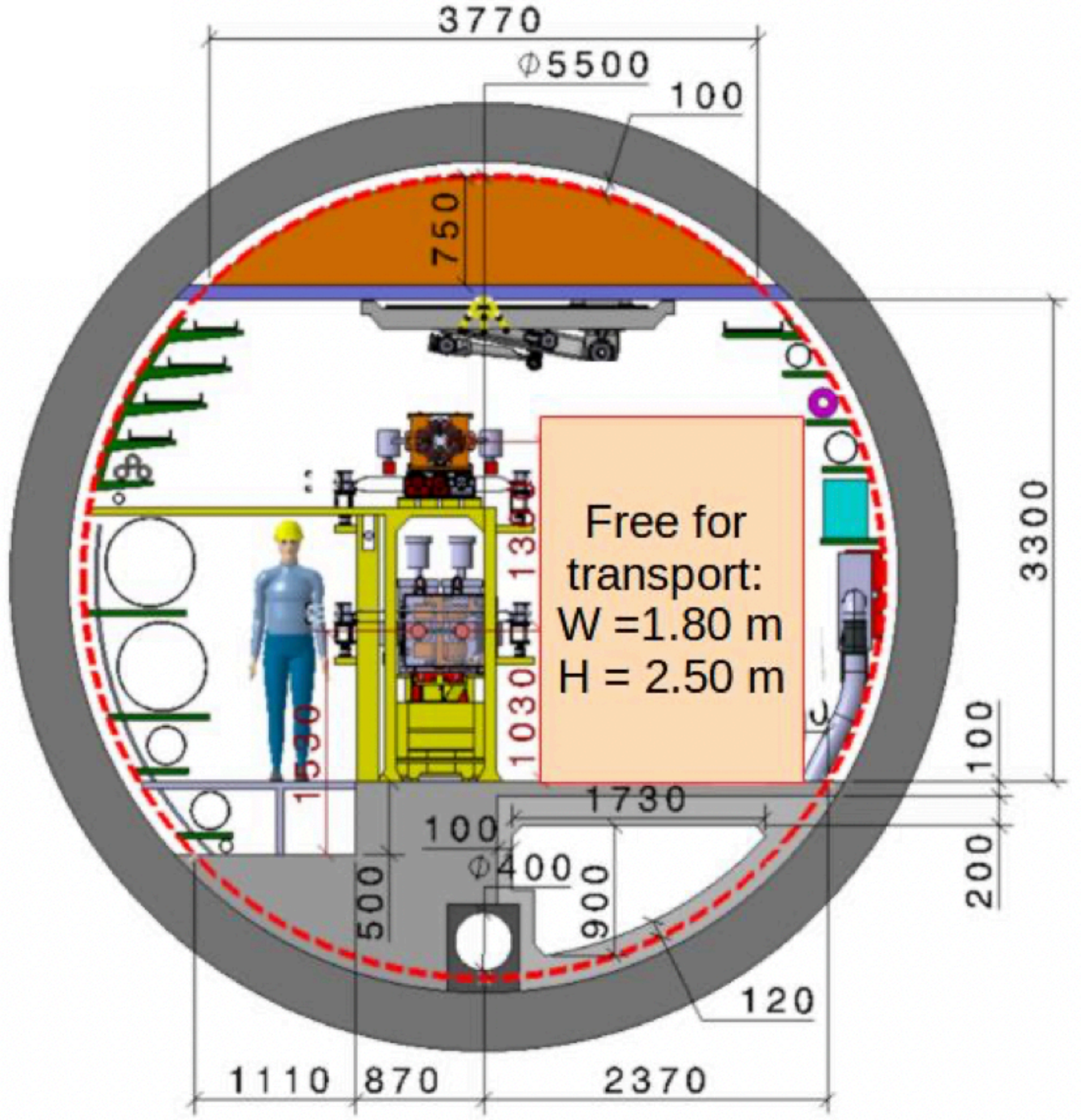


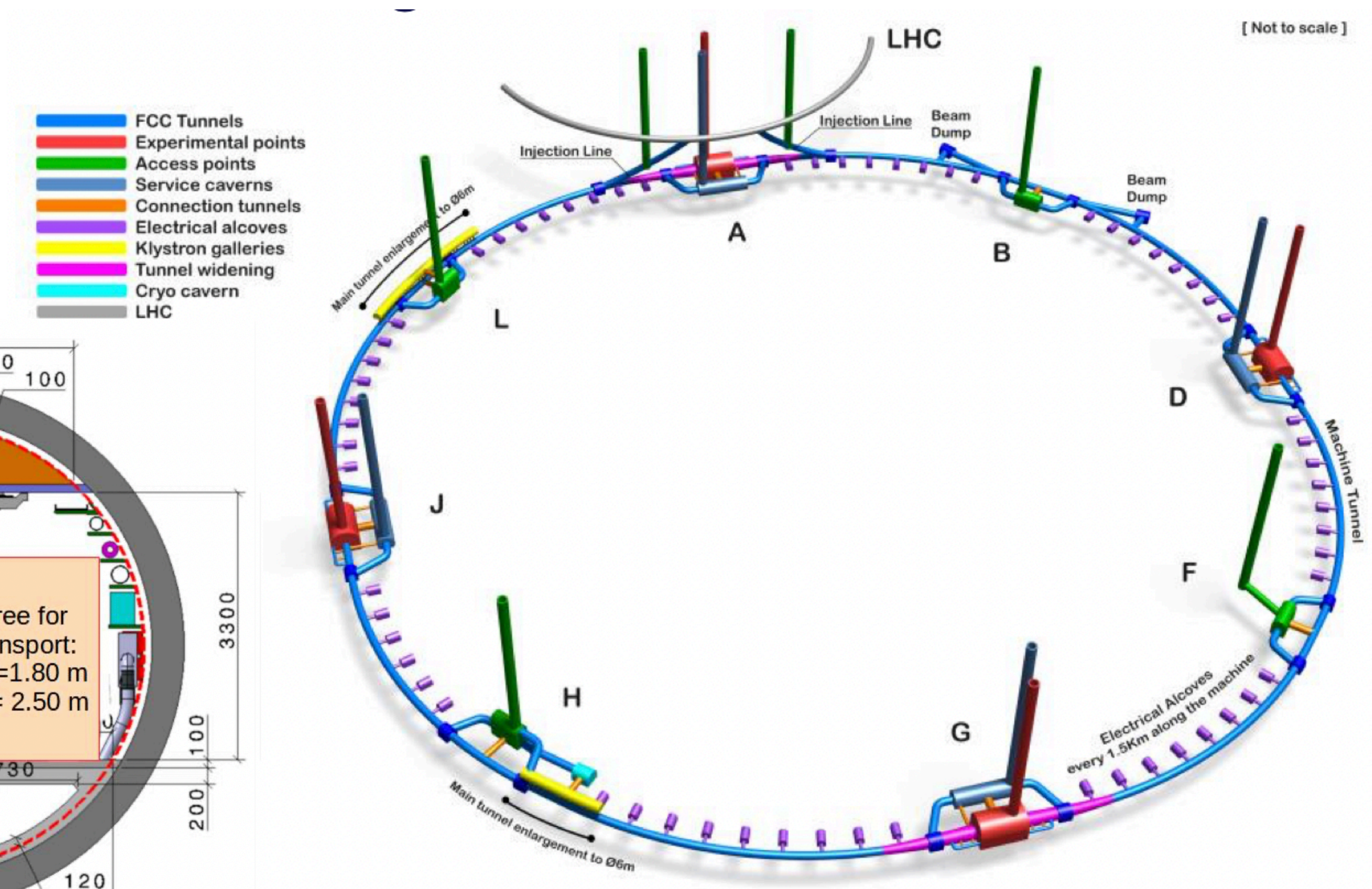
Julia Azumi Koch at FCC week

Civil engineering

Cristiana Colloca at FCC week

- ϕ5.5m ring as both the collider ring and the transportation tunnel
  - Both booster ring and collider ring include ~10000 magnets
  - Electric vehicles for transporting both people and material





- About 9M cubic meters of excavated material
  - Re-use for construction
  - Assess pollution risk

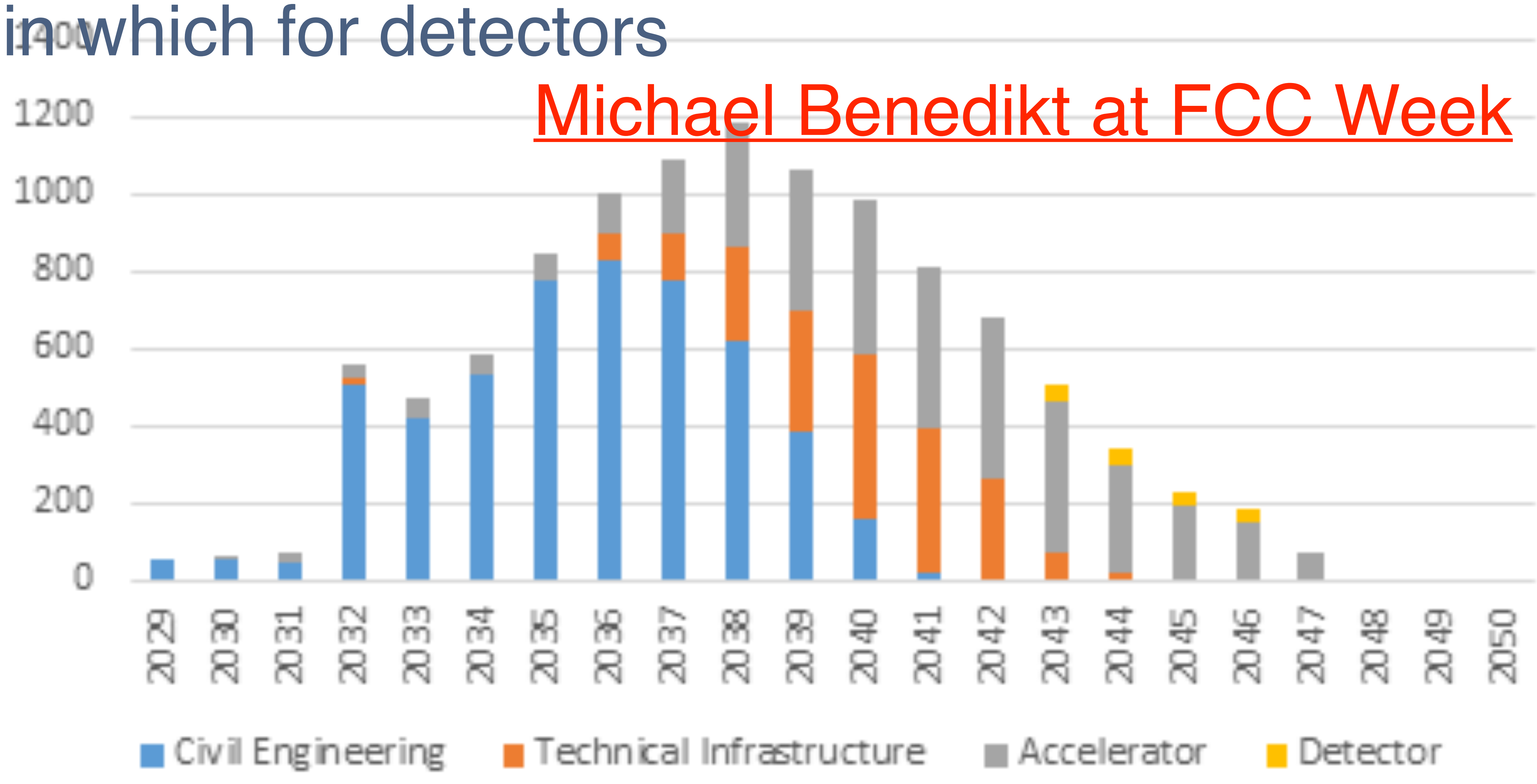
Cost estimate

Construction cost CERN-ACC-2019-0007

Domain	Cost in MCHF
Stage 1 - Civil Engineering	5,400
Stage 1 - Technical Infrastructure	2,200
Stage 1 - FCC-ee Machine and Injector Complex	4,000
Stage 2 - Civil Engineering complement	600
Stage 2 - Technical Infrastructure adaptation	2,800
Stage 2 - FCC-hh Machine and Injector complex	13,600
TOTAL construction cost for integral FCC project	**28,600**

400 in which for detectors

Michael Benedikt at FCC Week



Operational cost

CERN Meyrin, SPS, FCC	Z	W	H	TT
Beam energy (GeV)	45.6	80	120	182.5
Energy consumption (TWh/y)	1.82	1.92	2.09	2.54

1.5 - 2 times the power consumption of LHC

LHC operational cost in 2018 is ~250 MCHF (CERN budget 2018)

Jean-Paul Burnet at FCC Week

KIT contributions

Group members: Markus Klute, Clement Helsens, Xunwu Zuo

Projects:

- Software and computing
  - Key4hep, EDM4hep, analysis framework
  - Sample generation and management
- Physics performance
  - $B^+/B_c^+ \to \tau^+\nu_\tau$ searches
  - (Planned) $H \to \tau\tau$ measurements
  - (Planned) Search for new scalars (h) in Zh production
  - (Planned) τ-ID algorithm and performance
- Technical support
  - FCC conference webpage

Management roles:

- Markus in FCC conference committee
- Clement in Software & Computing coordination