Challenges for Highest Energy Circular Colliders

M. Benedikt, D. Schulte, J. Wenninger,
F. Zimmermann

gratefully acknowledging input from
FCC global design study & CepC team

YEARS / ANS CERN

FCC
hh ee he

*Work supported by the **European Commission** under Capacities 7th Framework Programme, Grant Agreement 312453*

Future Circular Collider (FCC) study ; goals: CDR and cost review for the next European Strategy Update (2018)

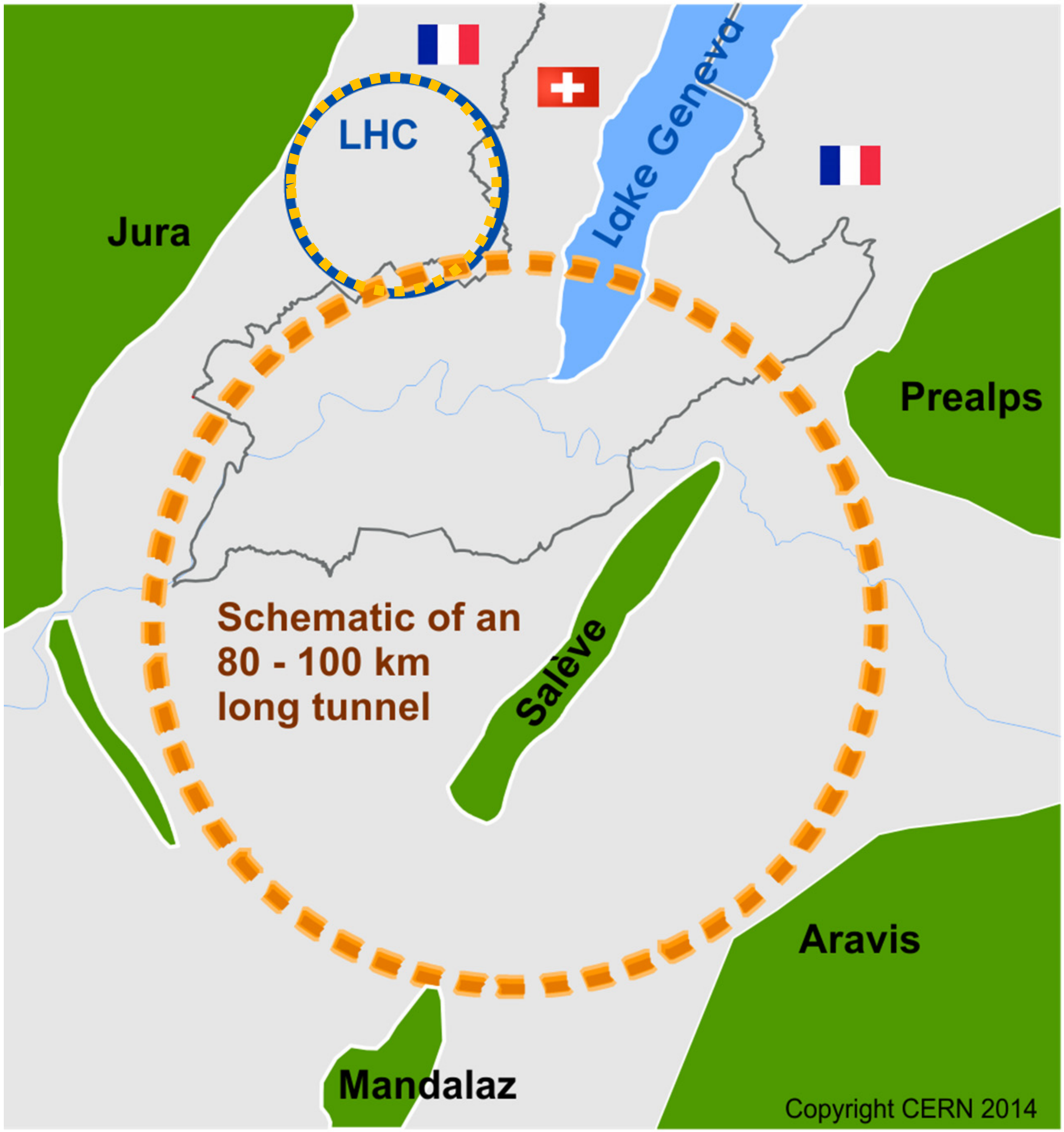
International collaboration :

- ***pp*-collider (*FCC-hh*)**
  → defining infrastructure requirements

~16 T ⇒ 100 TeV in 100 km
~20 T ⇒ 100 TeV in 80 km

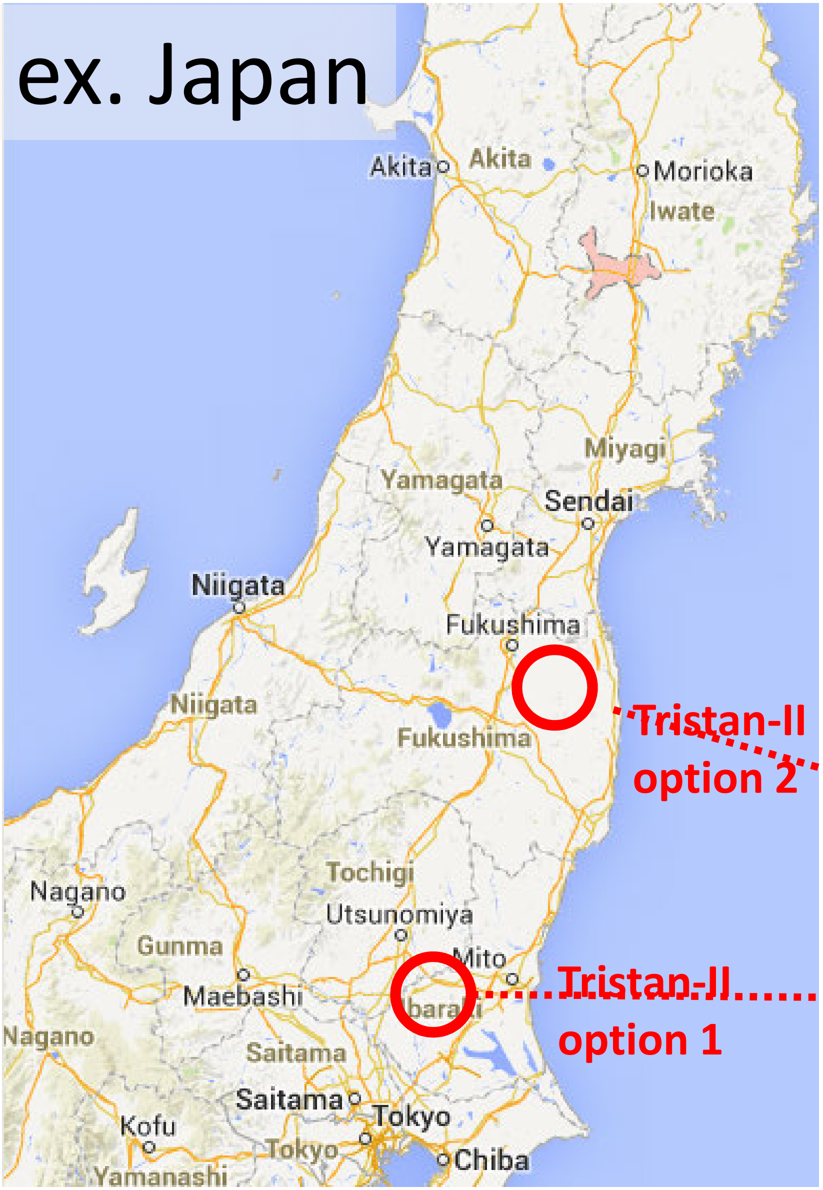
- including ***HE-LHC*** option: 16-20 T in LHC tunnel
- ***e^+e^-* collider (*FCC-ee/TLEP*)** as potential intermediate step
- ***p-e* (*FCC-he*) option**
- **100 km infrastructure** in Geneva area

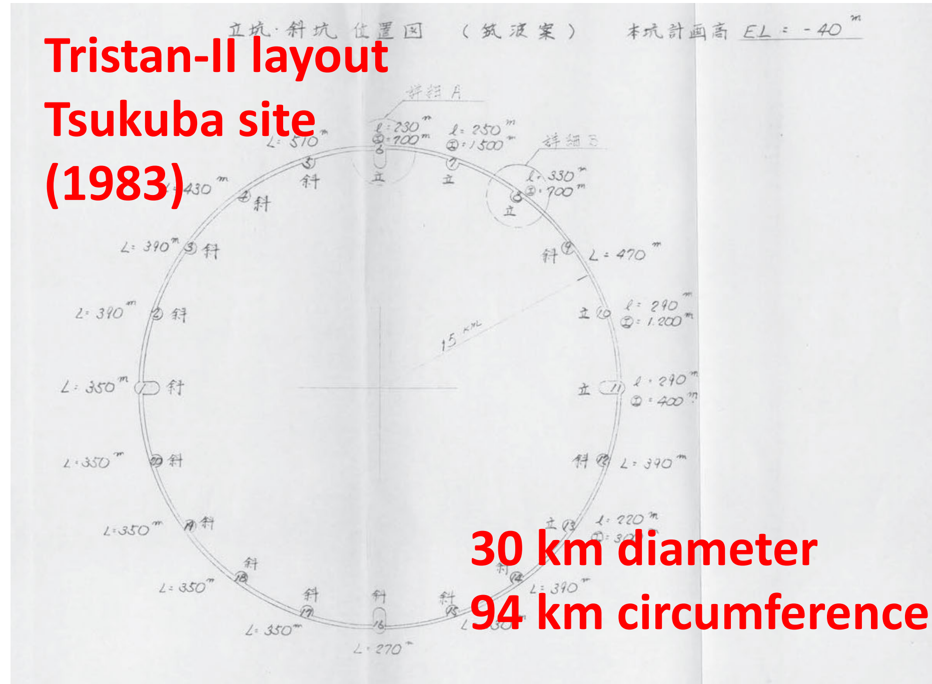
M. Benedikt

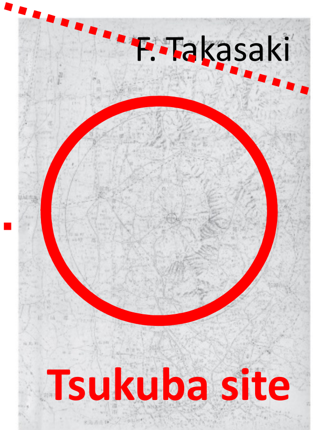


CepC/SppC study (CAS-IHEP), CepC CDR end of 2014, e^+e^- collisions ~2028; *pp* collisions ~2042

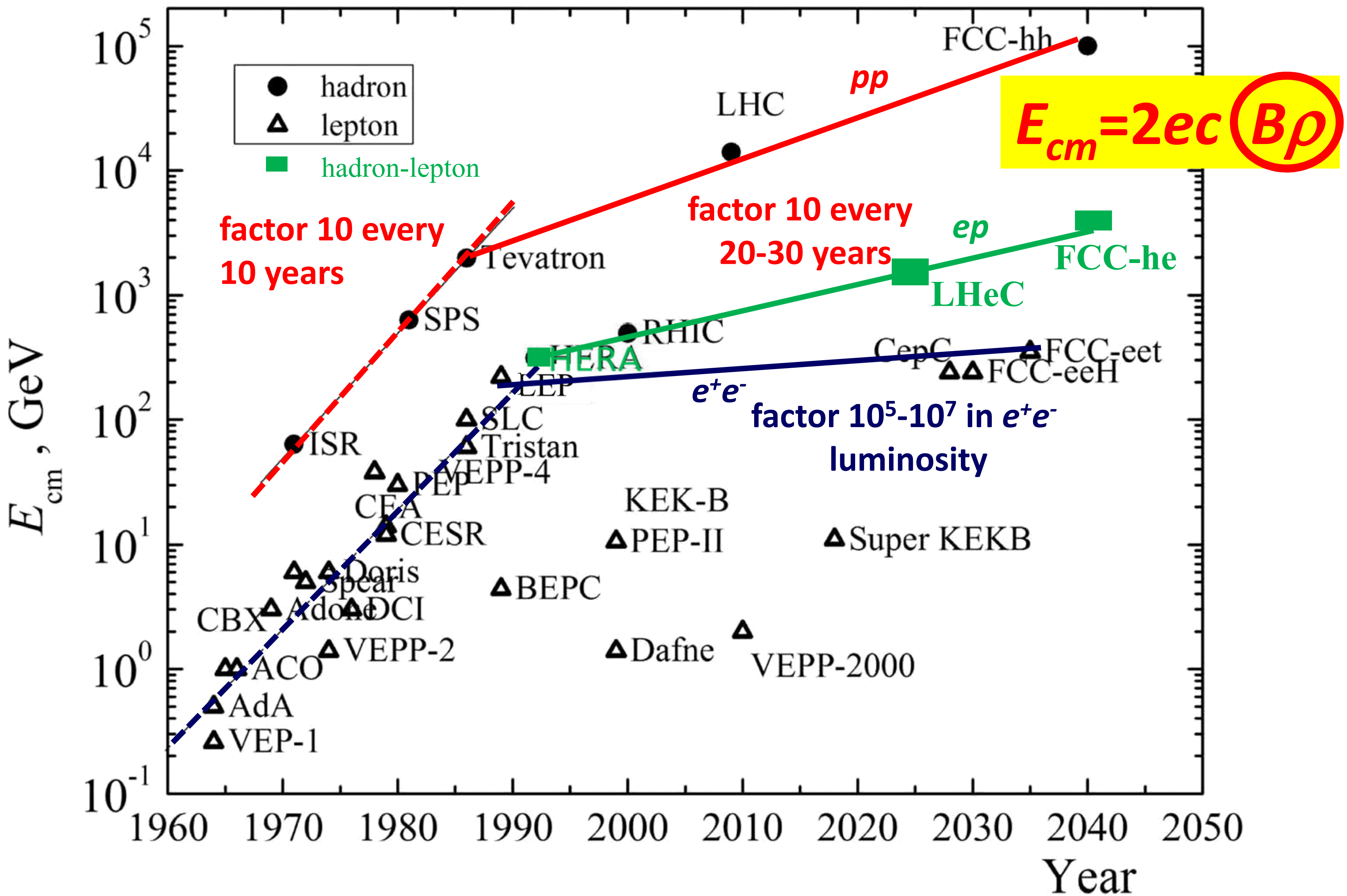
previous studies in Italy (ELOISATRON), USA (SSC, VLHC, VLLC), and Japan (TRISTAN-II)





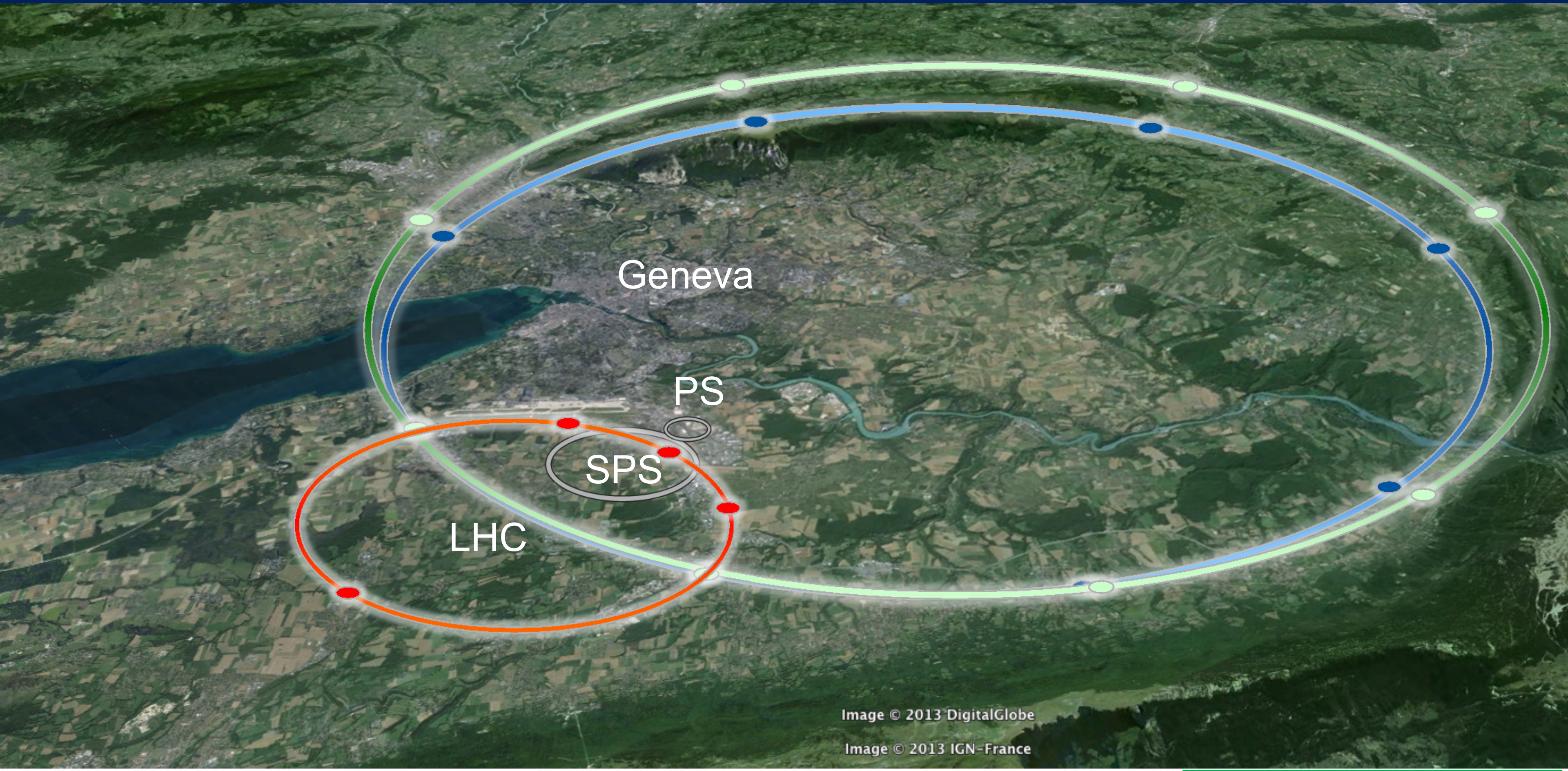


collider c.m. energy vs. year



Courtesy V. Shiltsev,

FCC-hh: 100 TeV *pp* collider



LHC
27 km, 8.33 T
14 TeV (c.m.)

"HE-LHC"
27 km, **20 T**
33 TeV (c.m.)

FCC-hh (alternative)
80 km, **20 T**
100 TeV (c.m.)

FCC-hh (baseline)
100 km, **16 T**
100 TeV (c.m.)

B. Strauss

FCC-hh opens three physics windows

➥ Access to new particles in the few TeV to 30 TeV mass range, beyond LHC reach

➥ Immense/much-increased rates for phenomena in the sub-TeV mass range → increased precision w.r.t. LHC and possibly ILC

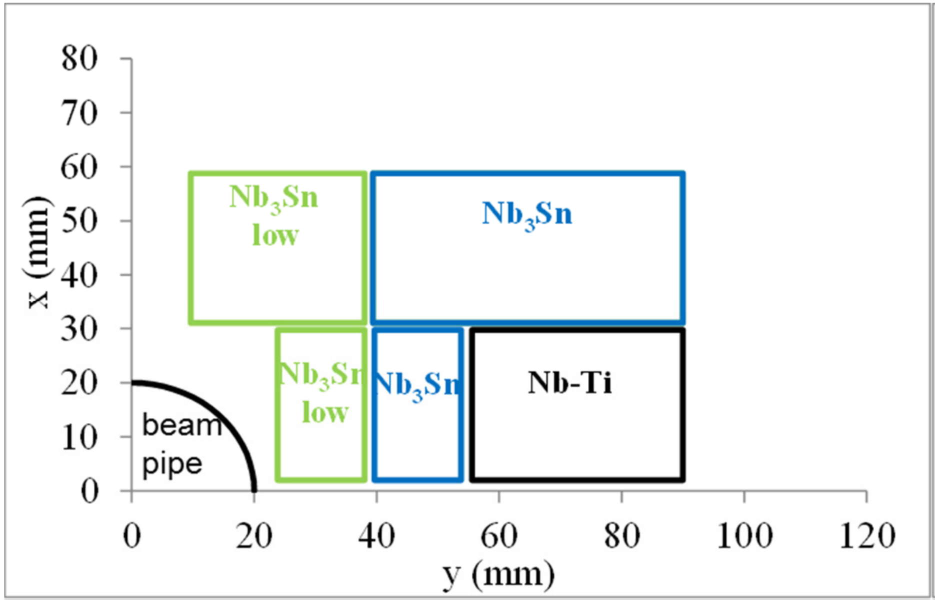
➥ Access to very rare processes in the sub-TeV mass range → search for stealth phenomena, invisible at the LHC

M. Mangano

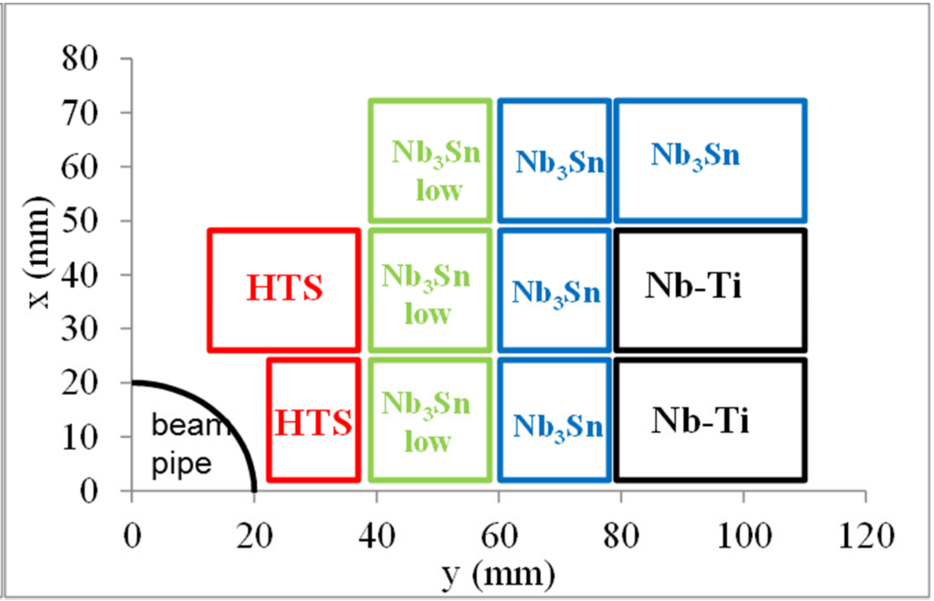
parameter	LHC	HL-LHC	FCC-hh
c.m. energy [TeV]	14		100
dipole magnet field [T]	8.33		16 (20)
circumference [km]	36.7		100 (83)
luminosity $[10^{34}\ cm^{-2}s^{-1}]$	1	5	5 [→20?]
bunch spacing [ns]	25		25 (5)
events / bunch crossing	**27**	**135**	**170 (34)**
bunch population $[10^{11}]$	1.15	2.2	1 (0.2)
norm. transverse emitt. [mm]	3.75	2.5	2.2 (0.44)
IP beta-function [m]	0.55	0.15	1.1
IP beam size [mm]	16.7	7.1	6.8 (3)
synchrotron rad. [W/m/aperture]	0.17	0.33	28 (44)
critical energy [keV]	0.044		4.3 (5.5)
total syn.rad. power [MW]	**0.0072**	**0.0146**	**4.8 (5.8)**
longitudinal damping time [h]	**12.9**		**0.54 (0.32)**

cost-optimized high-field dipole magnets

15-16 T: *Nb-Ti* & *Nb$_3$Sn*



20 T: *Nb-Ti* & *Nb$_3$Sn* & *HTS*



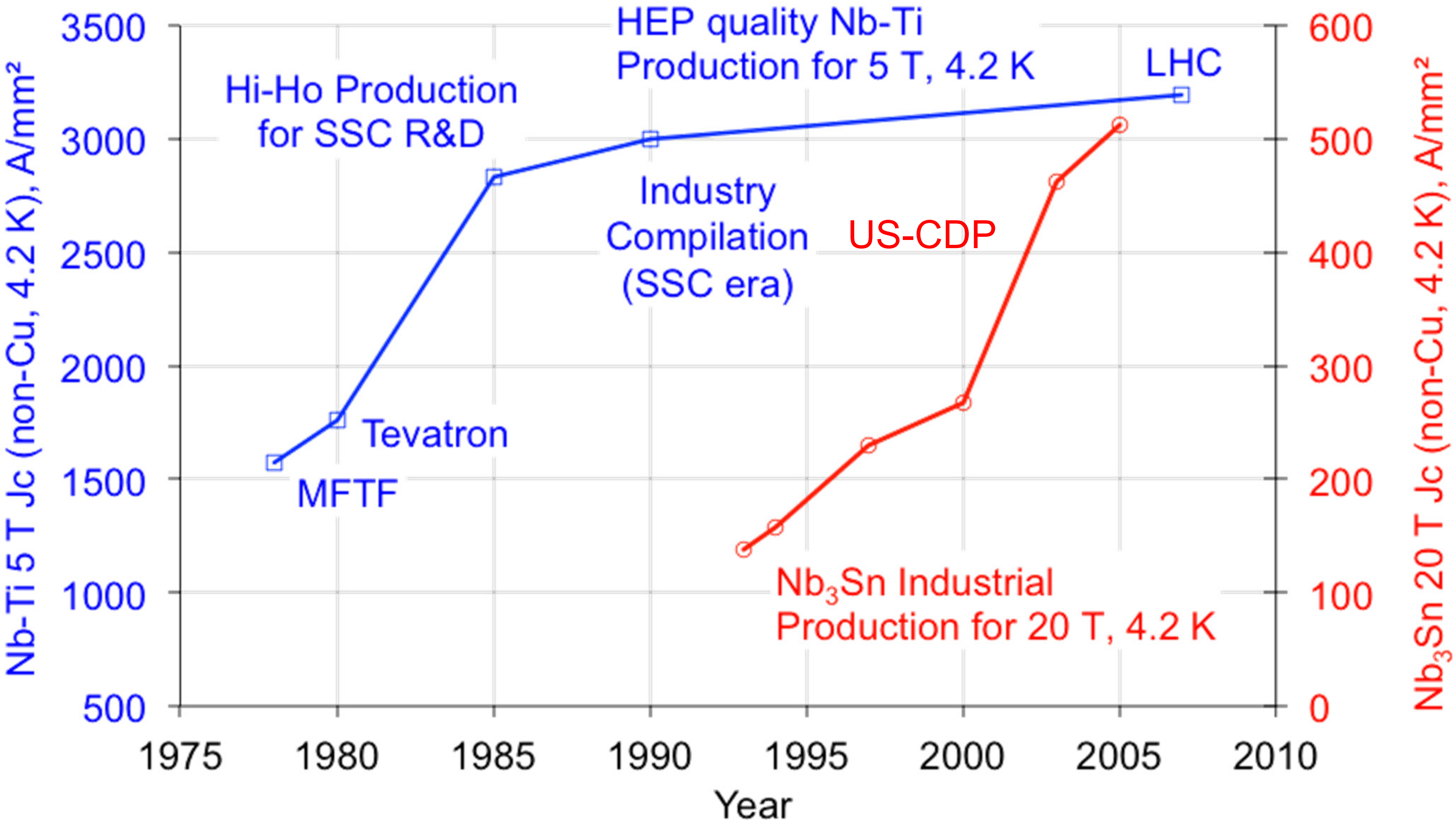
only a quarter is shown

"hybrid magnets"

example block-coil layout

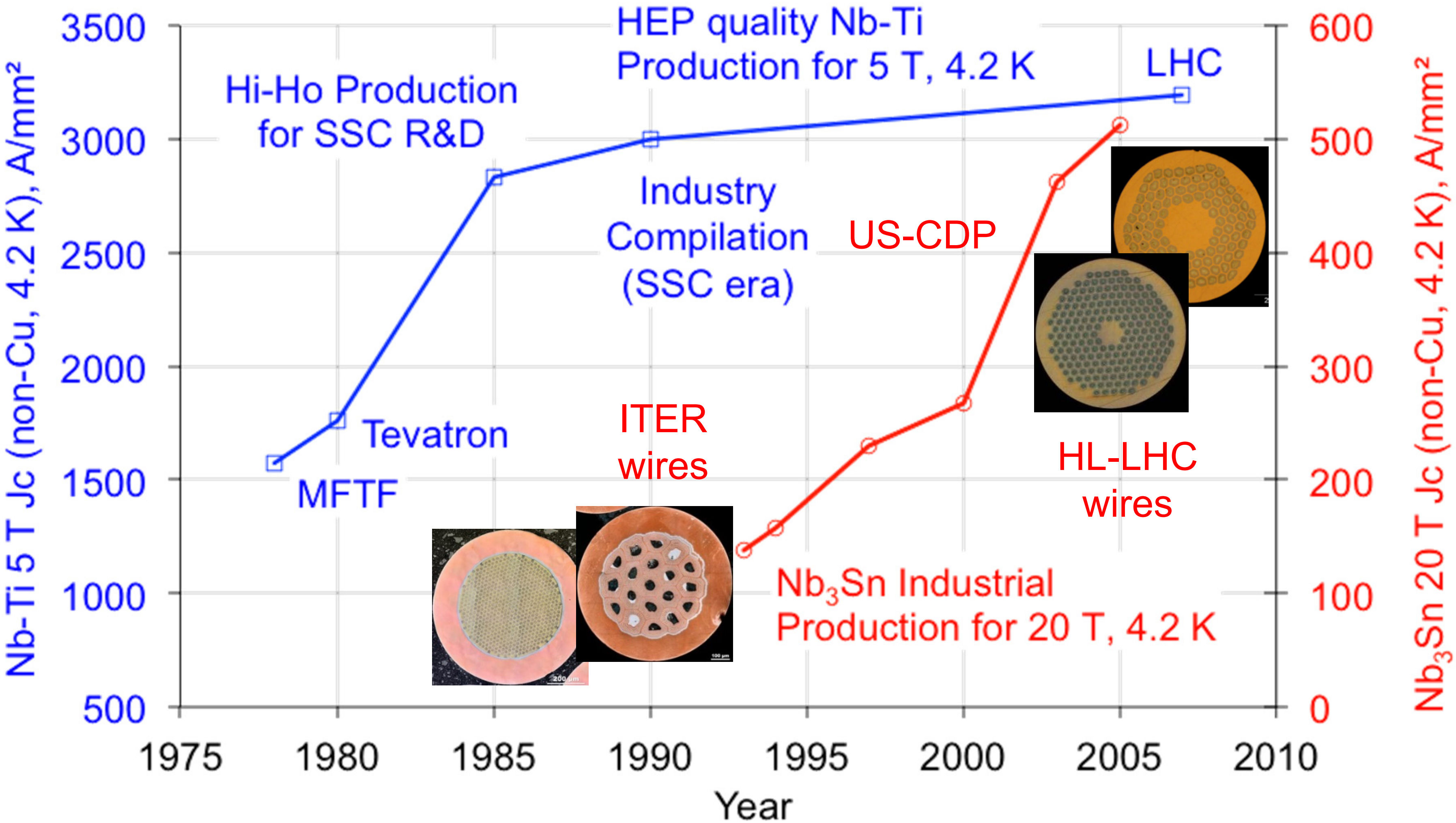
L. Rossi, E. Todesco, P. McIntyre

Nb_3Sn vs *Nb-Ti* SC wire production



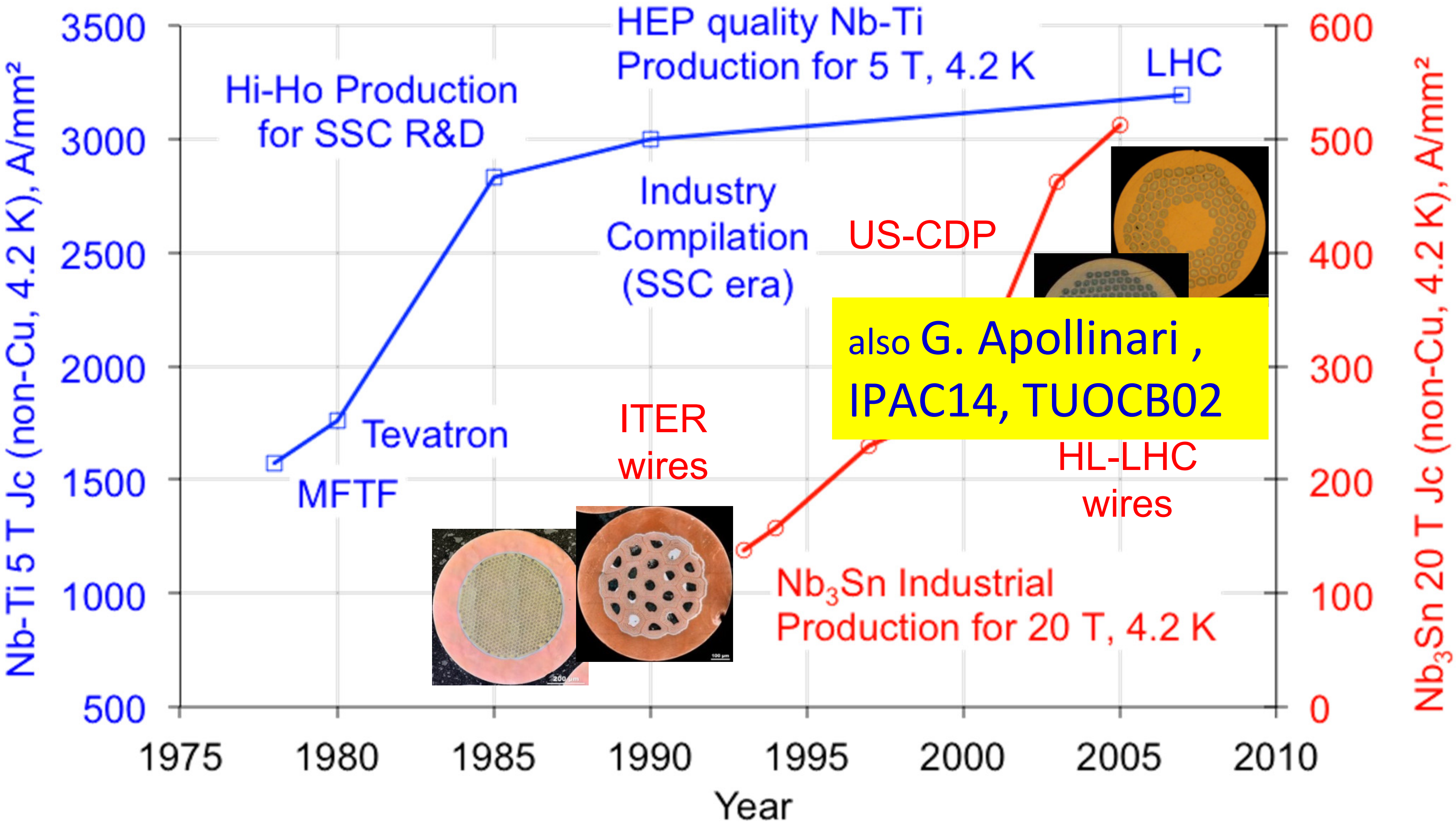
B. Strauss, data by courtesy of J. Parrell (US DOE OST)

Nb_3Sn vs *Nb-Ti* SC wire production



B. Strauss, data by courtesy of J. Parrell (US DOE OST)

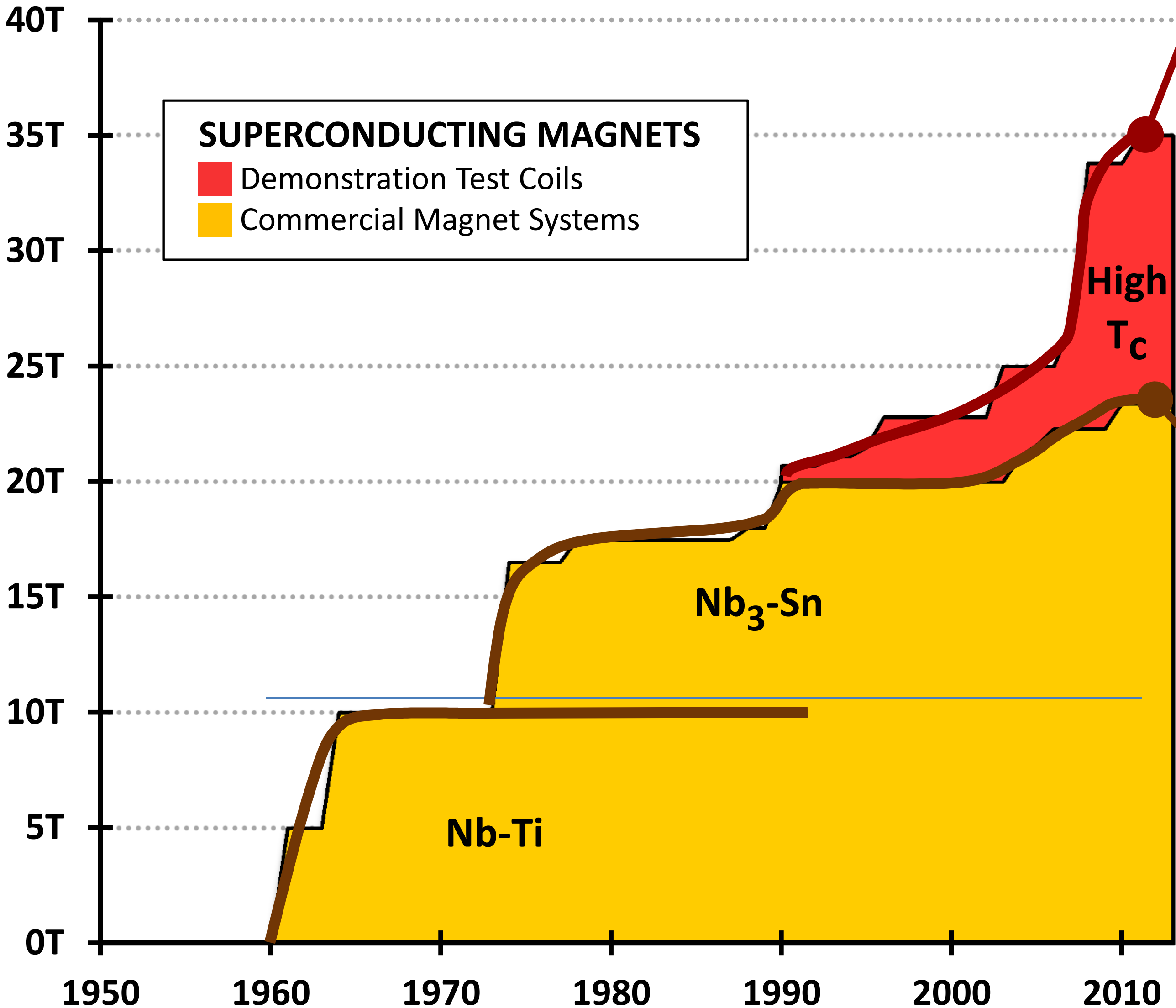
Nb_3Sn vs *Nb-Ti* SC wire production



B. Strauss, data by courtesy of J. Parrell (US DOE OST)

superconducting magnet technology

SC solenoid magnets (dipoles to follow)



35 T Proof-of-Principle Demo

(4T HTS Test Coil in a 31T Background Magnetic Field)

ϕ 39 mm

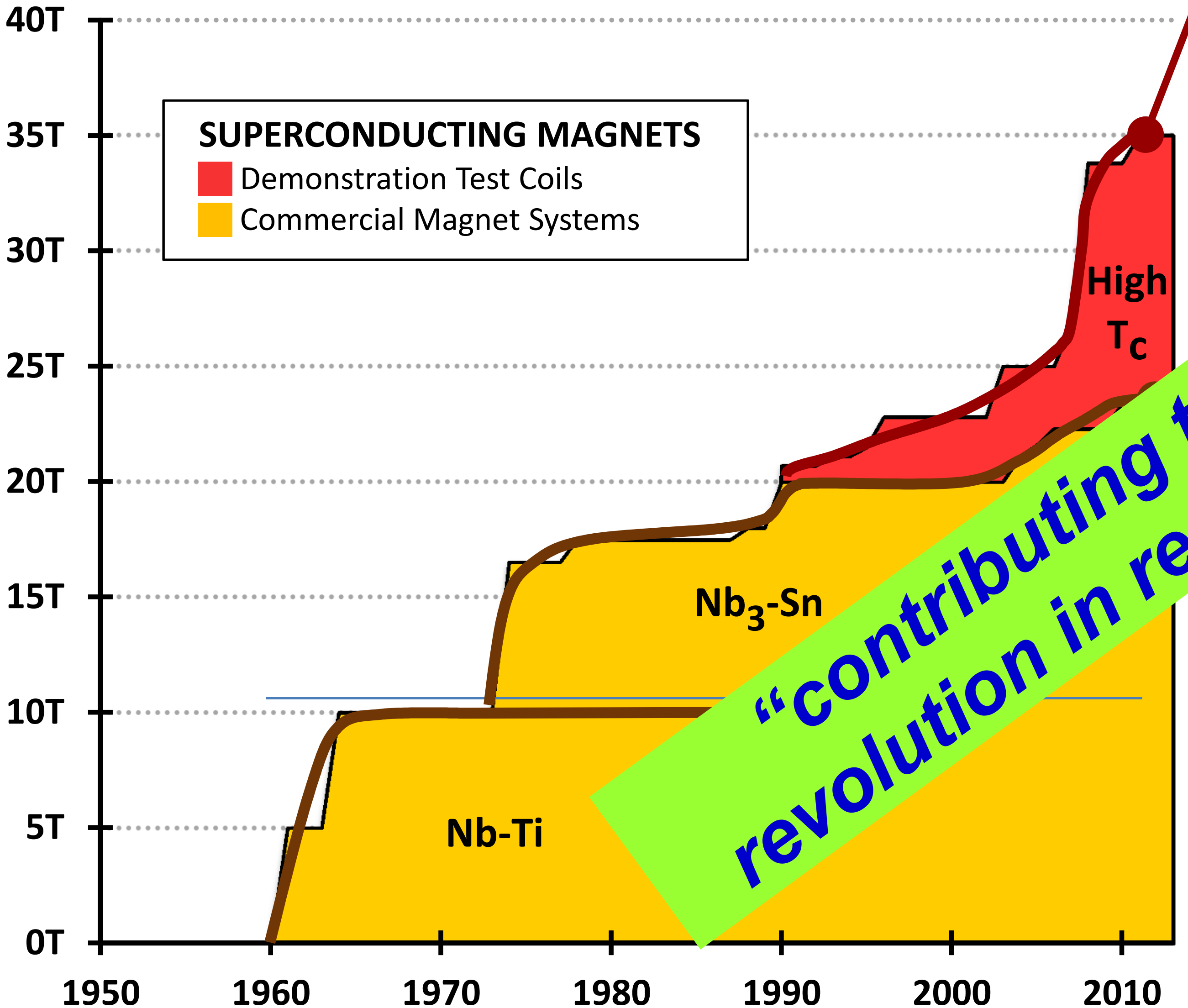
23.5 T (1GHz NMR) Nb_3-Sn Superconducting Magnets

(Manufactured Commercially)

G. Boebinger, NHMFL

superconducting magnet technology

SC solenoid magnets (dipoles to follow)



35 T Proof-of-Principle Demo

(4T HTS Test Coil in a 31T Background Magnetic Field)

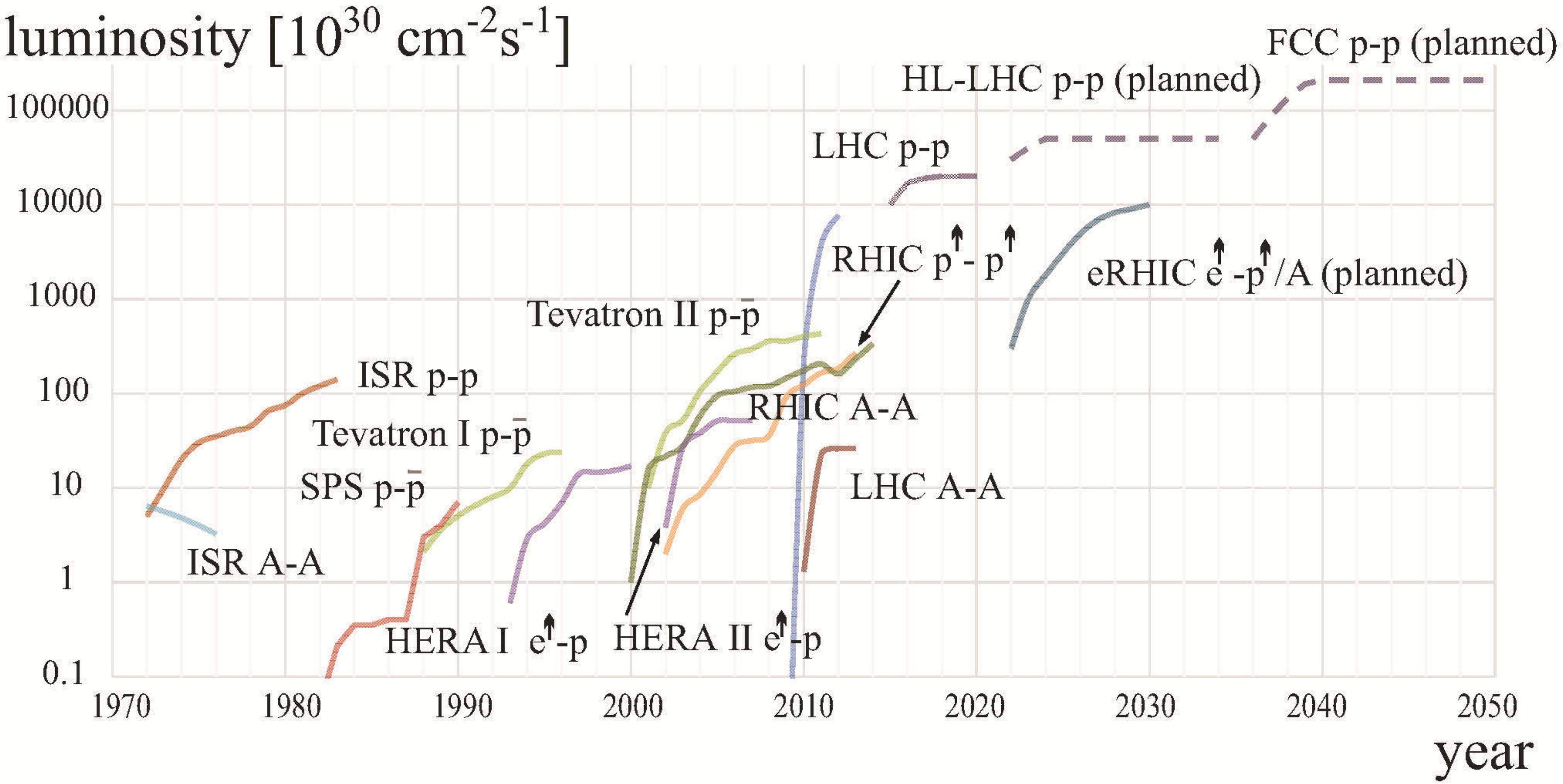
ϕ 39 mm

23.5 T (1GHz NMR) Nb_3-Sn Superconducting Magnets

(Manufactured Commercially)

G. Boebinger, NHMFL

hadron-collider peak luminosity vs. year



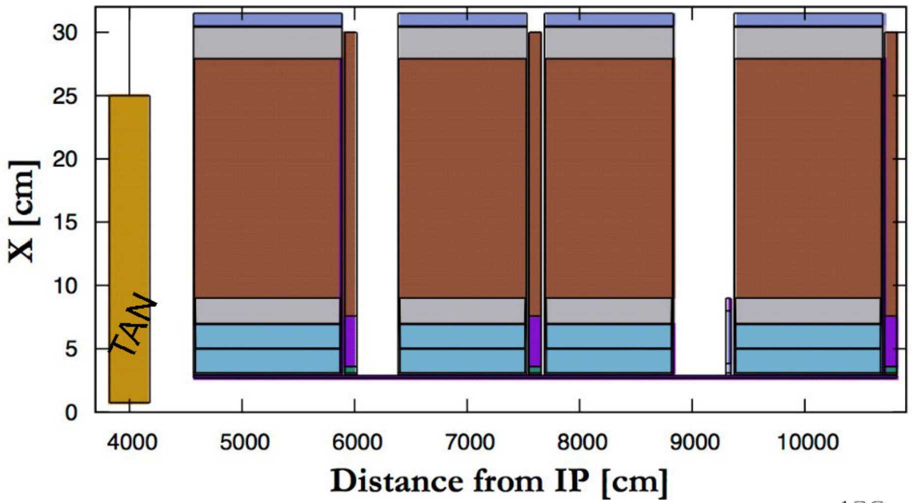
Courtesy W. Fischer

LHC run 1 (2012-13) accumulated more integrated luminosity than all previous hadron colliders together!

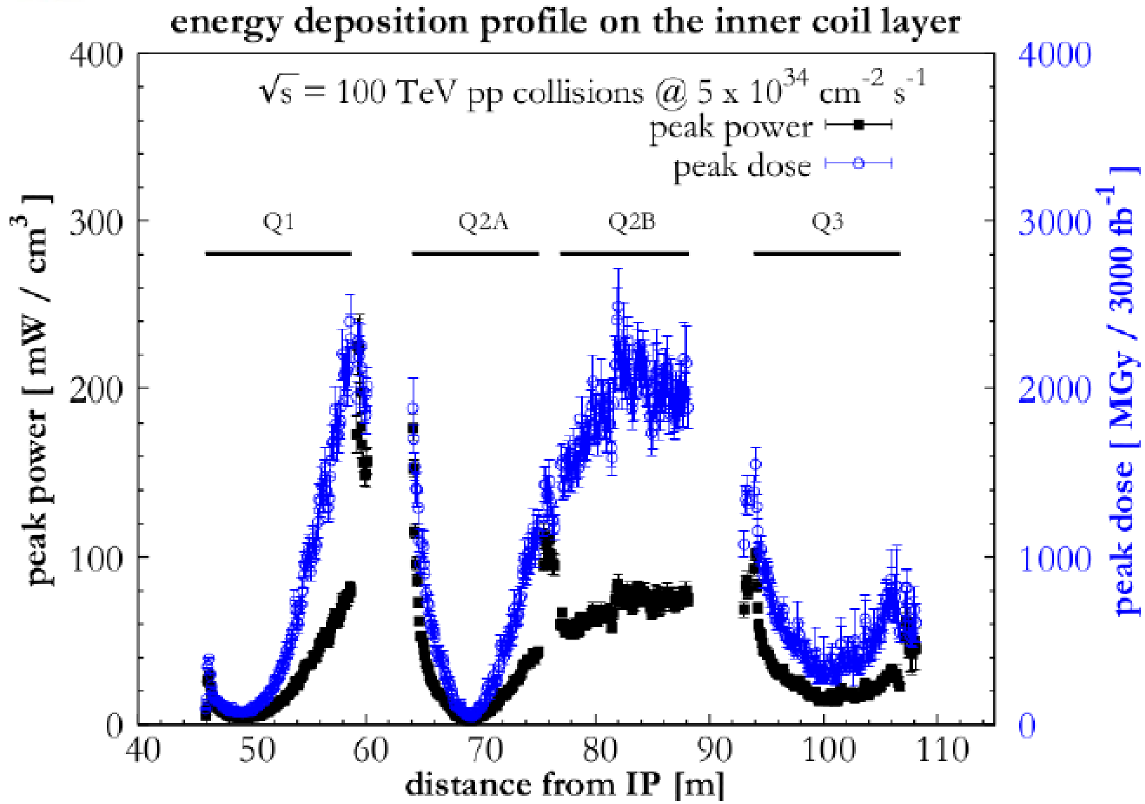
pp IR – radiation from collision debris

F. Cerutti and L. Esposito

FLUKA model



IR peak power and dose

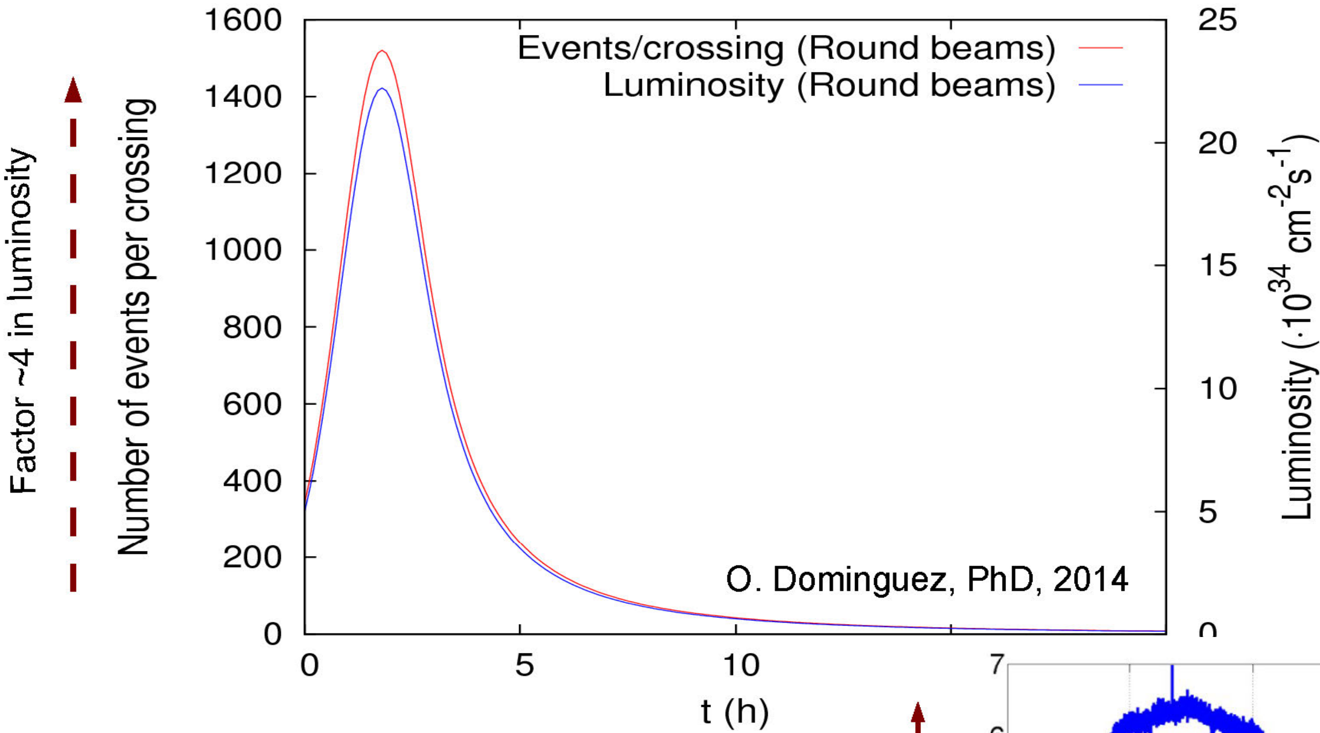


HL-LHC **IR can handle 10x more radiation than** ***LHC***

FCC-hh **IR radiation another 10-100x higher**

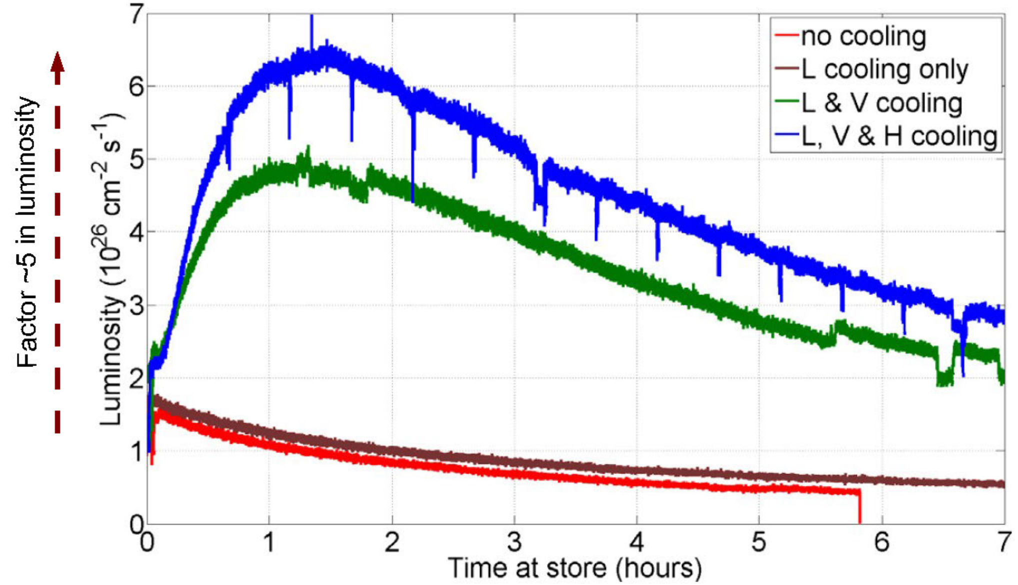
R. Tomas

luminosity evolution with syn. rad. damping



emittance control by noise excitation!?

M. Blaskiewicz et al.

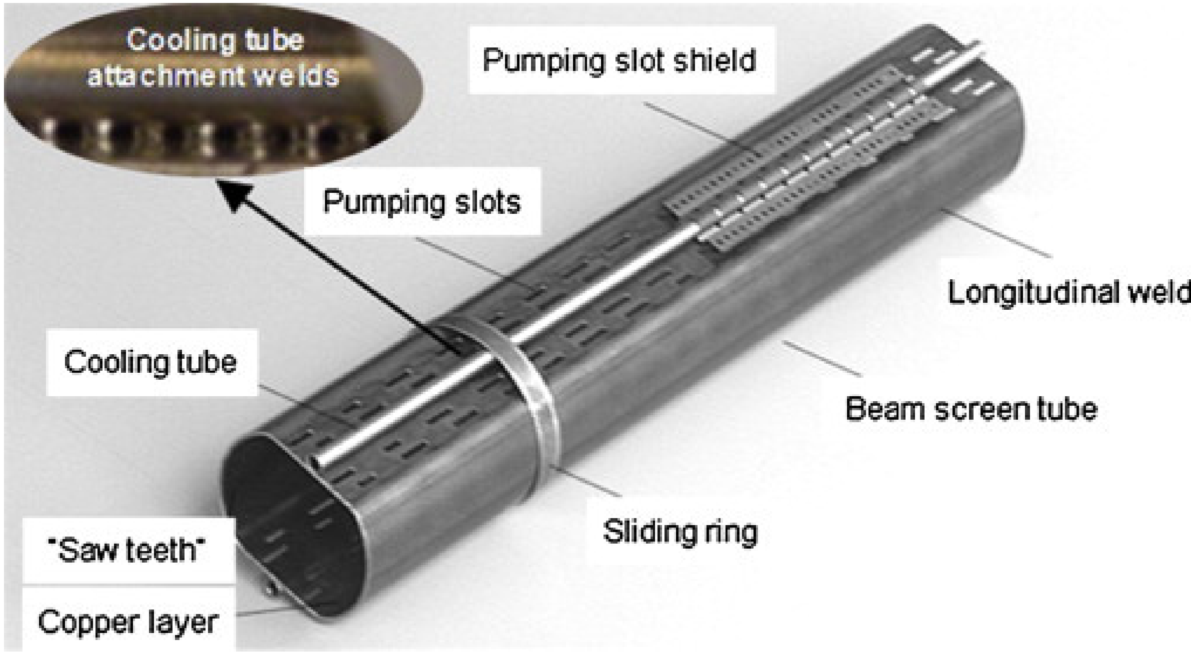


extremely similar to RHIC operation with stochastic cooling

R. Tomas

LHC-type beam pipe?

synchrotron radiation (SR): 28 W/m/beam at 16 T



SR power mostly cooled at beam screen temperature; part going to magnets at 2-4 K

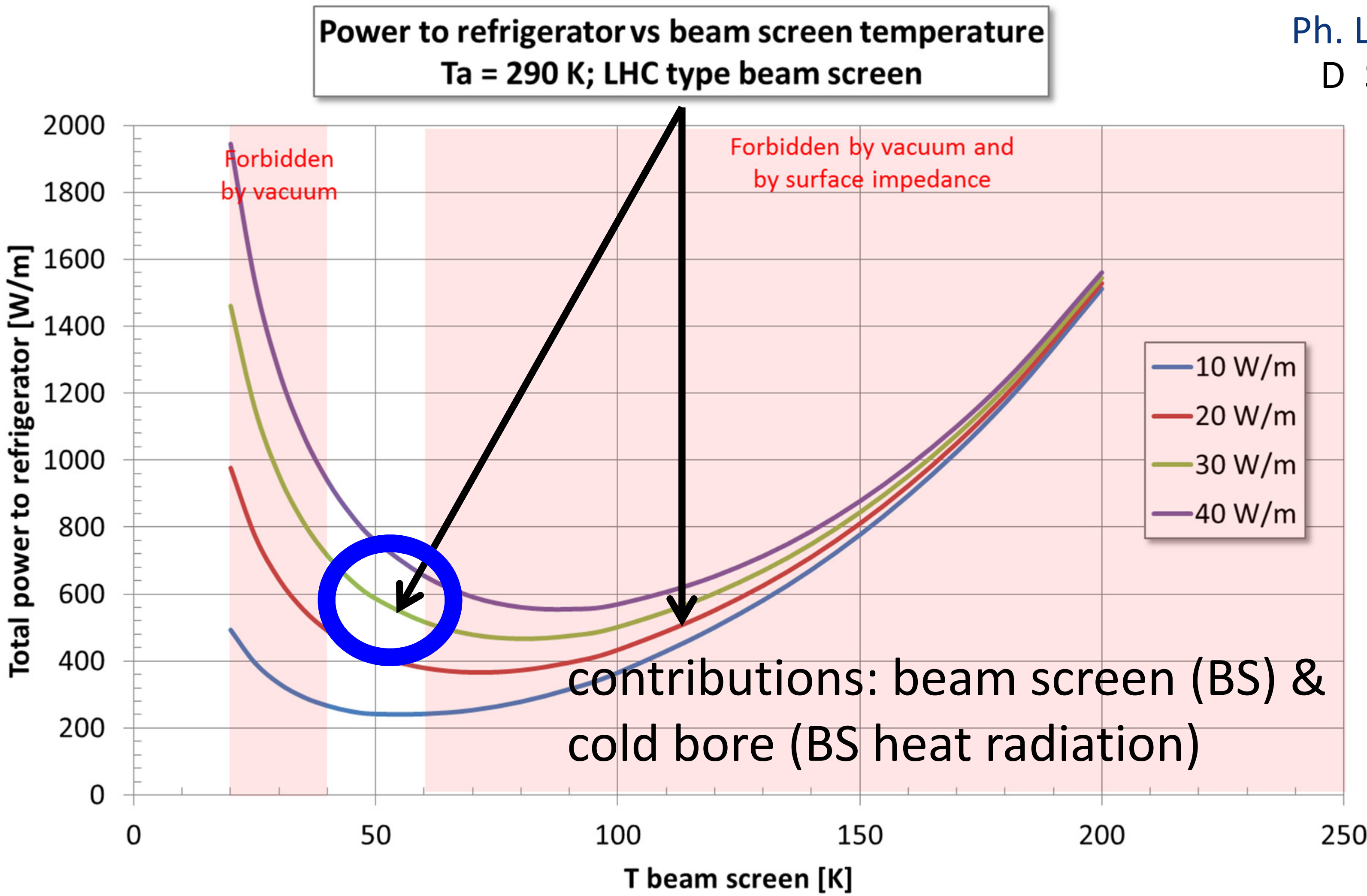
options:

- LHC-type copper coated beam screen (baseline)
- LHC-type beam screen coated with HTS
  + advanced cryogens (*He-Ne* mixtures)
- photon stops at room temperature

D. Schulte

total cryo power for cooling of SR heat

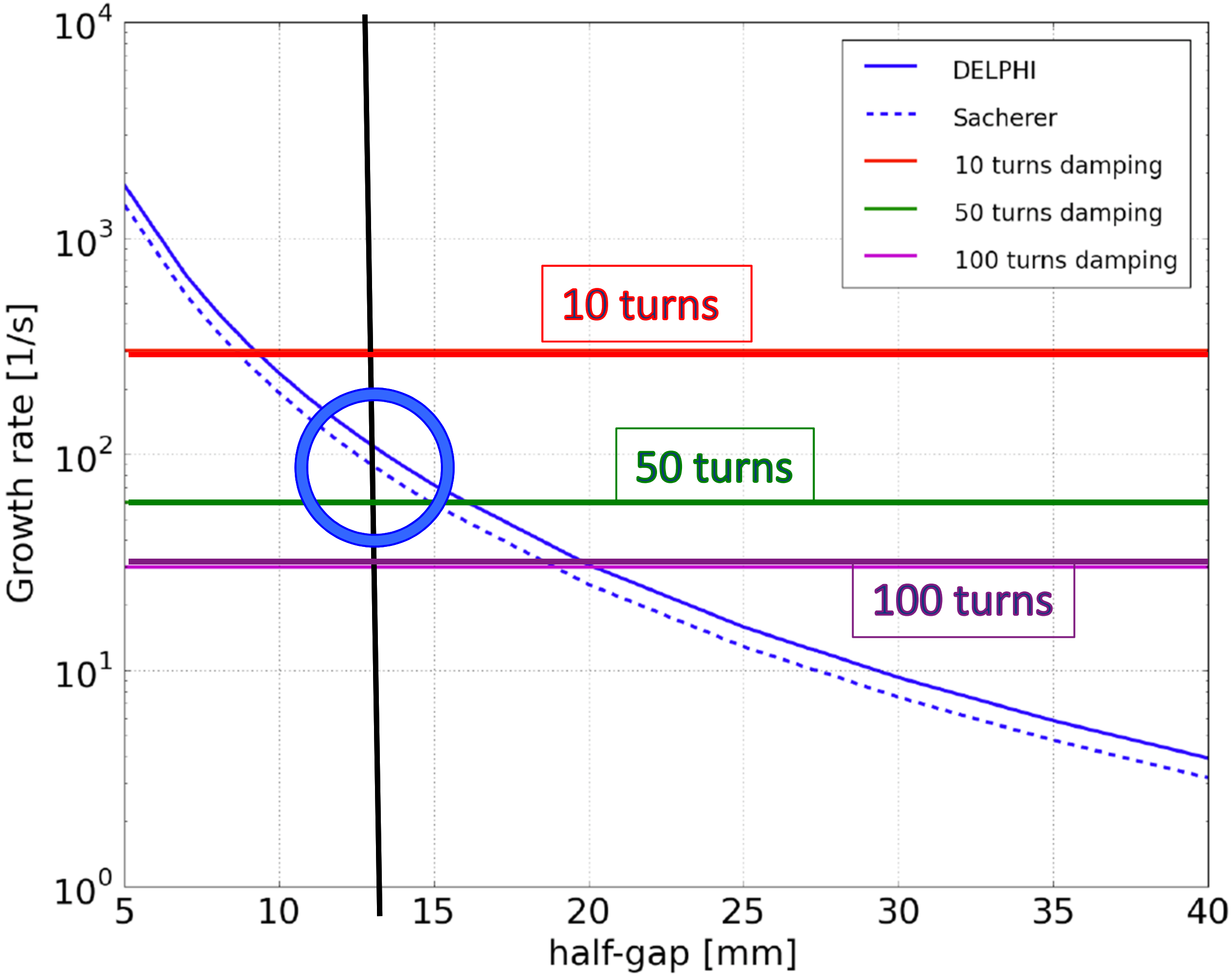
Ph. Lebrun
D Schulte



contributions: beam screen (BS) & cold bore (BS heat radiation)

optimum BS temperature range: 50-100 K ;
40-60 K favoured by impedance & vacuum considerations

resistive-wall instability



N. Mounet, G. Rumolo

need <50-turn feedback

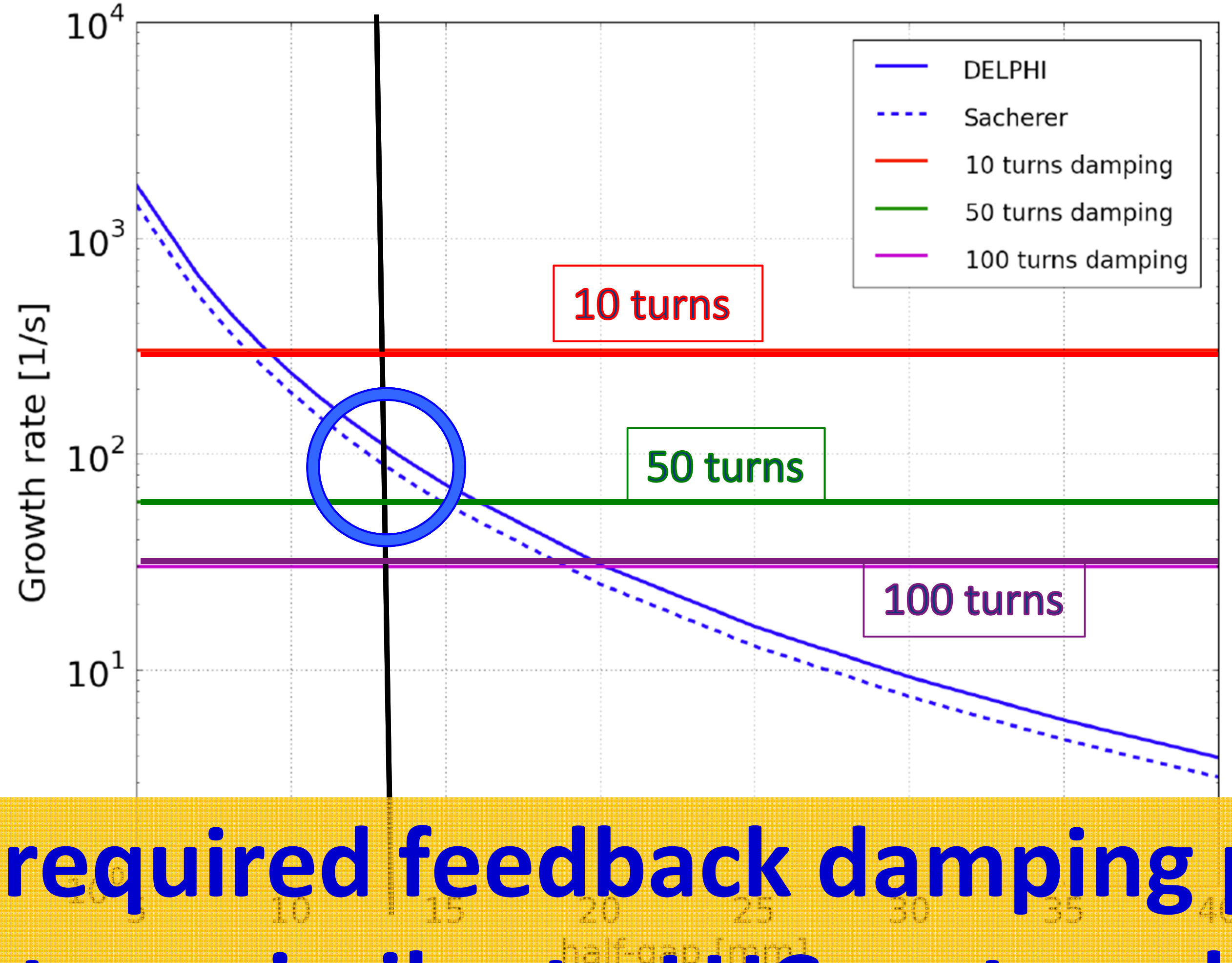
- or increase beam screen aperture
- or decrease beam current

TMCI is less important

multi-bunch effect at 50 K & injection; only resistive wall (infinite copper layer)

D Schulte

resistive-wall instability



N. Mounet, G. Rumolo

need <50-turn feedback

- or increase beam screen aperture
- or decrease beam current

TMCI is less important

multi-bunch effect at 50 K & injection;

required feedback damping per turn similar to LHC system, but time per turn 4x longer

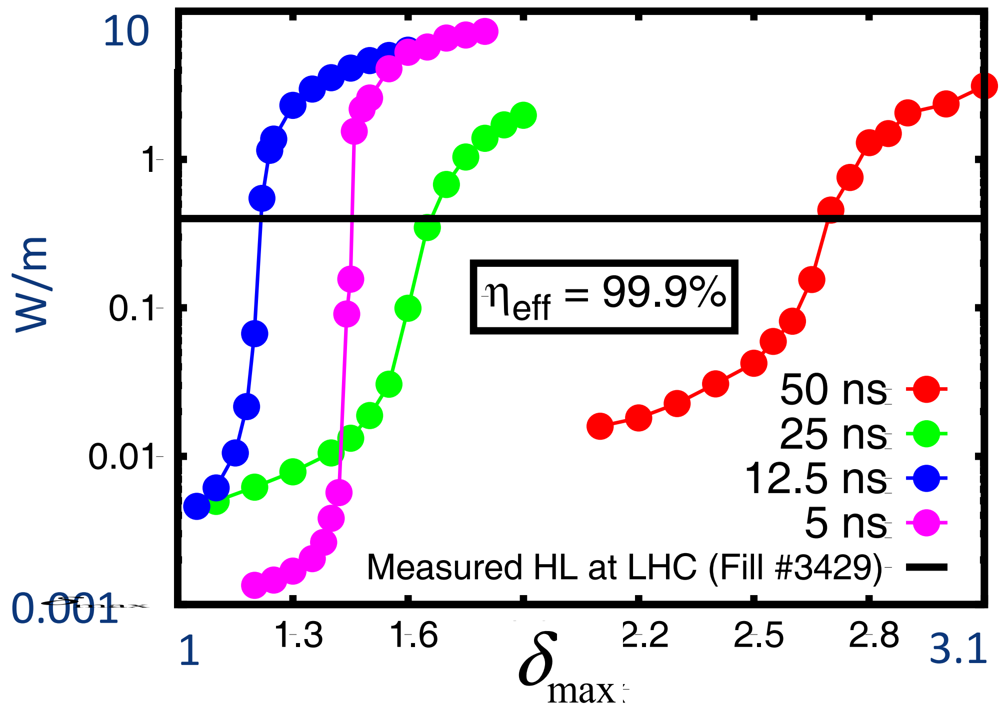
D Schulte

electron cloud

critical photon energy 4.3 keV
similar to 2-3 GeV light sources i.e. 100 x LHC

additional heat load
beam stability?

O. Dominguez Sanchez De La Blanca



<u>R&D items:</u>

- photon capture efficiency?
- dependence on beam-pipe aperture
- surface properties at 40-60 K
- surface properties of HTS coating

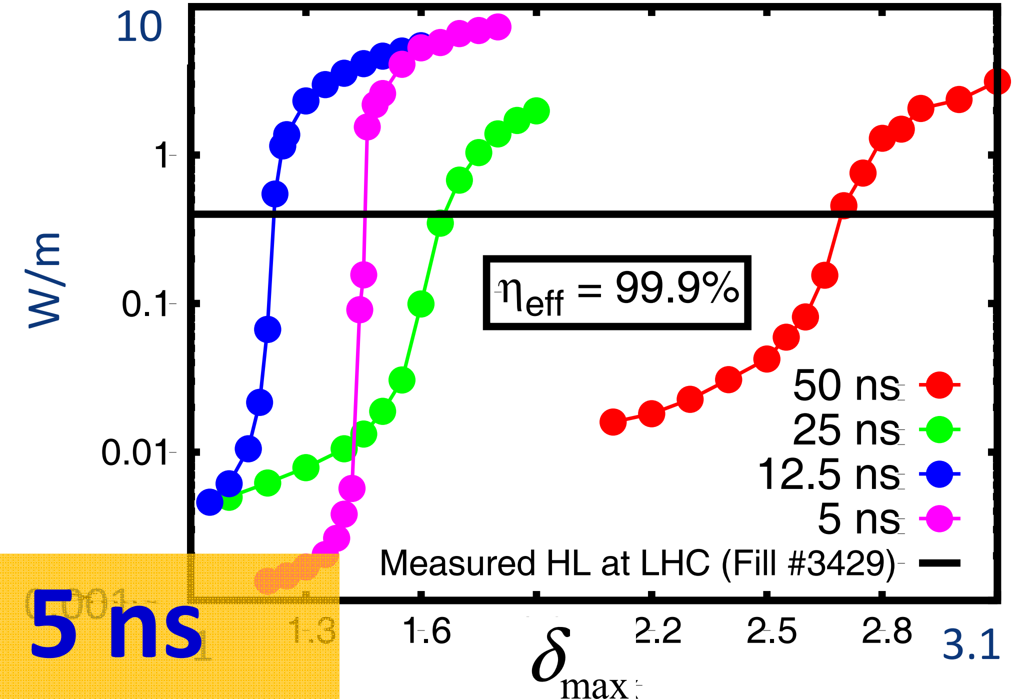
also G. Iadarola, H. Bartosik, et al, IPAC2014, TUPME027

electron cloud

critical photon energy 4.3 keV
similar to 2-3 GeV light
sources i.e. 100 x LHC

additional heat load
beam stability?

O. Dominguez Sanchez De La Blanca

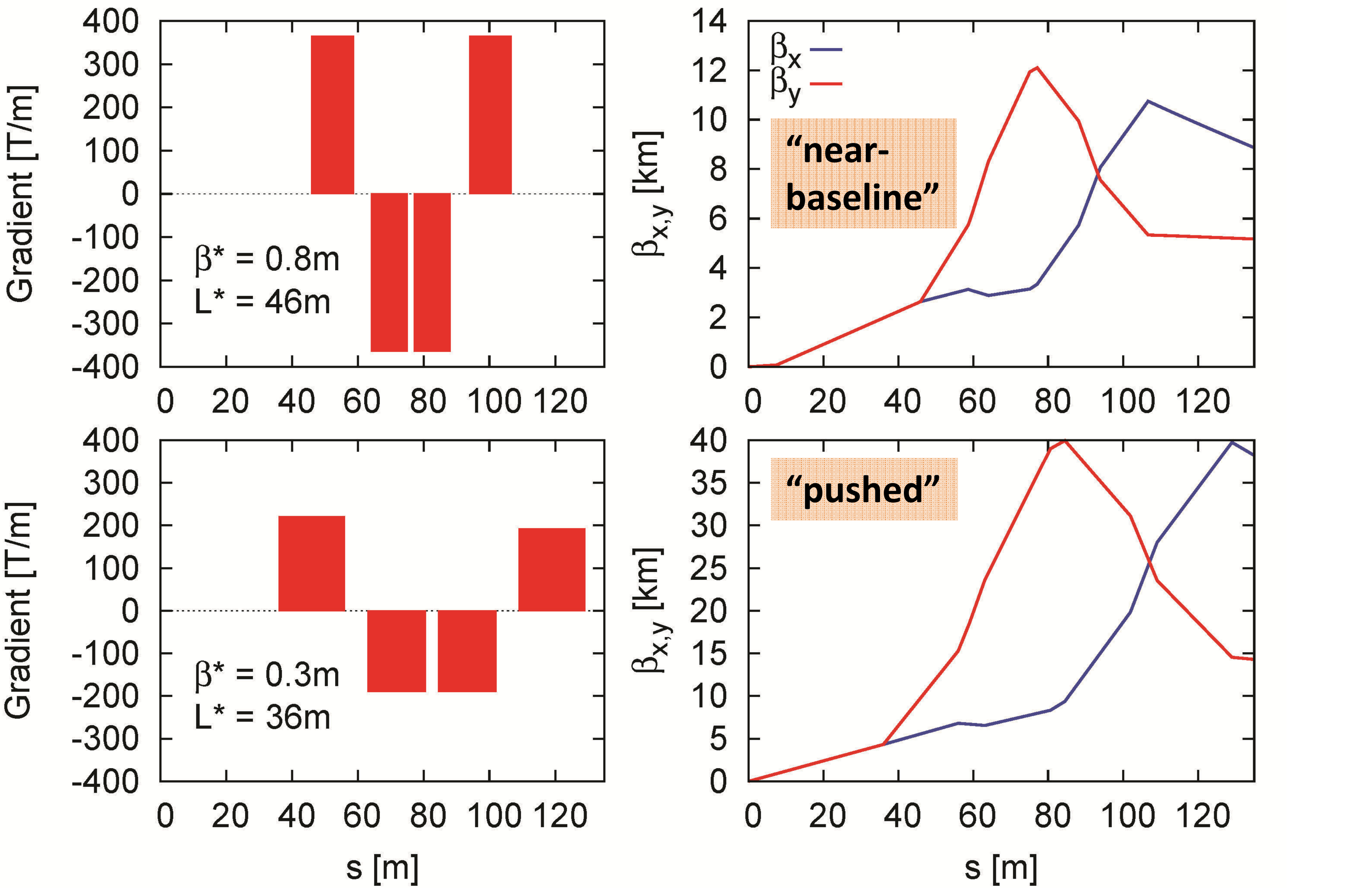


aside from 25 ns, 5 ns could be possible bunch spacing→ better use of SR damping & 4-5 times higher luminosity

also G. Iadarola, H. Bartosik, et al, IPAC2014, TUPME027

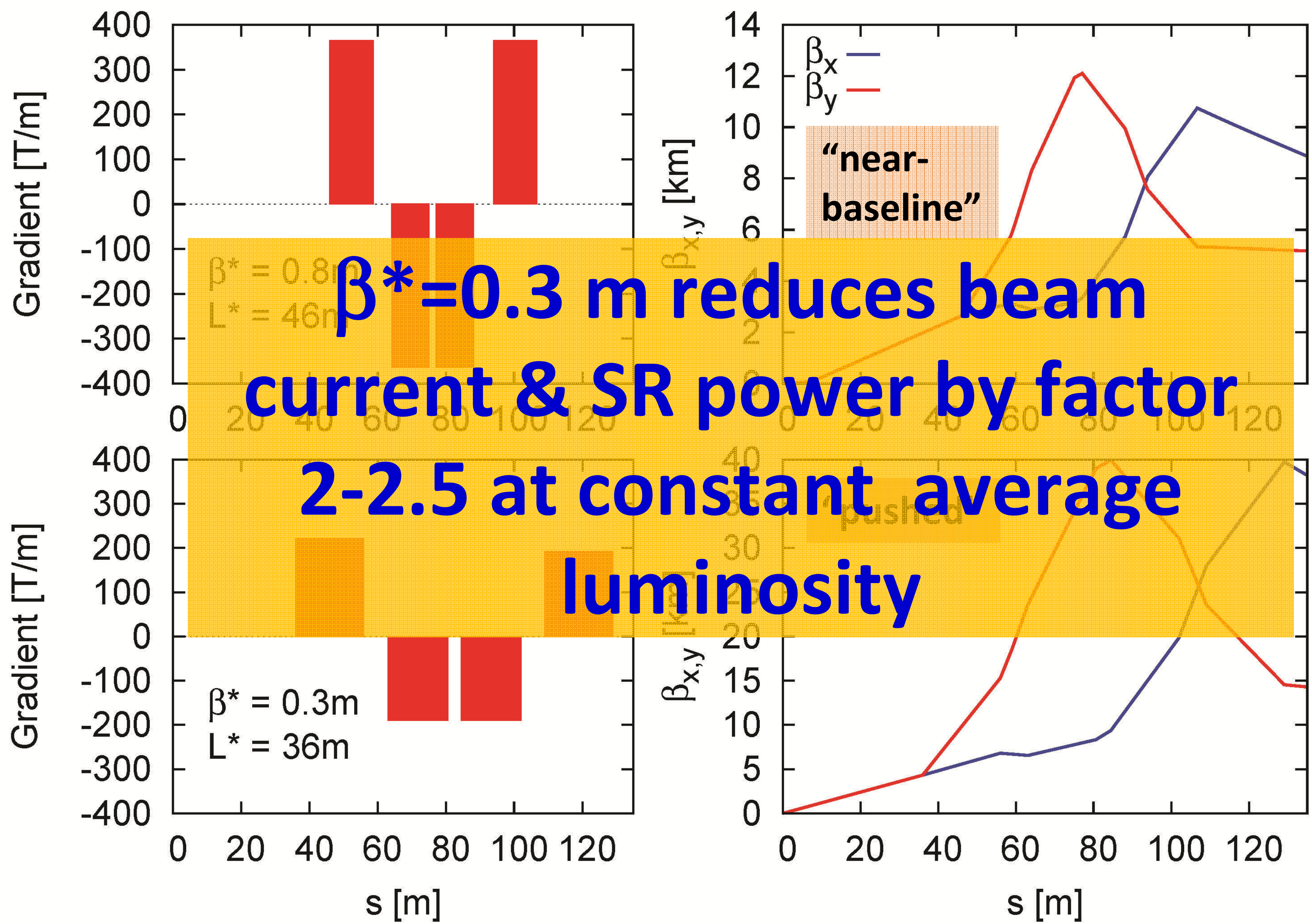
D. Schulte

pp IR optics – low β* at 100 TeV?



R. Tomas, R. Martin, E. Todesco et al.

pp IR optics – low β* at 100 TeV?



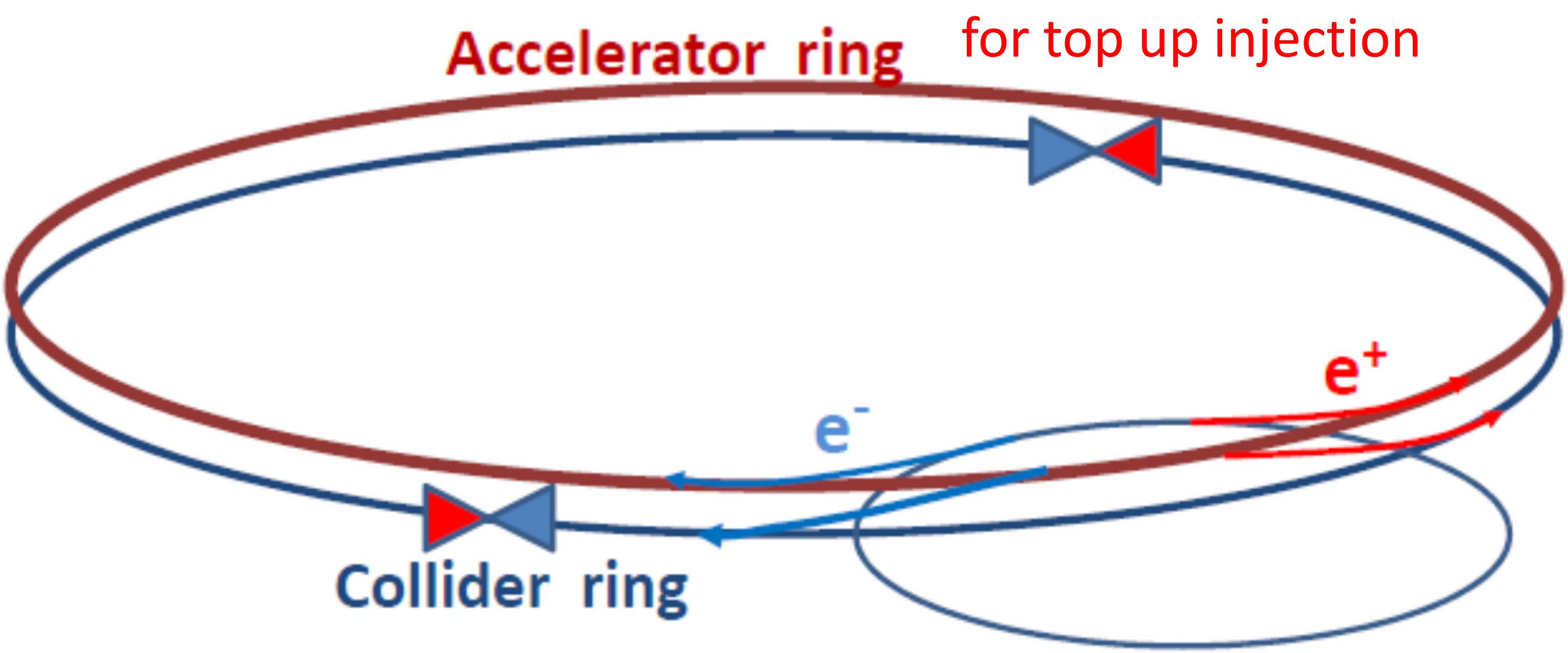
β*=0.3 m reduces beam current & SR power by factor 2-2.5 at constant average luminosity

R. Tomas, R. Martin, E. Todesco et al.

FCC-ee: e^+e^- collider up to 350 (500) GeV

circumference ≈100 km

A. Blondel

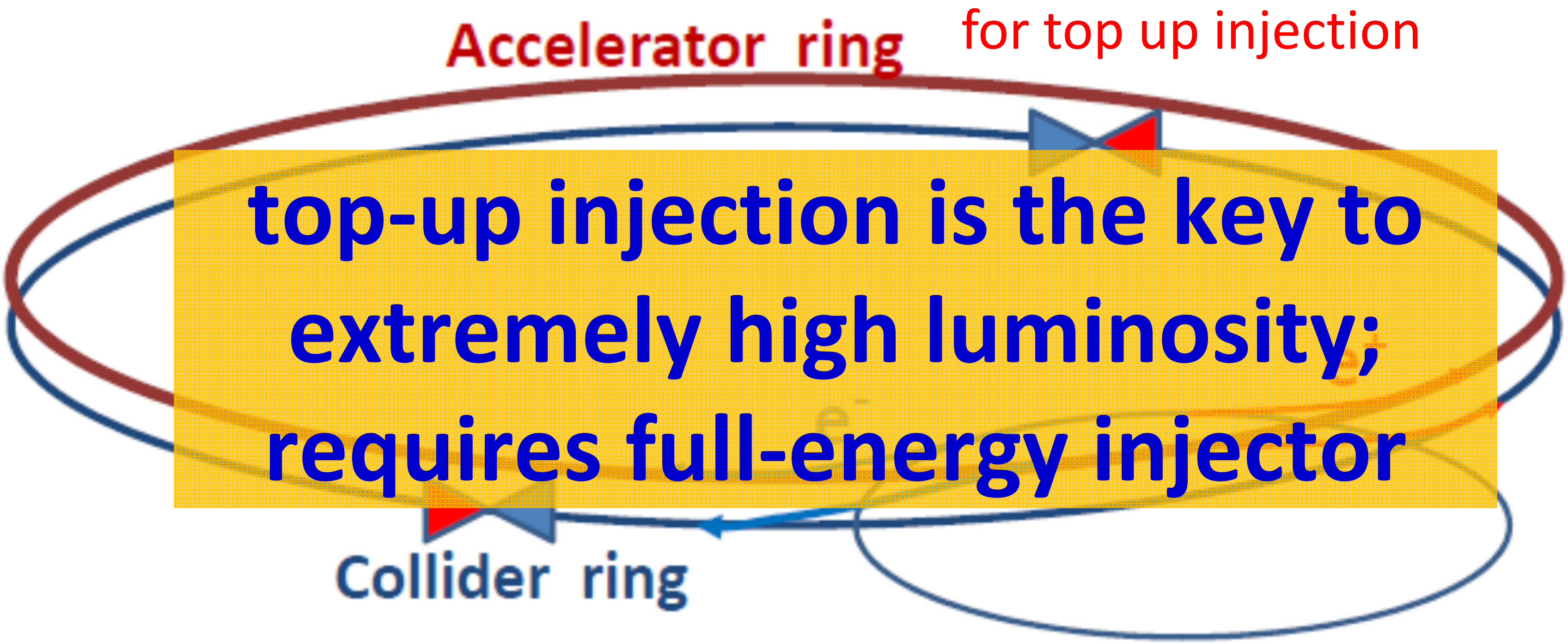


short beam lifetime (~τ_{LEP2}/40) due to high luminosity **supported by top-up injection** (used at KEKB, PEP-II, SLS,…); top-up **also avoids ramping & thermal transients, + eases tuning**

FCC-ee: e^+e^- collider up to 350 (500) GeV

circumference ≈100 km

A. Blondel



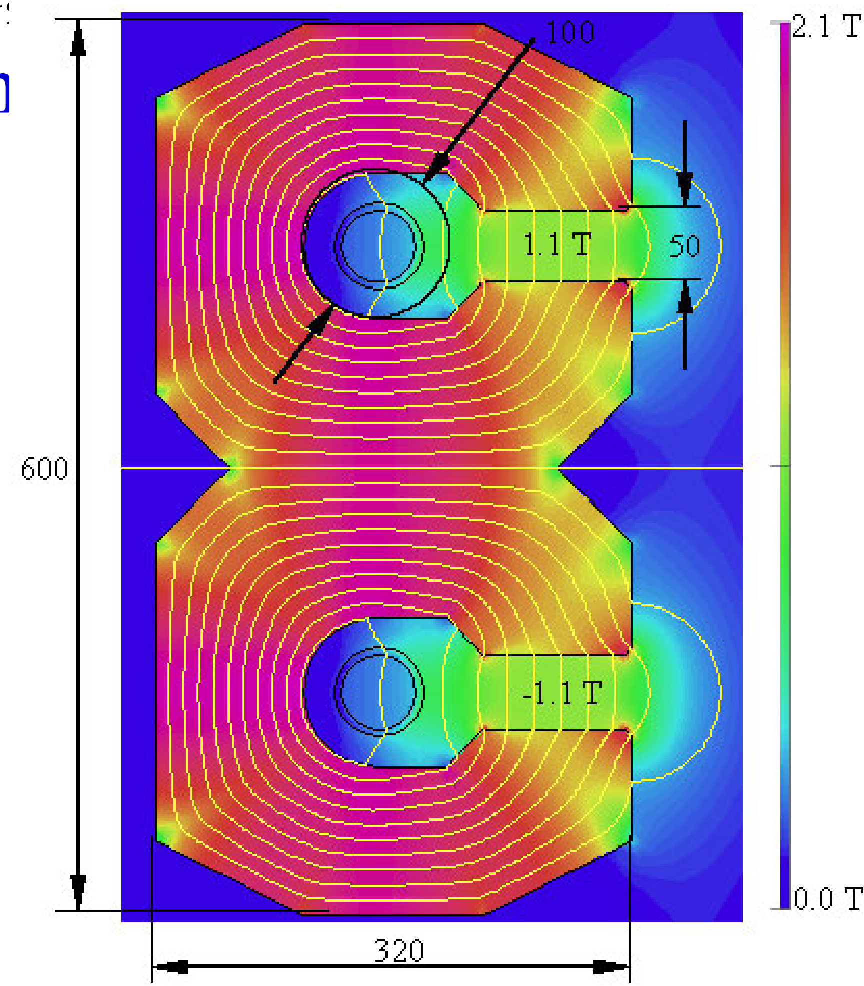
top-up injection is the key to extremely high luminosity; requires full-energy injector

short beam lifetime (~τ_{LEP2}/40) due to high luminosity **supported by top-up injection** (used at KEKB, PEP-II, SLS,…); top-up **also avoids ramping & thermal transients, + eases tuning**

FCC-ee/hh: hybrid NC & SC arc magnets

twin-aperture iron-dominated, compact hybrid "transmission line" dipoles - for injector synchrotrons in FCC tunnel

- resistive cable for lepton machine
- superconducting for hadron operation



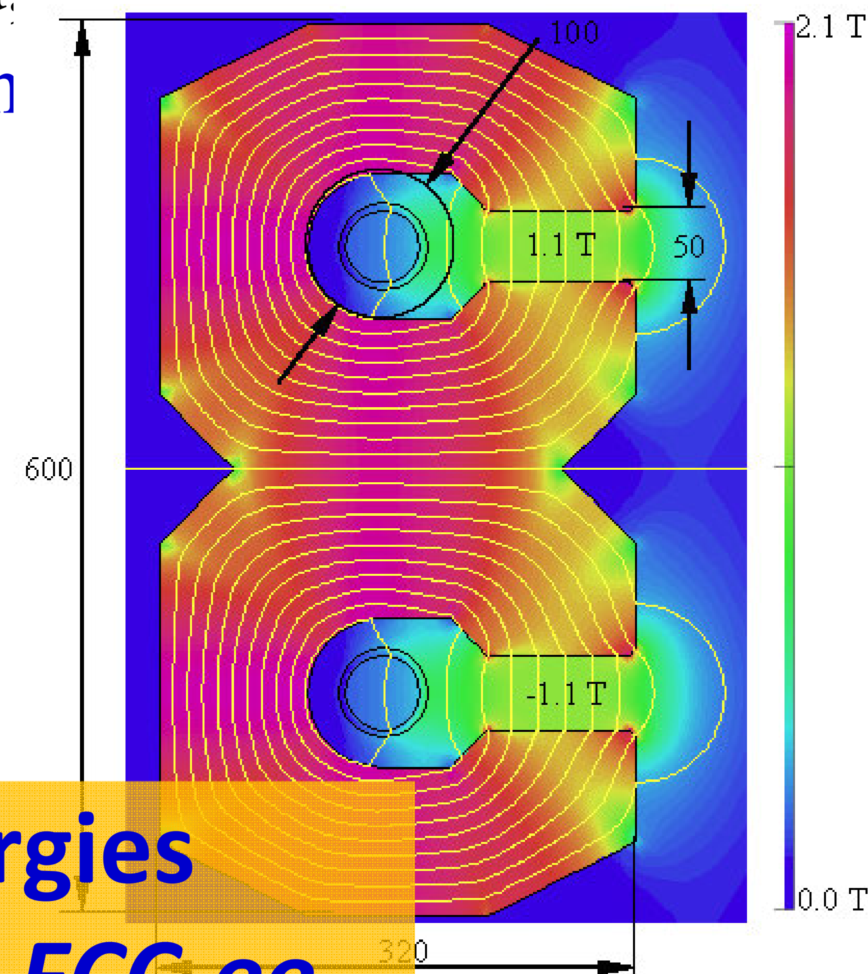
required dynamic range ~100
hadron extraction 1.1 T
lepton injection: 10 mT

A. Milanese, H. Piekarz, L. Rossi, IPAC2014, TUOCB01

FCC-ee/hh: hybrid NC & SC arc magnets

twin-aperture iron-dominated, compact hybrid "transmission line" dipoles - for injector synchrotrons in FCC tunnel

- resistive cable for lepton machine
- superconducting for hadron operation



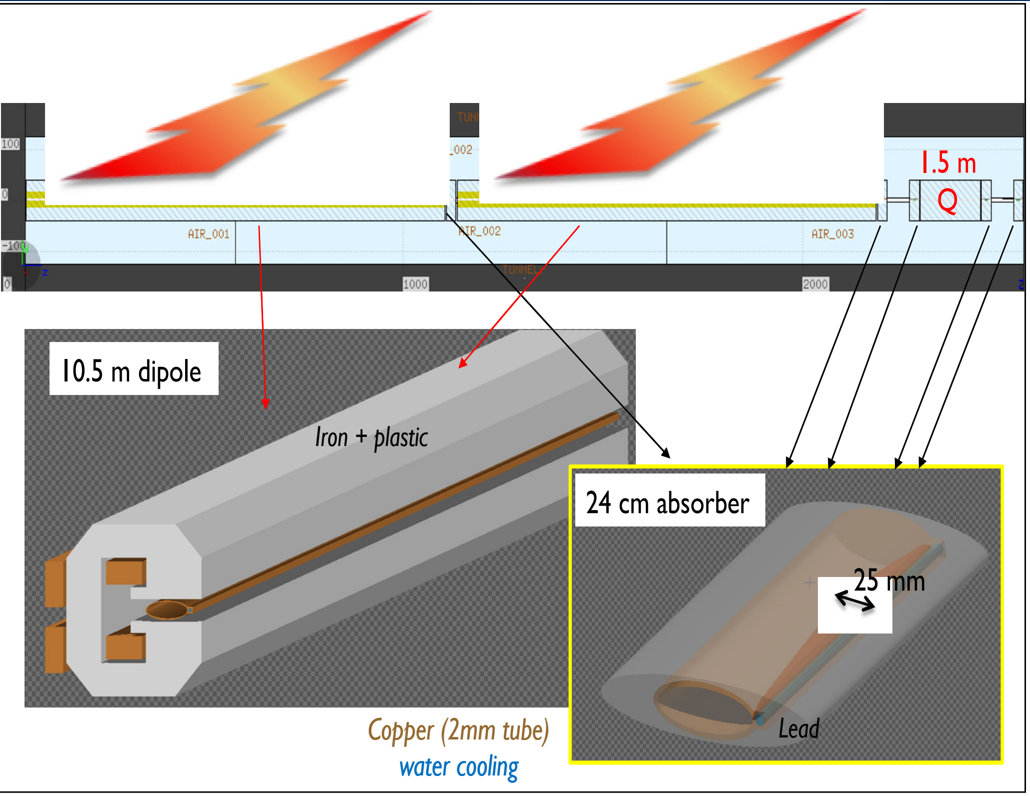
hadron extraction 1.1 T

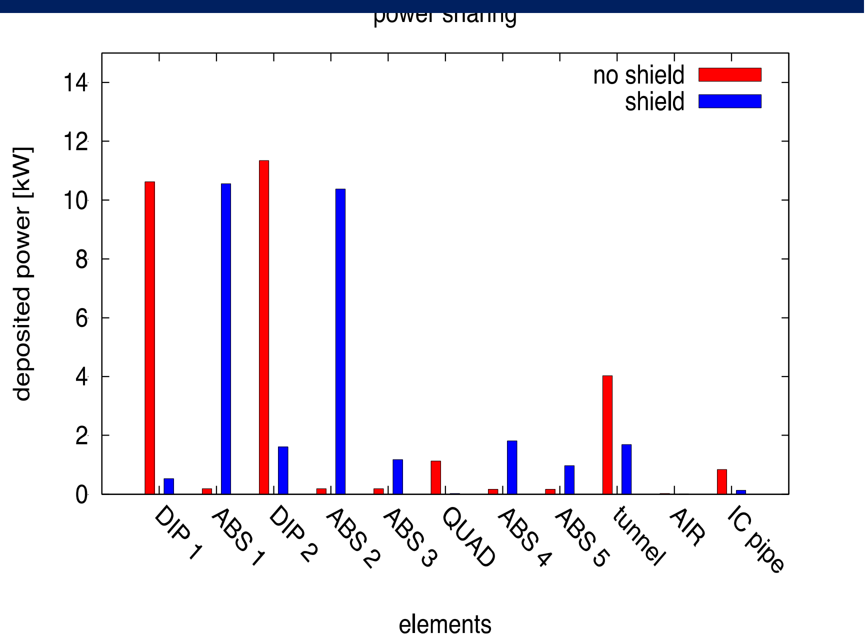
one of many synergies between *FCC-hh* and *FCC-ee*

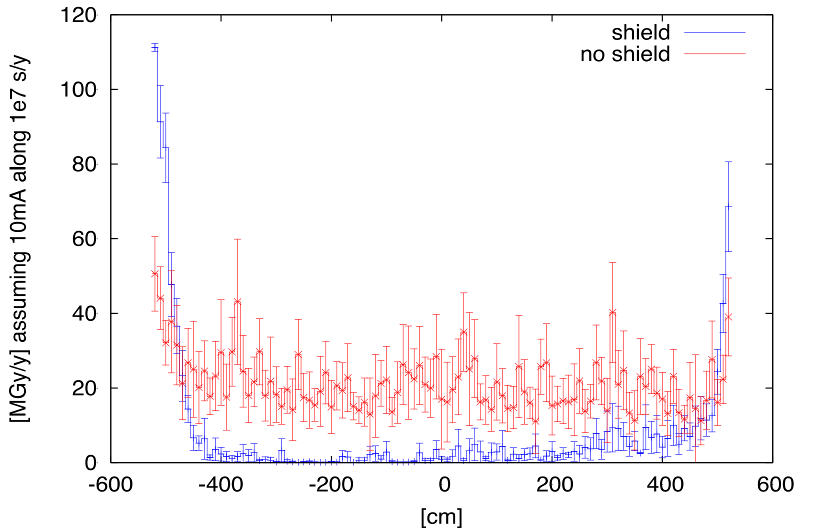
A. Milanese, H. Piekarz, L. Rossi, IPAC2014, TUOCB01

parameter	LEP2	FCC-ee					CepC
		Z	Z (c.w.)	W	H	t	H
E_{beam} [GeV]	104	45	45	80	120	175	120
circumference [km]	26.7	100	100	100	100	100	54
current [mA]	3.0	1450	1431	152	30	6.6	16.6
$P_{SR,tot}$ [MW]	22	100	100	100	100	100	100
no. bunches	4	16700	29791	4490	1360	98	50
N_b [10^{11}]	4.2	1.8	1.0	0.7	0.46	1.4	3.7
ε_x [nm]	22	29	0.14	3.3	0.94	2	6.8
ε_y [pm]	250	60	1	1	2	2	20
β^*_x [m]	1.2	0.5	0.5	0.5	0.5	1.0	0.8
β^*_y [mm]	50	1	1	1	1	1	1.2
σ^*_y [nm]	3500	250	32	130	44	45	160
$\sigma_{z,SR}$ [mm]	11.5	1.64	2.7	1.01	0.81	1.16	2.3
$\sigma_{z,tot}$ [mm] (w beamstr.)	11.5	2.56	5.9	1.49	1.17	1.49	2.7
hourglass factor F_{hg}	0.99	0.64	0.94	0.79	0.80	0.73	0.61
L/IP [10^{34} cm^{-2}s^{-1}]	0.01	28	212	12	6	1.7	1.8
τ_{beam} [min]	300	287	39	72	30	23	40

FCC-ee: Shielding 100 MW SR at 350 GeV

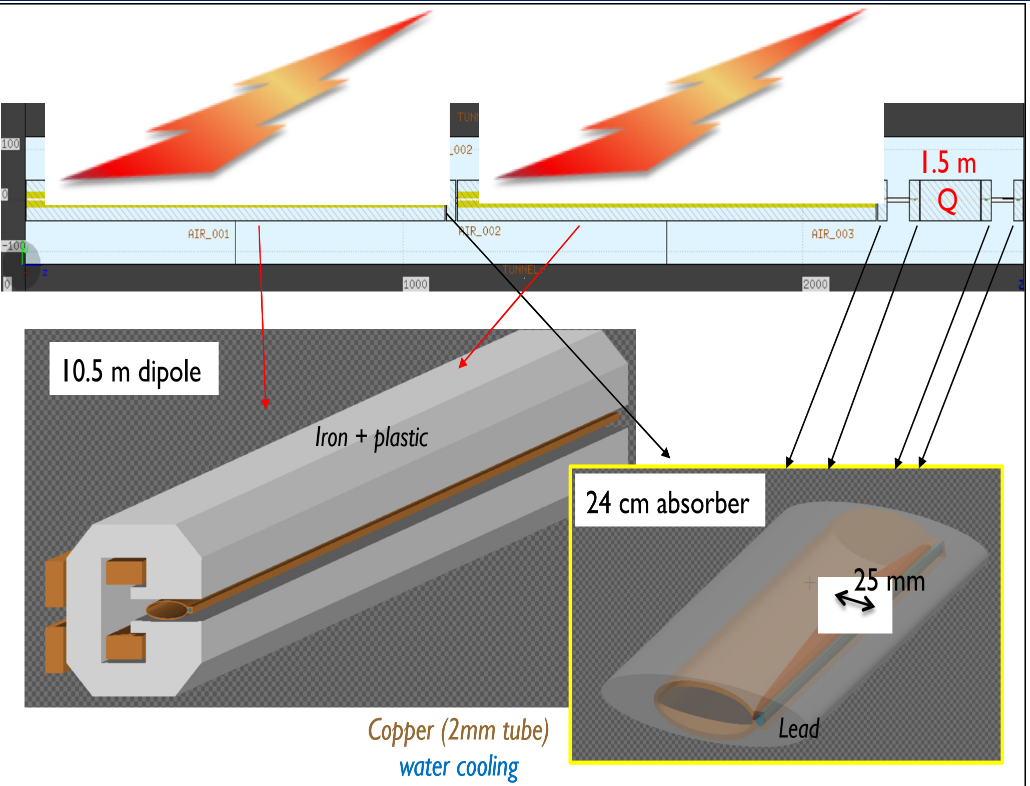


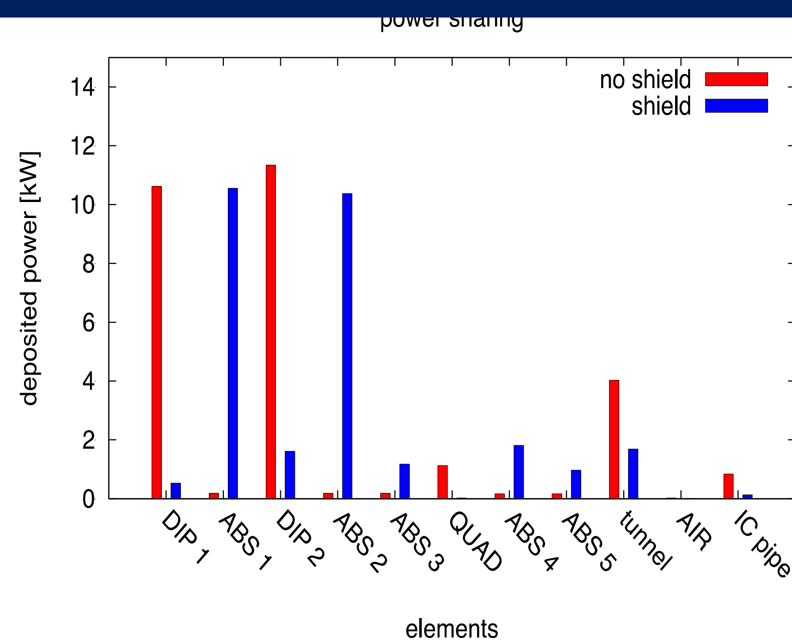


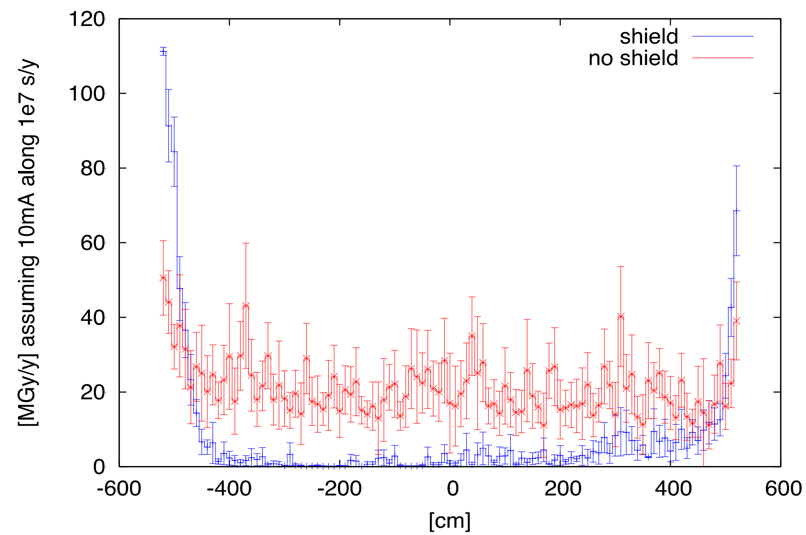


L. Lari et al., IPAC2014, THPRI011

FCC-ee: Shielding 100 MW SR at 350 GeV



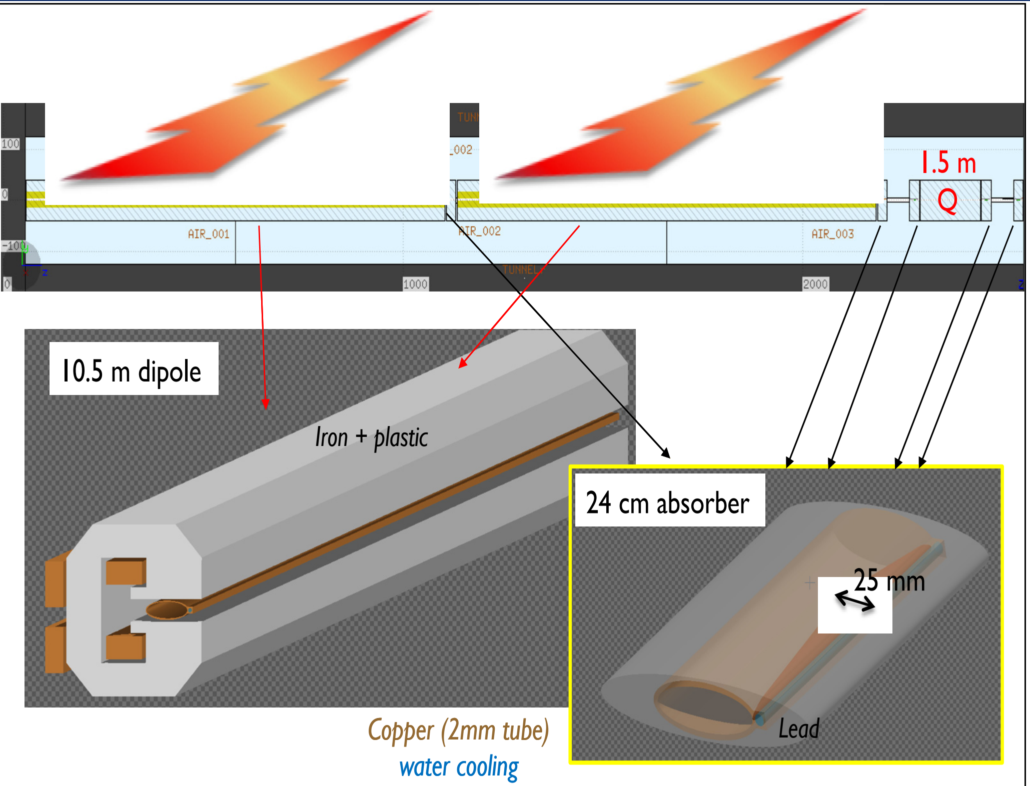


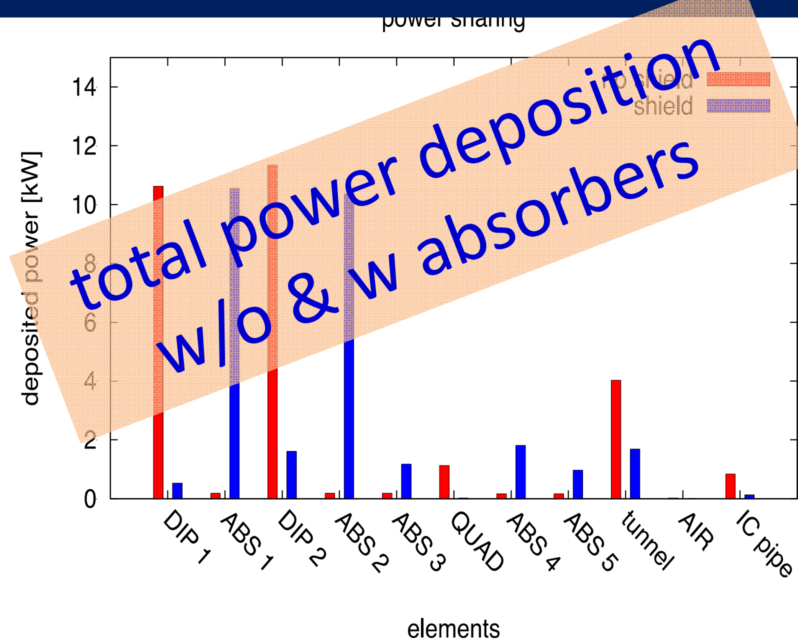


FLUKA geometry layout for half FODO cell, dipoles details, preliminary absorber design incl. 5 cm external *Pb* shield

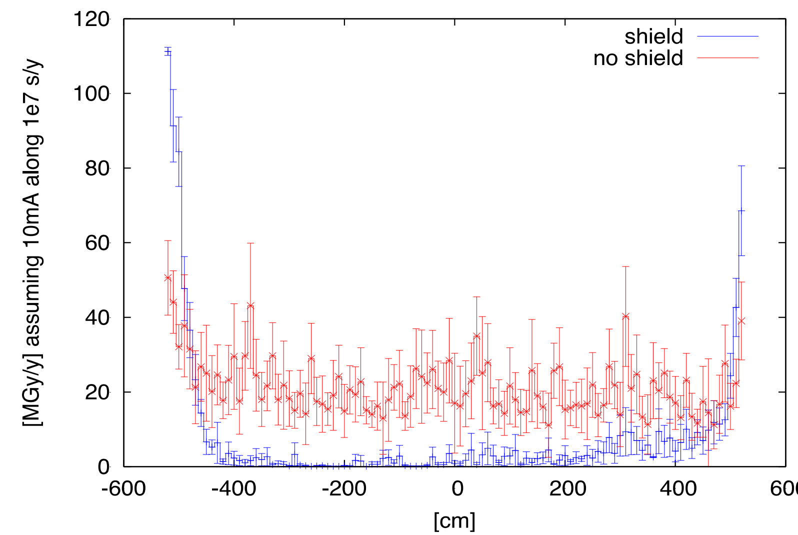
L. Lari et al., IPAC2014, THPRI011

FCC-ee: Shielding 100 MW SR at 350 GeV





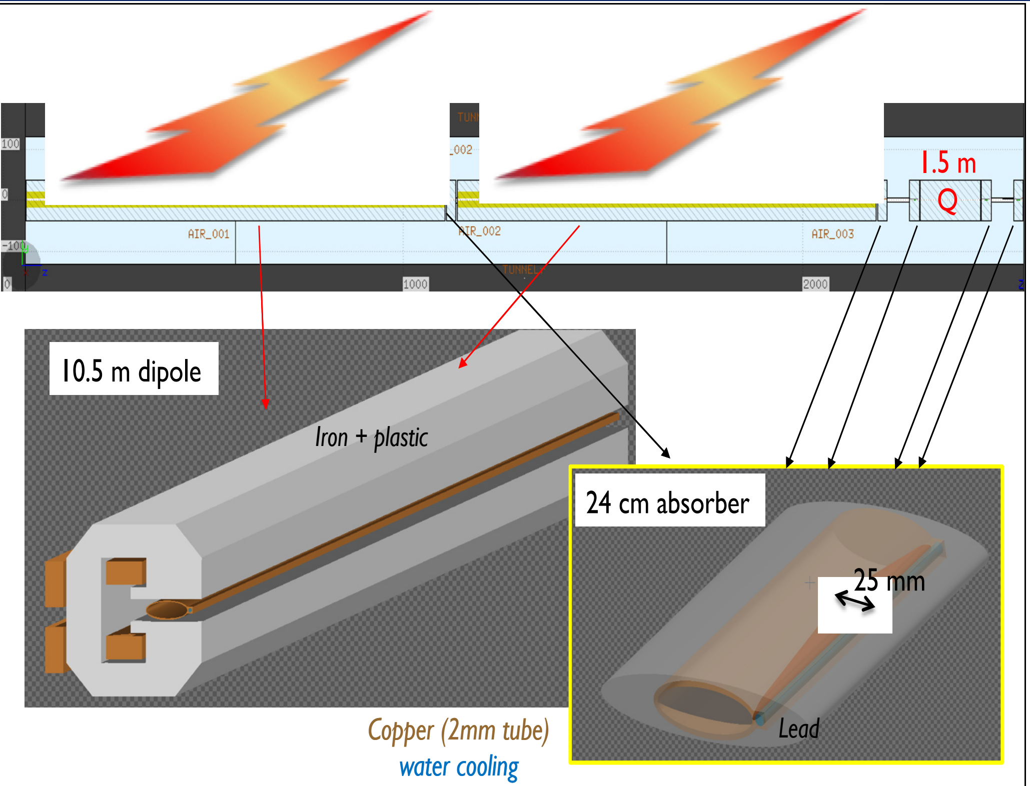
total power deposition w/o & w absorbers

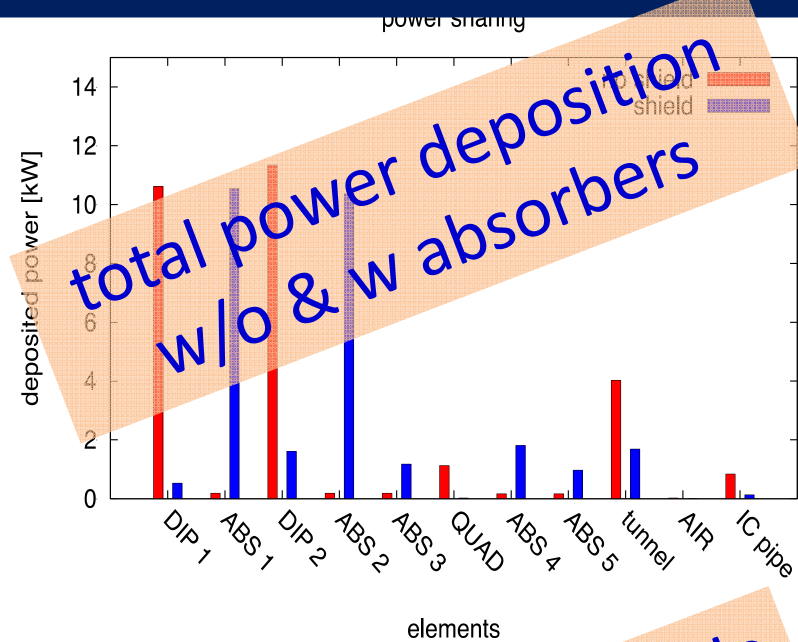


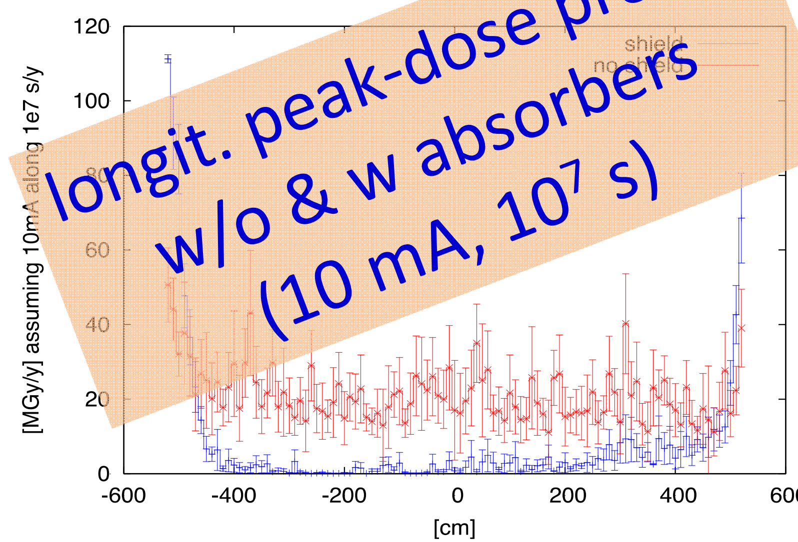
FLUKA geometry layout for half FODO cell, dipoles details, preliminary absorber design incl. 5 cm external *Pb* shield

L. Lari et al., IPAC2014, THPRI011

FCC-ee: Shielding 100 MW SR at 350 GeV



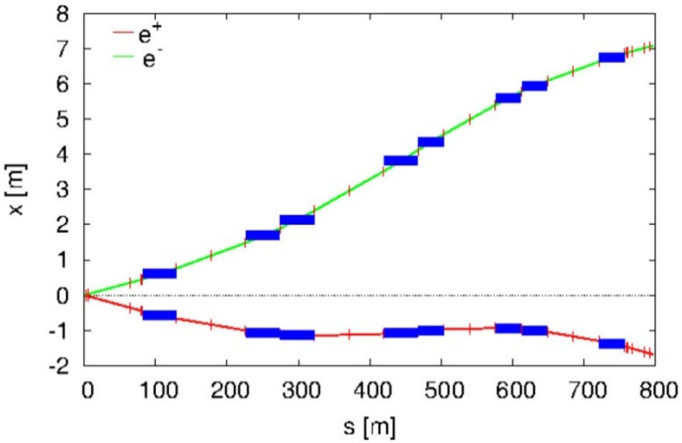


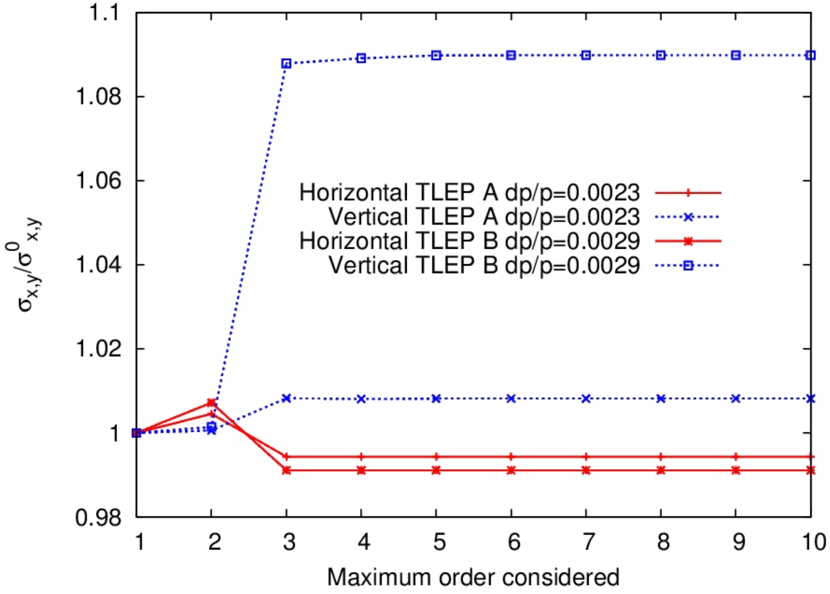


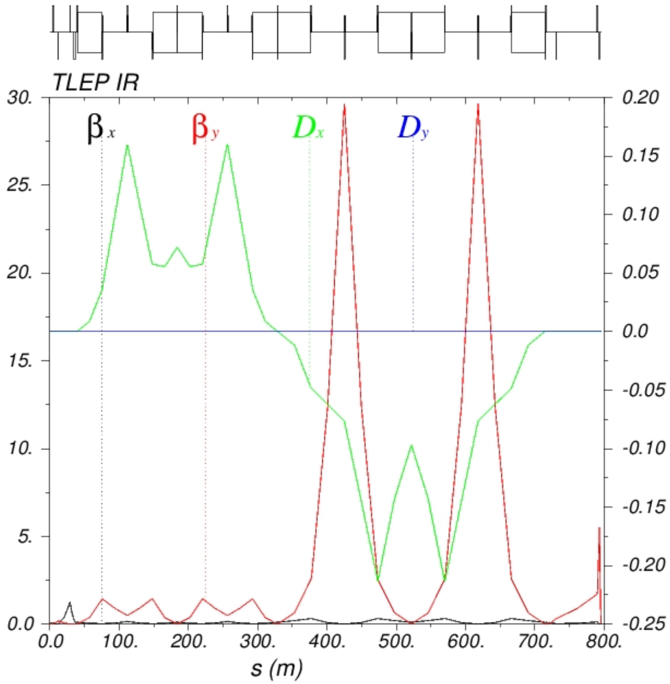
FLUKA geometry layout for half FODO cell, dipoles details, preliminary absorber design incl. 5 cm external *Pb* shield

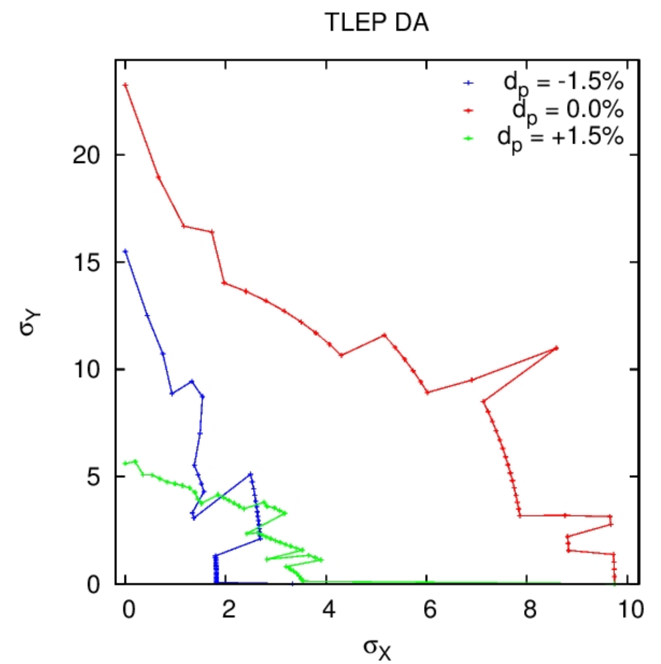
L. Lari et al., IPAC2014, THPRI011

FCC-ee IR design #1



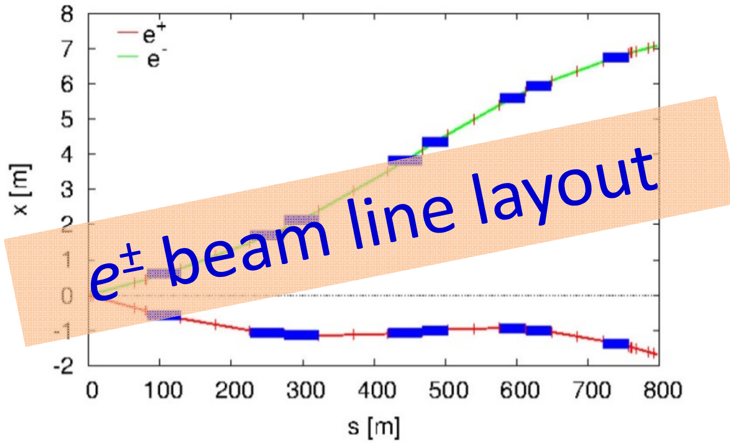


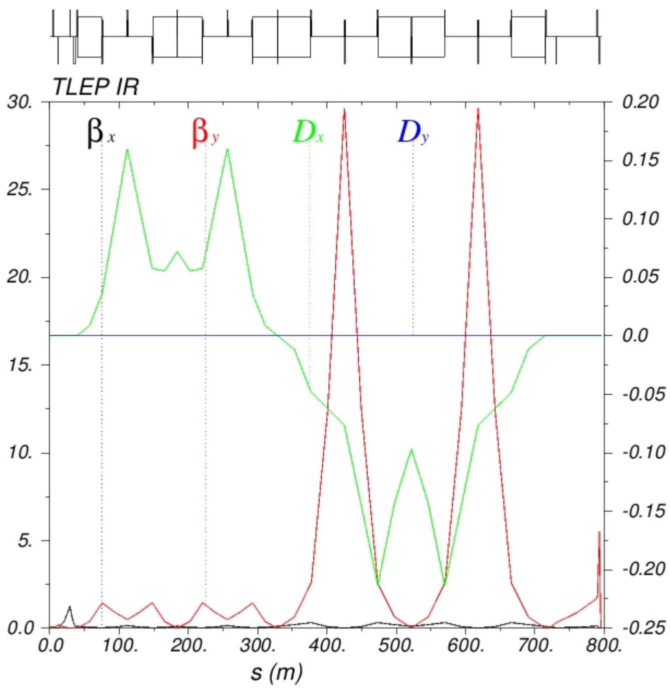


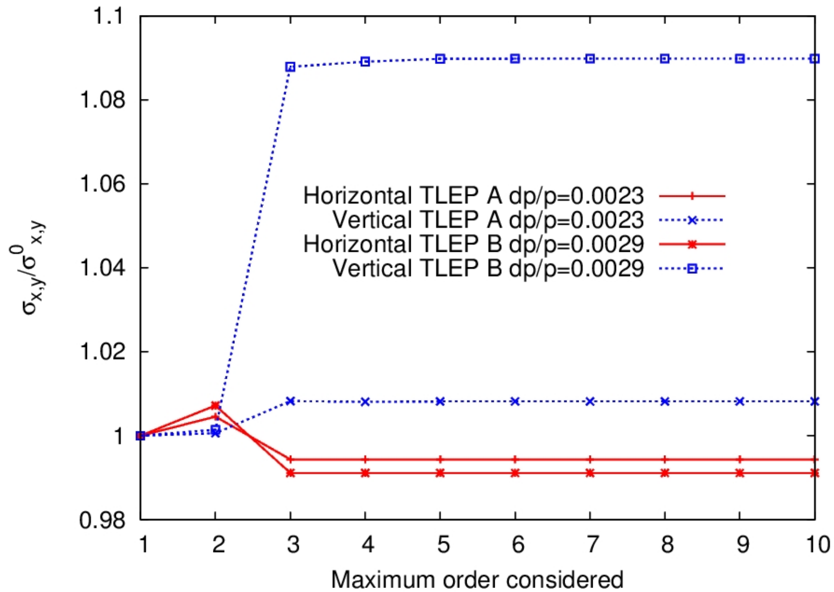


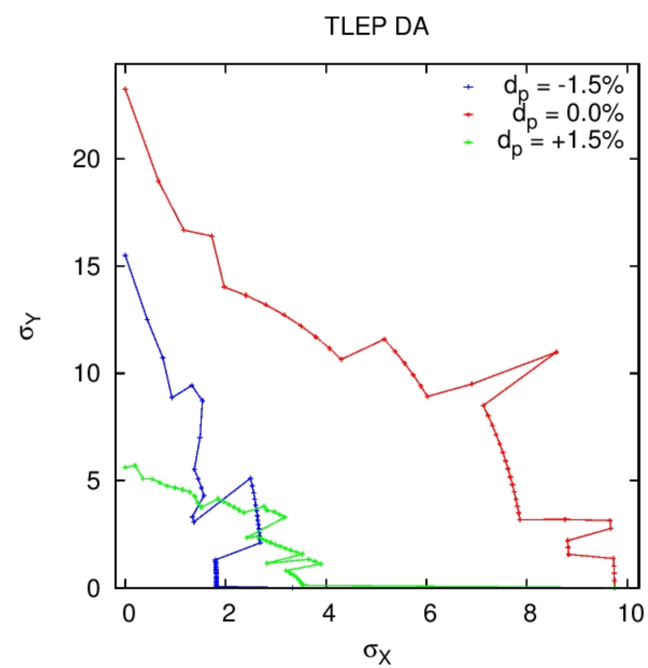
H. Garcia, L. Medina, R. Tomas, IPAC2014, T

FCC-ee IR design #1



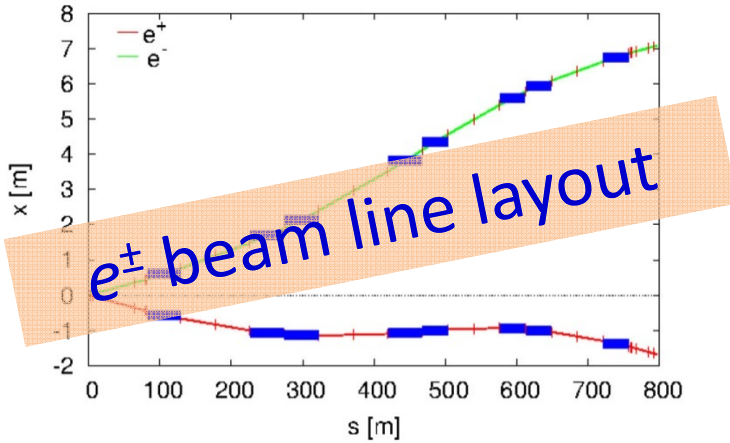


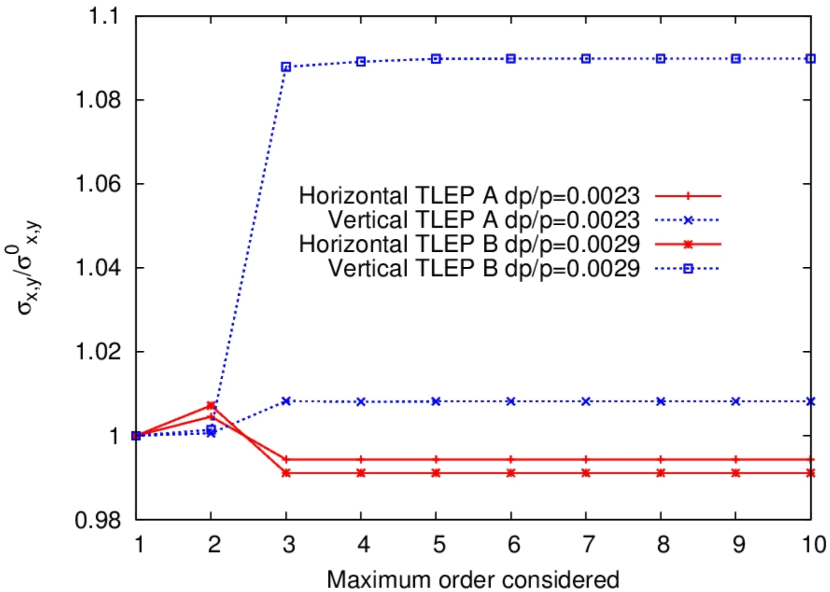


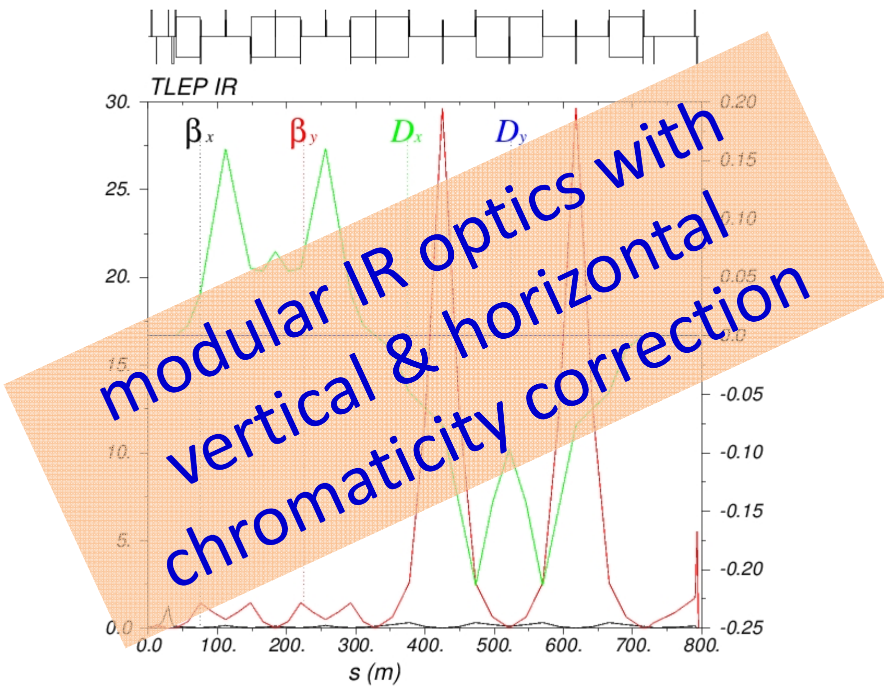


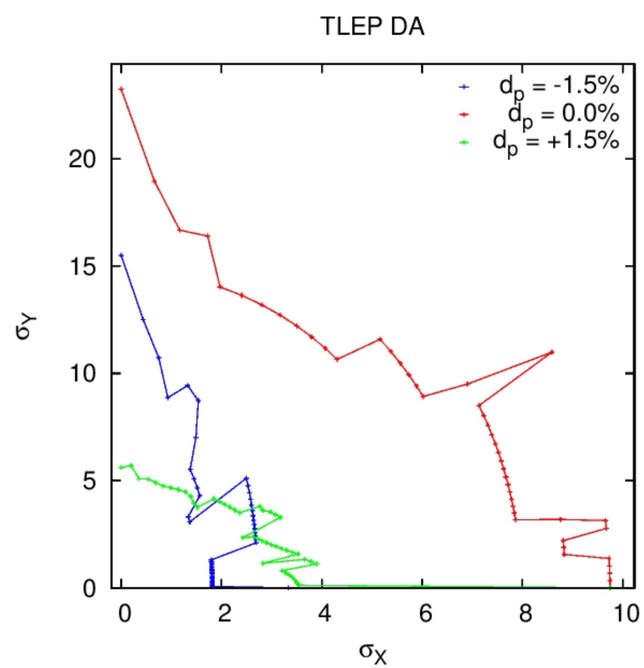
H. Garcia, L. Medina, R. Tomas, IPAC2014, T

FCC-ee IR design #1



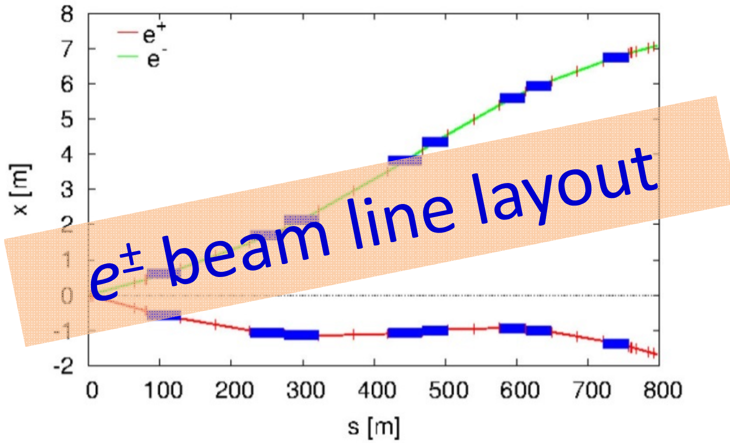


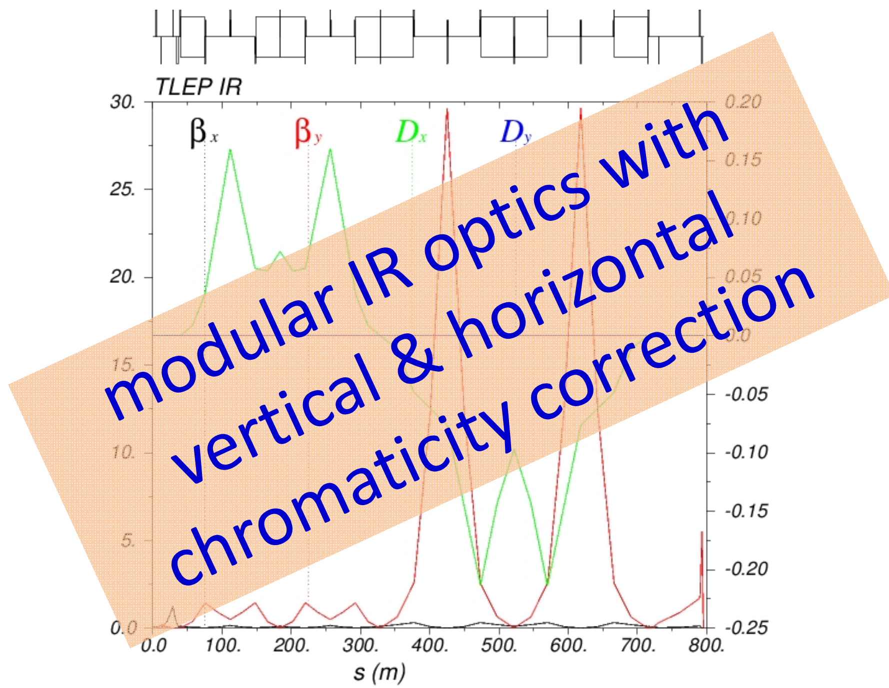


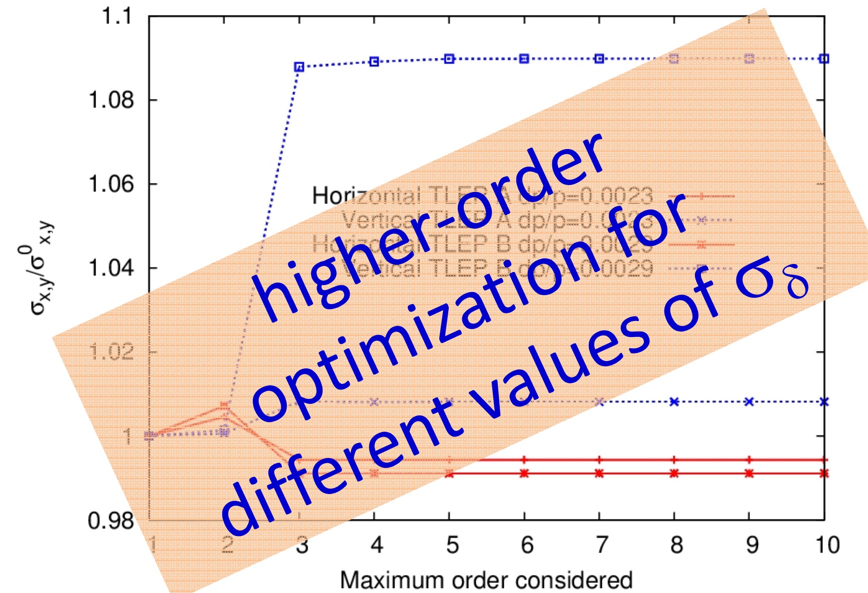


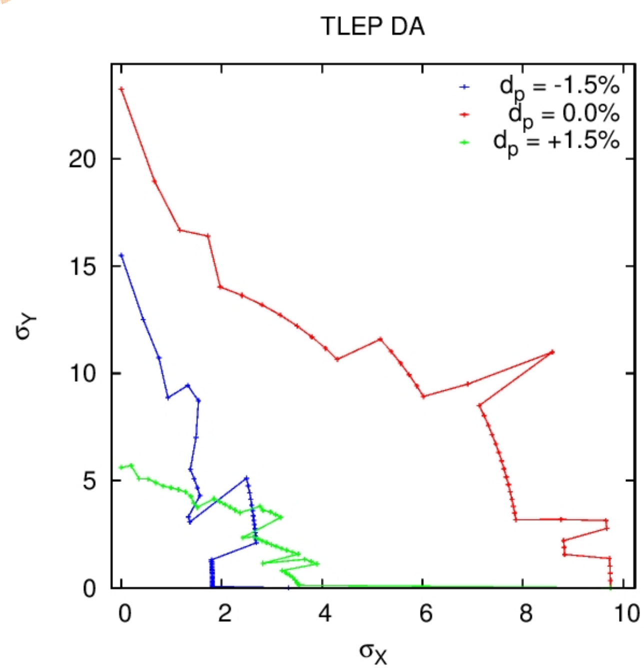
H. Garcia, L. Medina, R. Tomas, IPAC2014, T

FCC-ee IR design #1



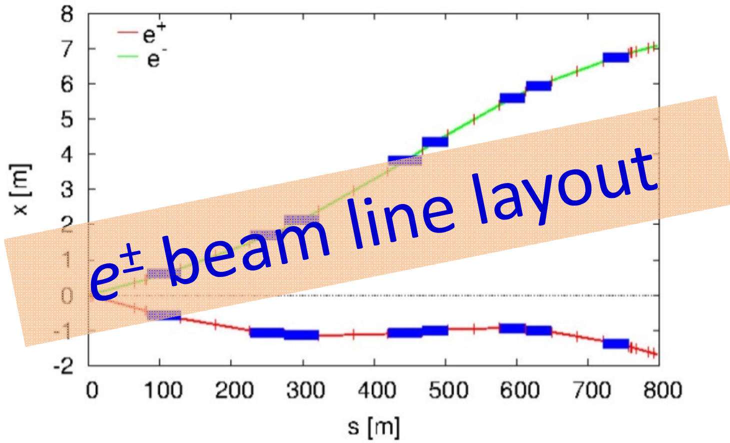


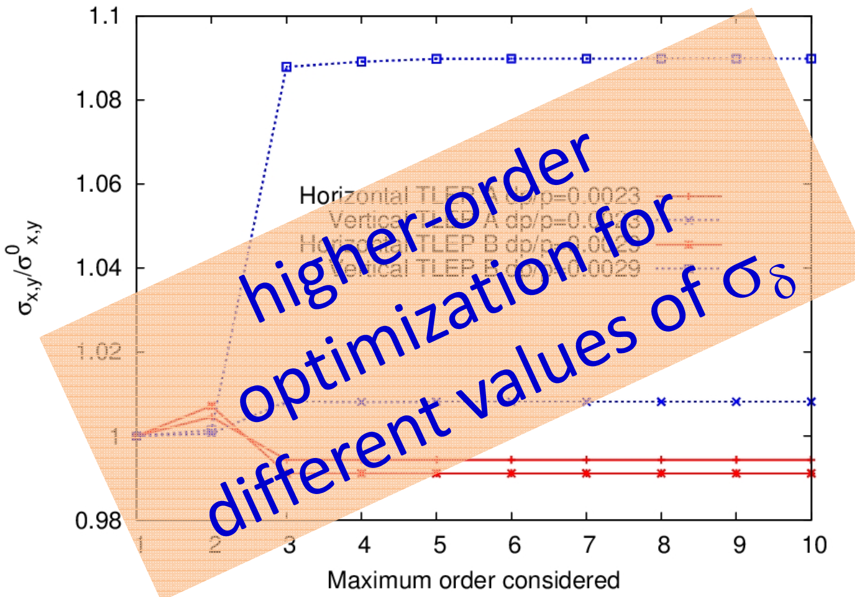


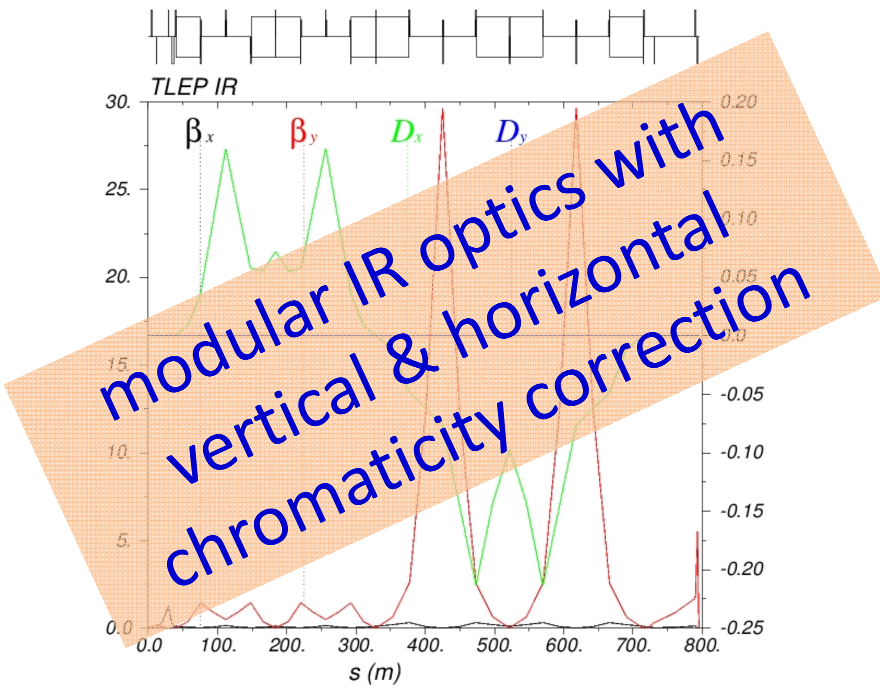


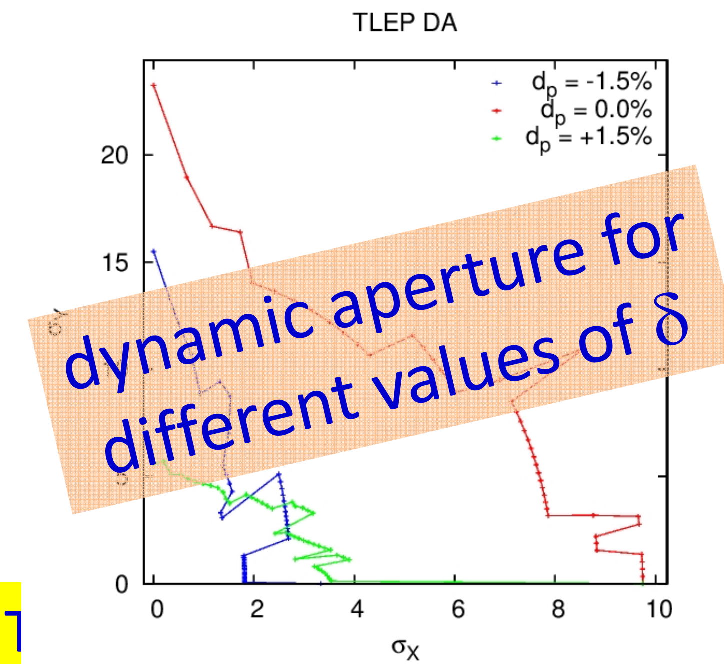
H. Garcia, L. Medina, R. Tomas, IPAC2014, T

FCC-ee IR design #1



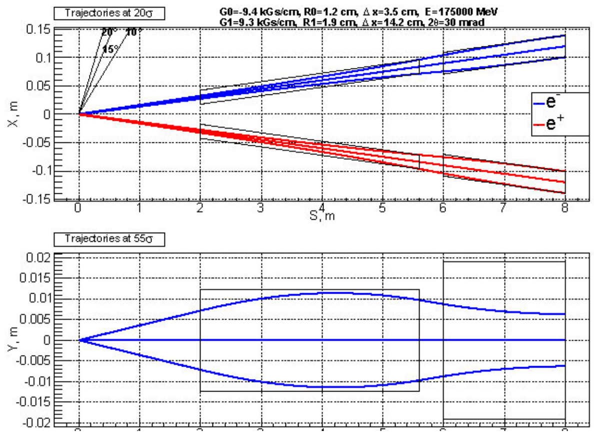


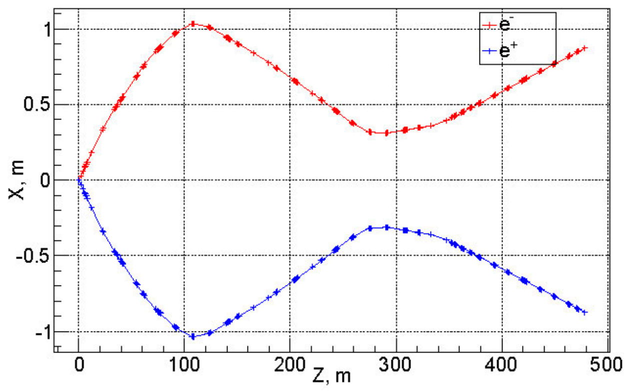


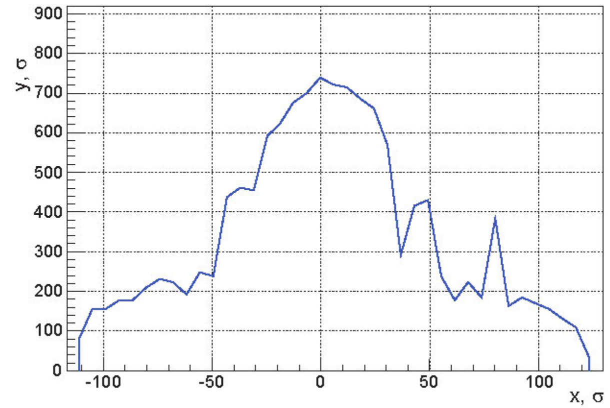


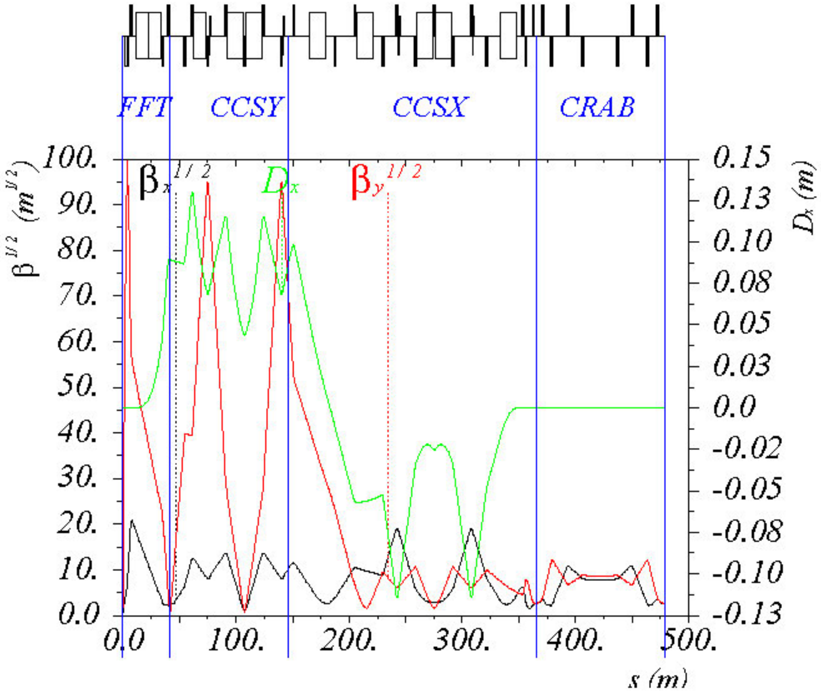
H. Garcia, L. Medina, R. Tomas, IPAC2014, T

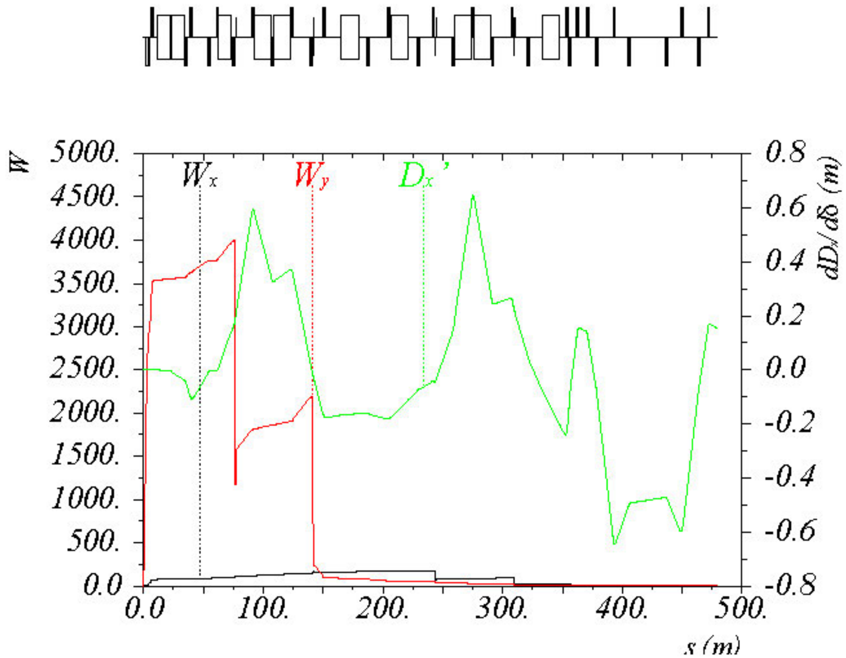
FCC-ee IR design #2





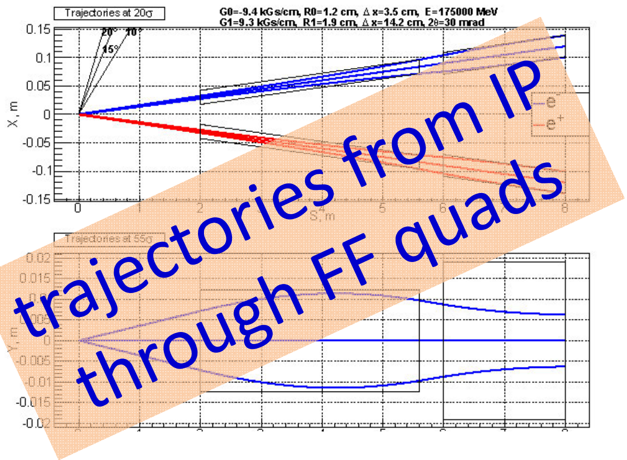


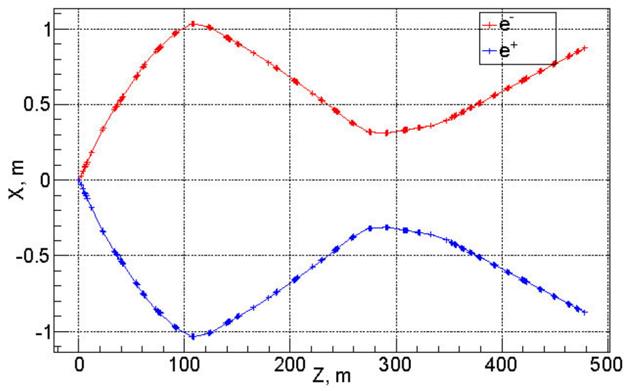


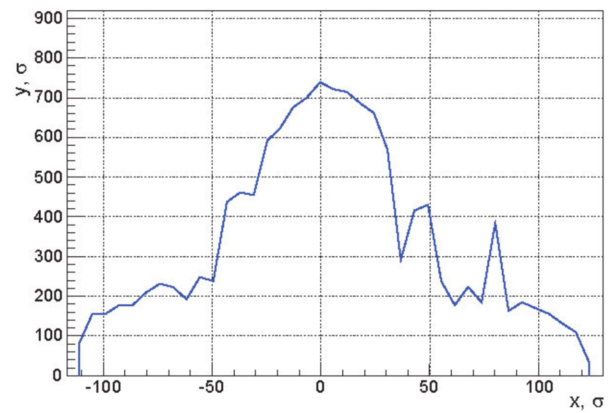


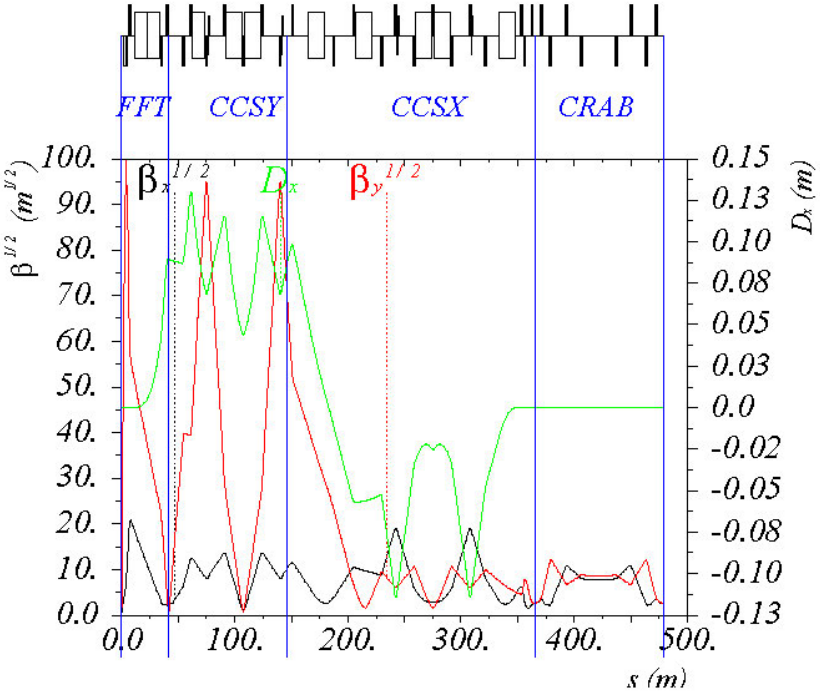
A. Bogomyagkov, E. Levichev, P. Piminov, IPAC2014, THPRI008

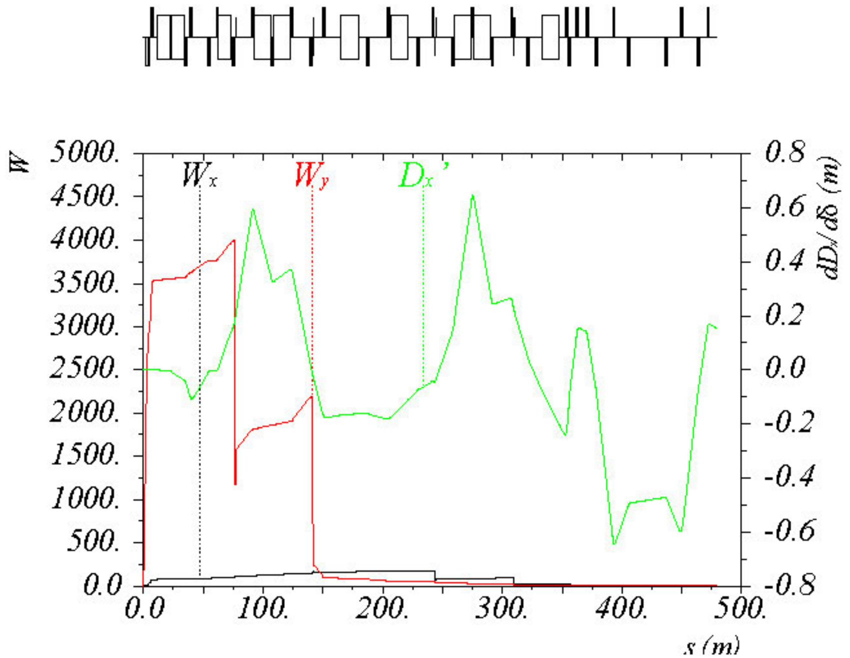
FCC-ee IR design #2





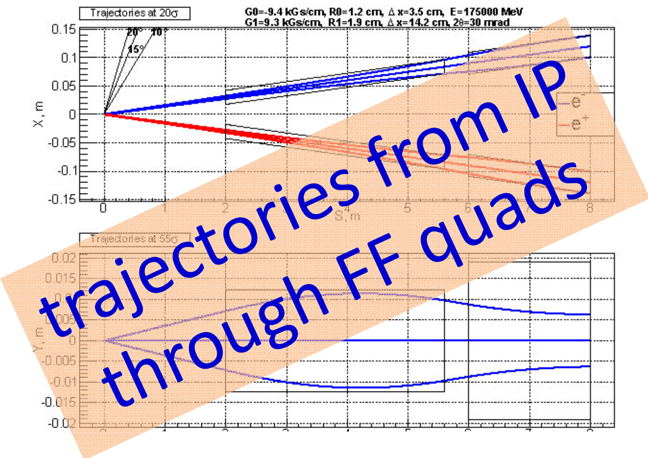


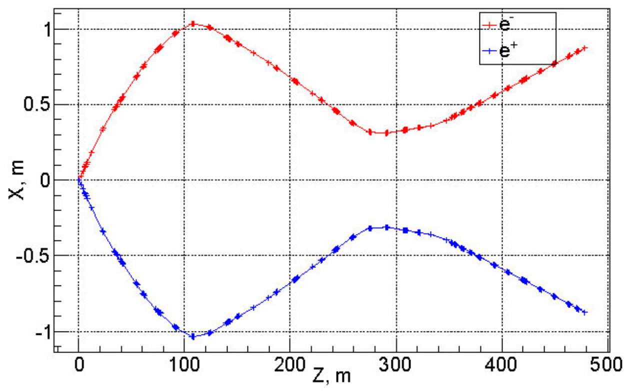


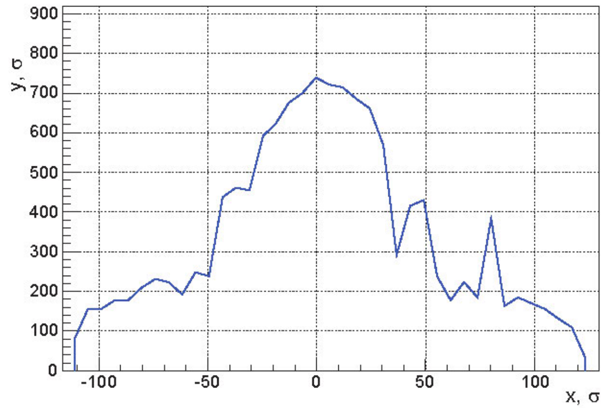


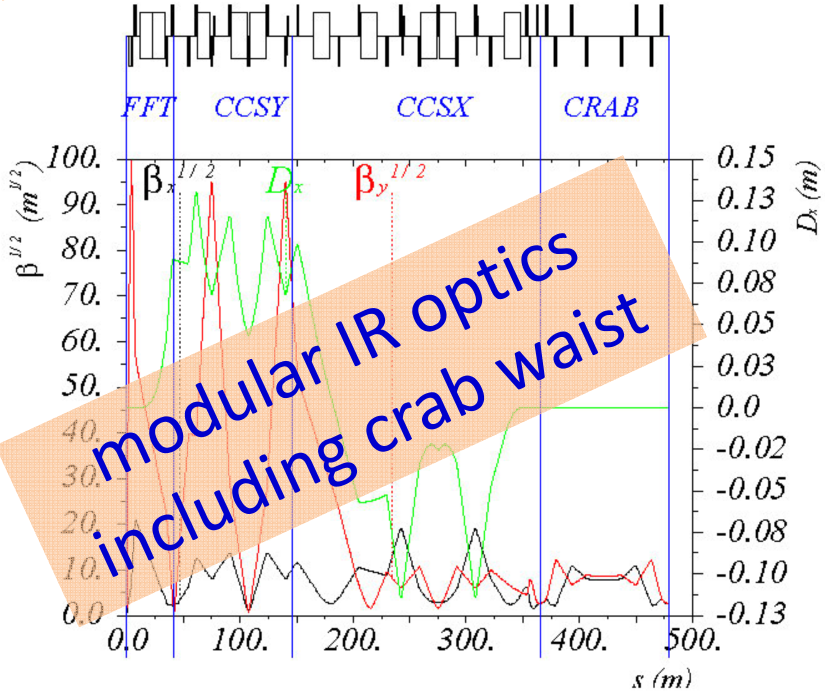
A. Bogomyagkov, E. Levichev, P. Piminov, IPAC2014, THPRI008

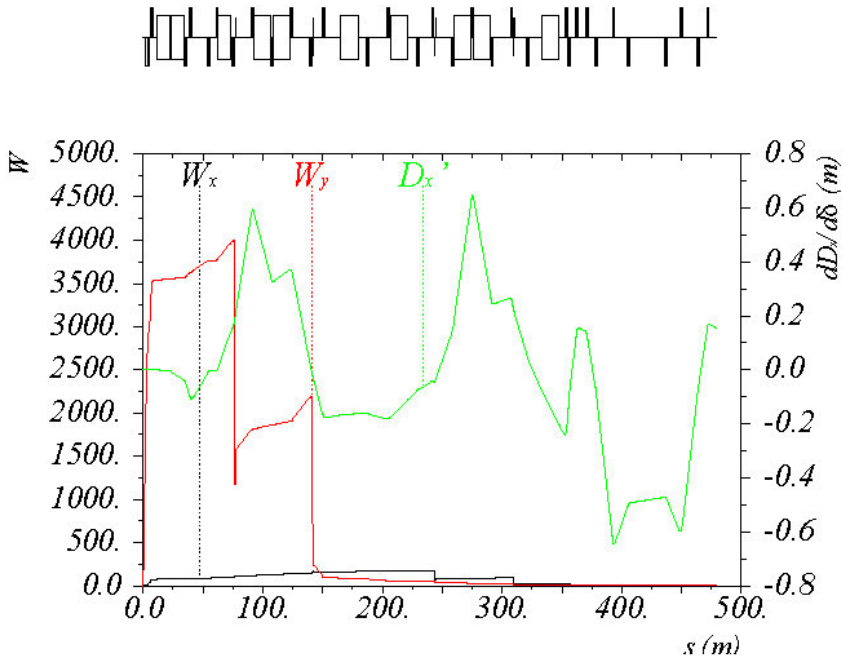
FCC-ee IR design #2





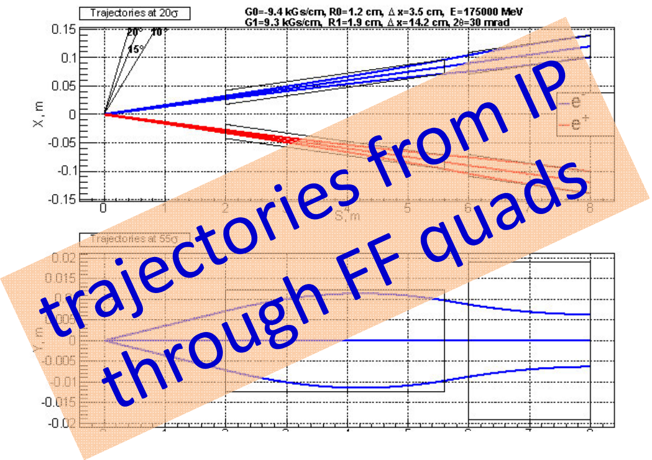


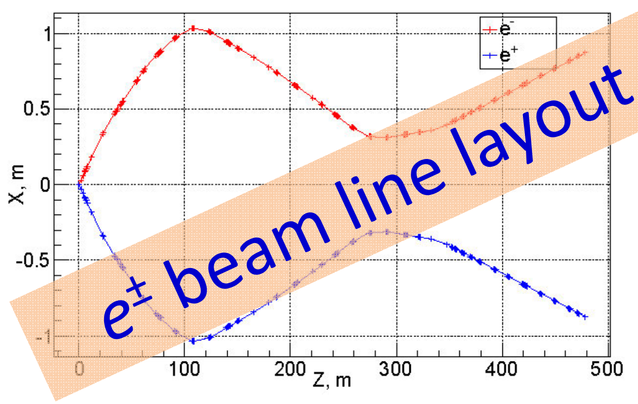


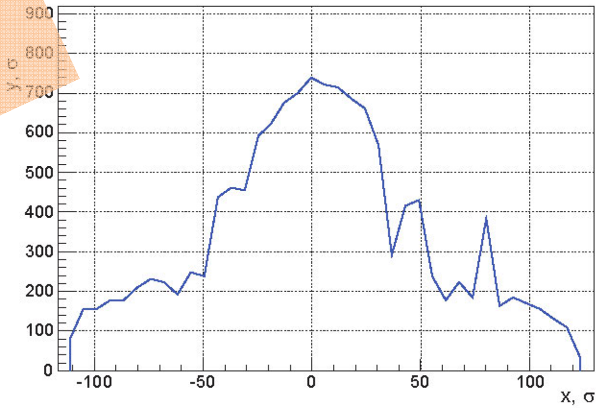


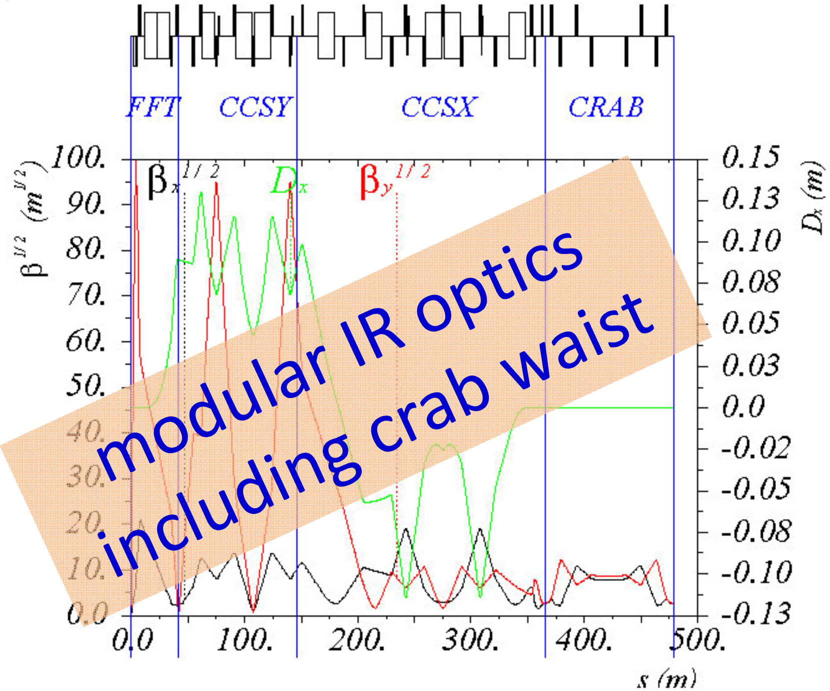
A. Bogomyagkov, E. Levichev, P. Piminov, IPAC2014, THPRI008

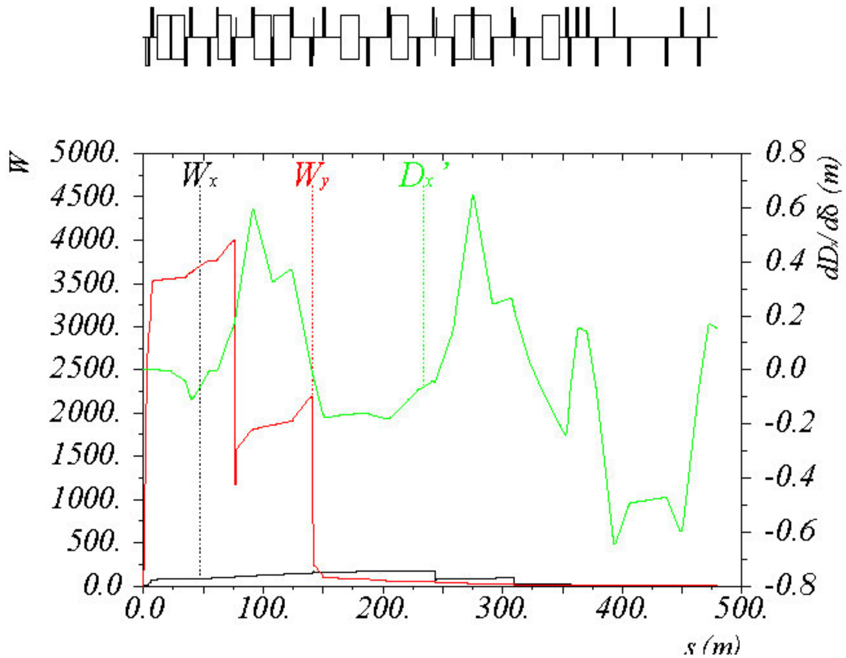
FCC-ee IR design #2





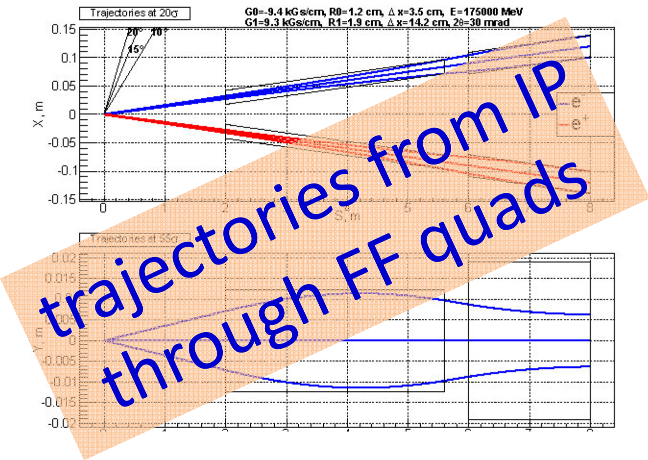


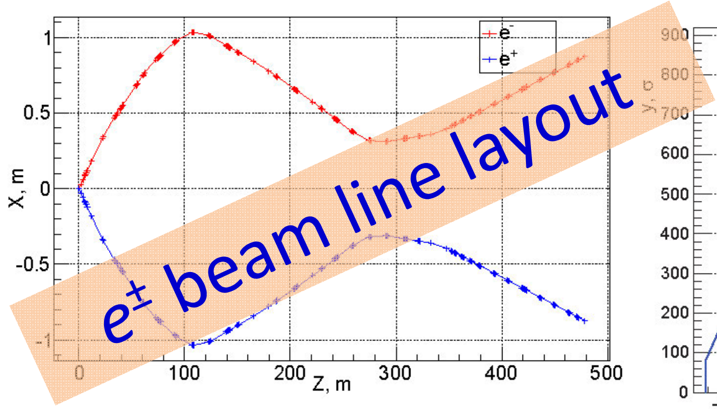


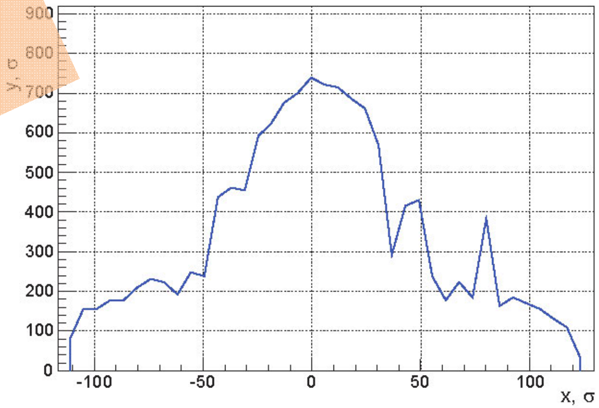


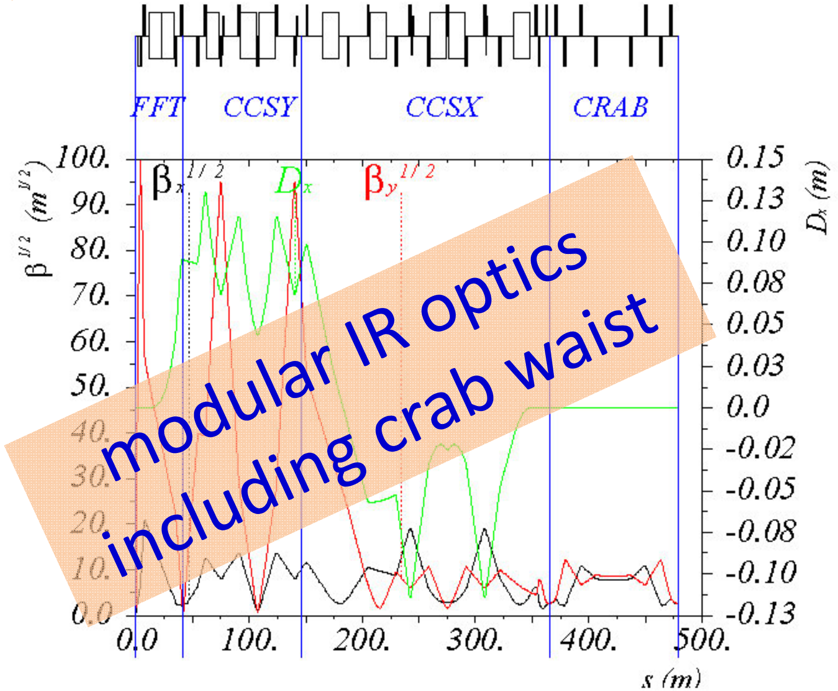
A. Bogomyagkov, E. Levichev, P. Piminov, IPAC2014, THPRI008

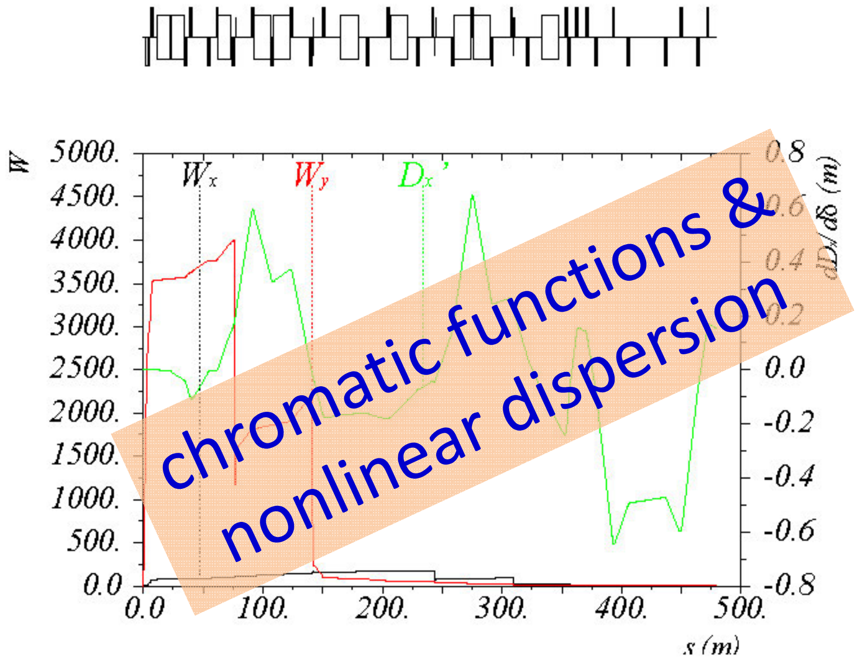
FCC-ee IR design #2





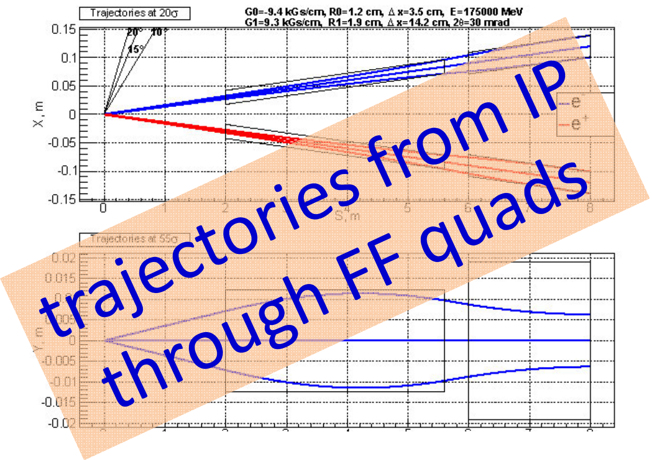


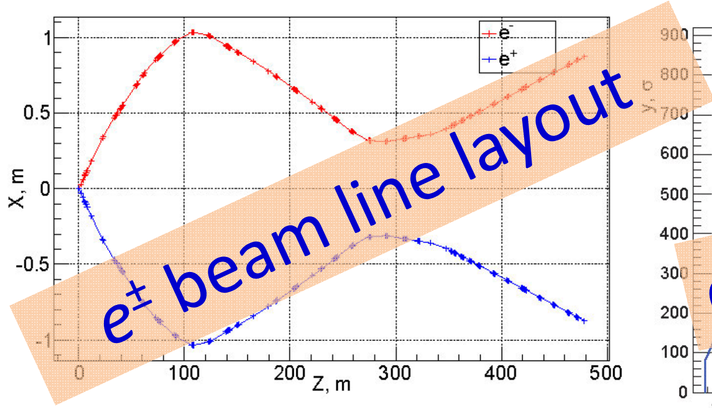


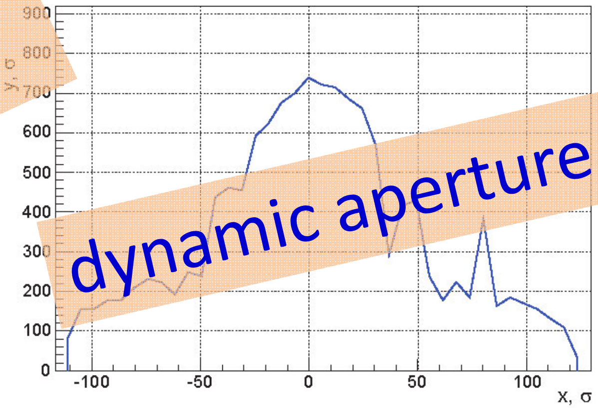


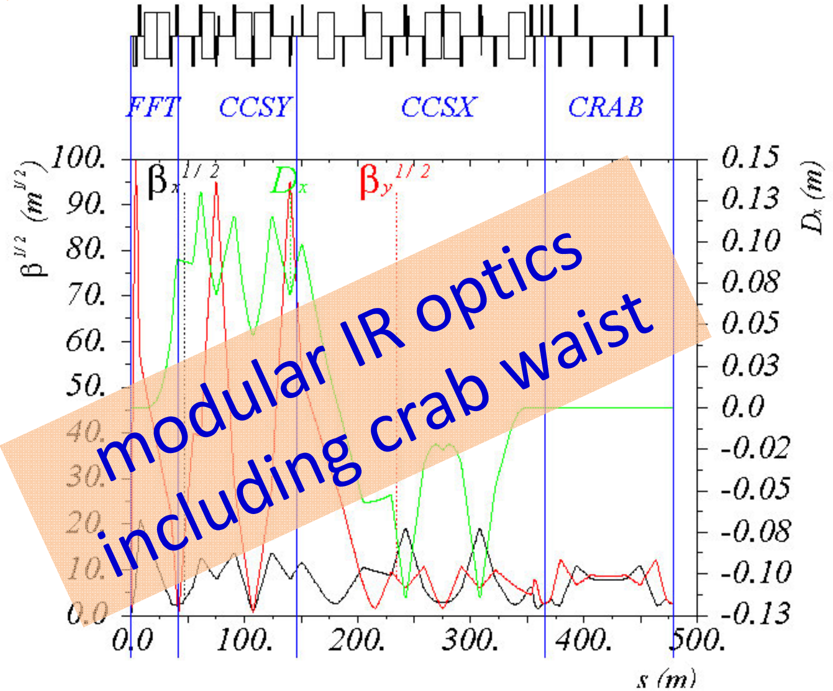
A. Bogomyagkov, E. Levichev, P. Piminov, IPAC2014, THPRI008

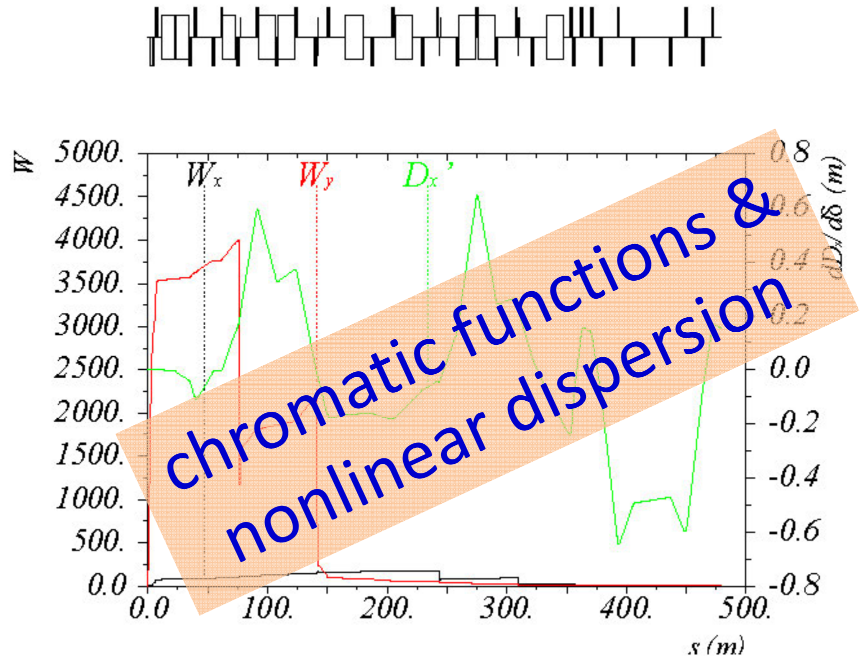
FCC-ee IR design #2











A. Bogomyagkov, E. Levichev, P. Piminov, IPAC2014, THPRI008

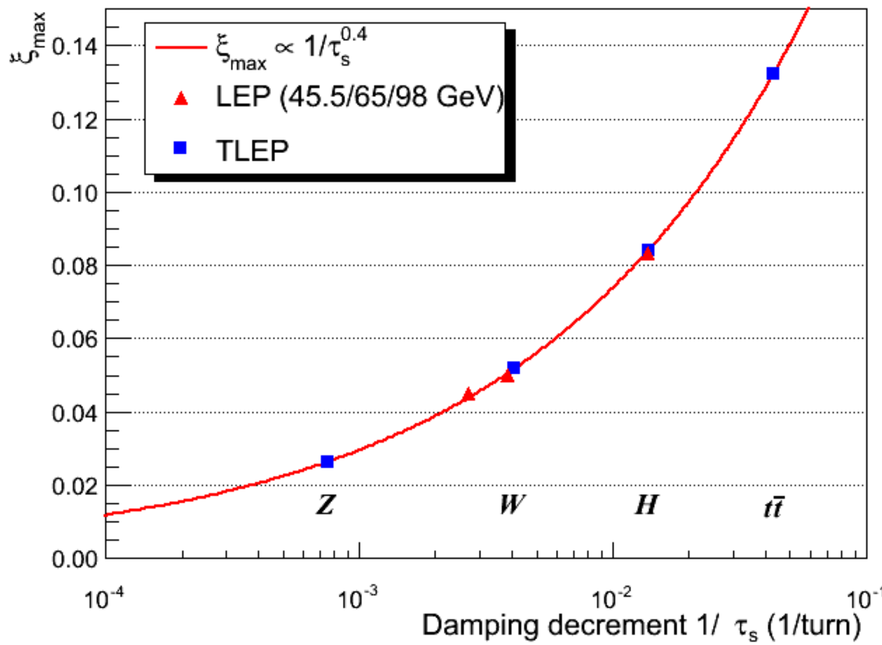
beam-beam tune shift & energy scaling

tune shift limits scaled from LEP data, confirmed by FCC simulations (S. White, K. Ohmi, A. Bogomyagkov, D Shatilov,…):

$$\xi_y \simeq \frac{\beta_y r_e N}{2\pi\gamma\sigma_x\sigma_y} \leq \xi_{y,\max}(E)$$

$$\xi_{y,\max}(E) \propto \frac{1}{\tau_s^{0.4}} \propto E^{1.2}$$

R. Assmann & K. Cornelis, EPAC2000

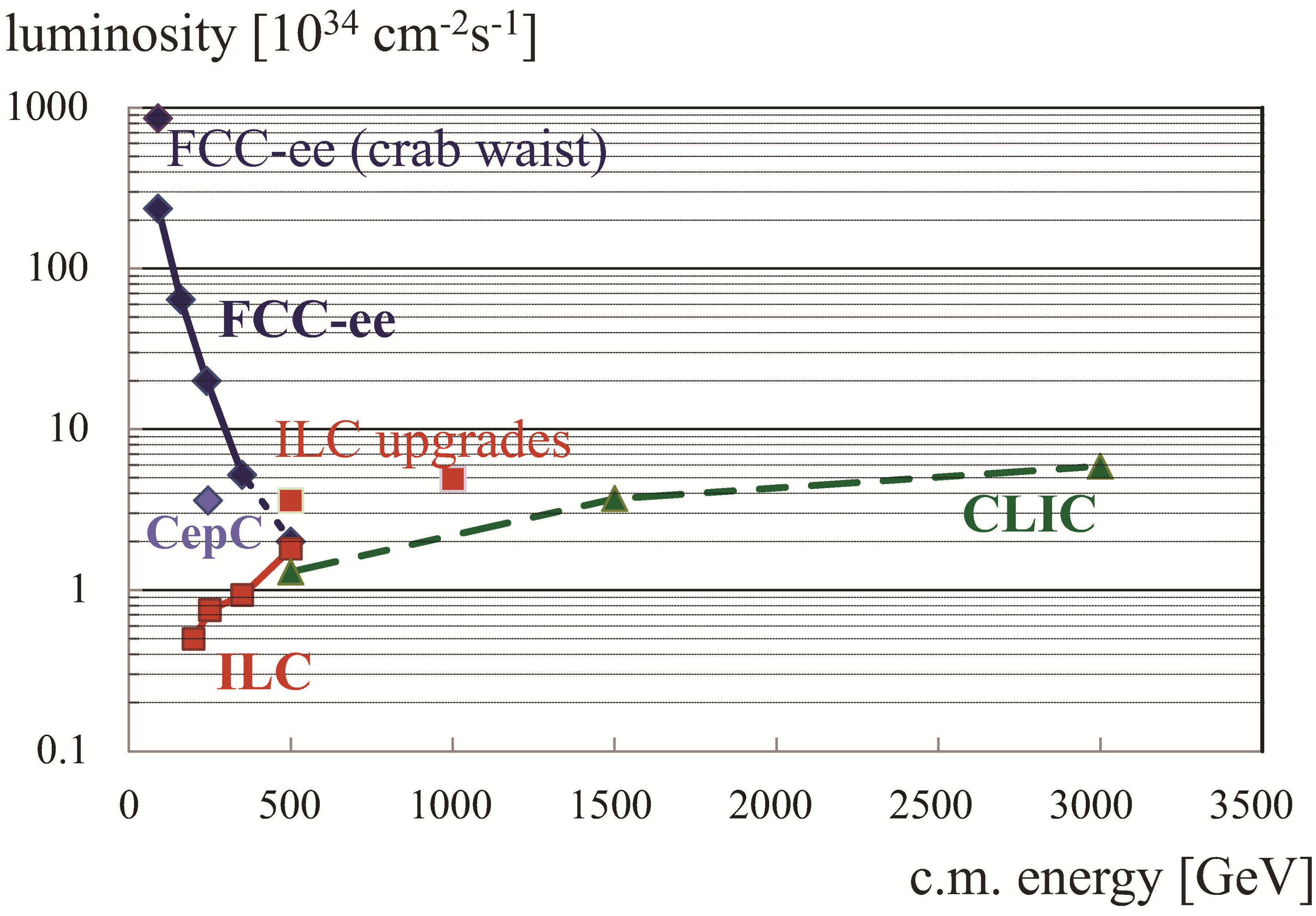


→ luminosity scaling with energy:

$$L = n_{IP}\frac{f_{coll}N^2}{4\pi\sigma_x\sigma_y}F_{hg} \propto \frac{\eta P_{SR}}{E^3}\frac{\xi_y}{\beta_y^*} \propto \frac{\eta_{w\to b}P_{wall}}{E^{1.8}}\frac{1}{\beta_y^*}$$

J. Wenninger

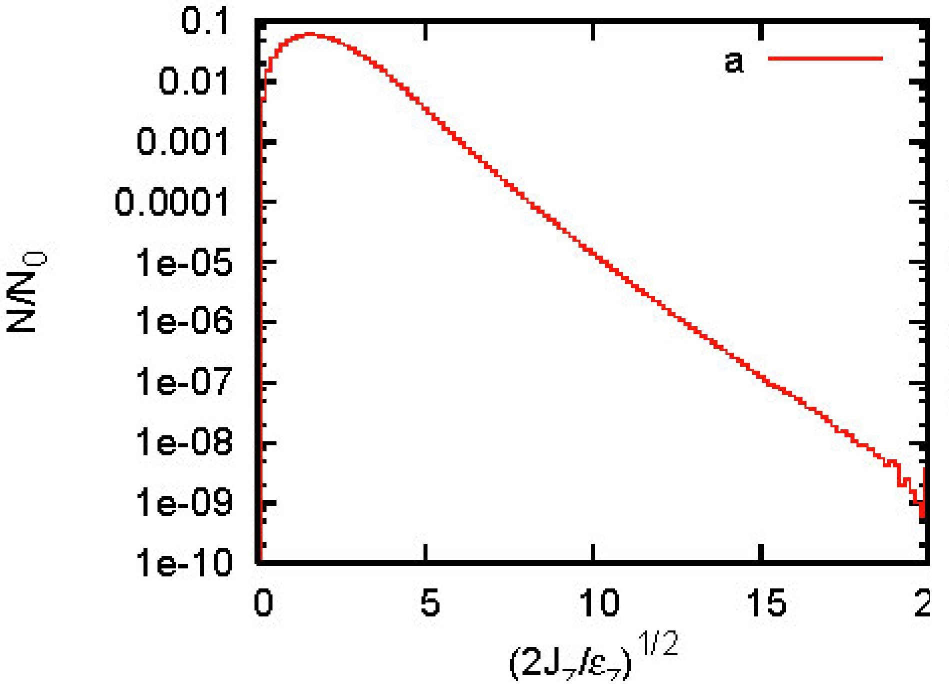
e^+e^- luminosity vs energy

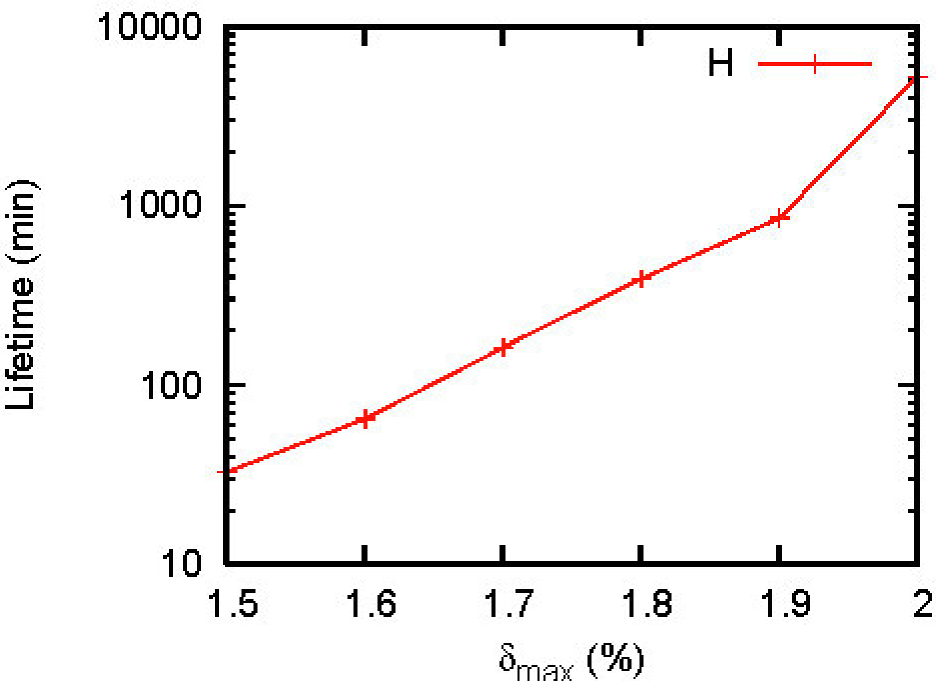


beamstrahlung lifetime

example: *FCC-ee H* (240 GeV c.m.)

equilibrium distribution w/o aperture limit from simulation → lifetime vs. momentum acceptance



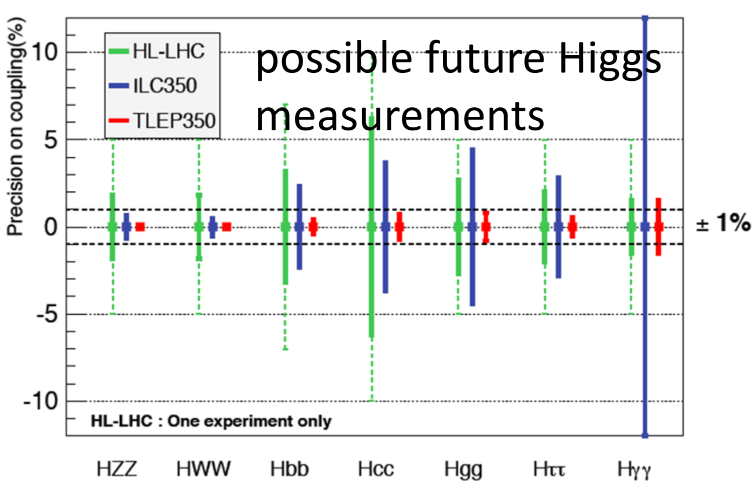


K. Ohmi et al., IPAC2014, THPRI003 & THPRI004

The Twin Frontiers of *FCC-ee* Physics

Precision Measurements

- Springboard for sensitivity to new physics
- Theoretical issues:
  - Higher-order QCD
  - Higher-order EW
  - Mixed QCD + EW



Rare Decays

- Direct searches for new physics
- Many opportunities
- Z: 10^{12}
- b, c, τ: 10^{11}
- W: 10^{8}
- H: 10^{6}
- t: 10^{6}

M. Bicer et al., "First Look at the Physics Case of TLEP," JHEP 01, 164 (2014)

J. Ellis

The Twin Frontiers of *FCC-ee* Physics

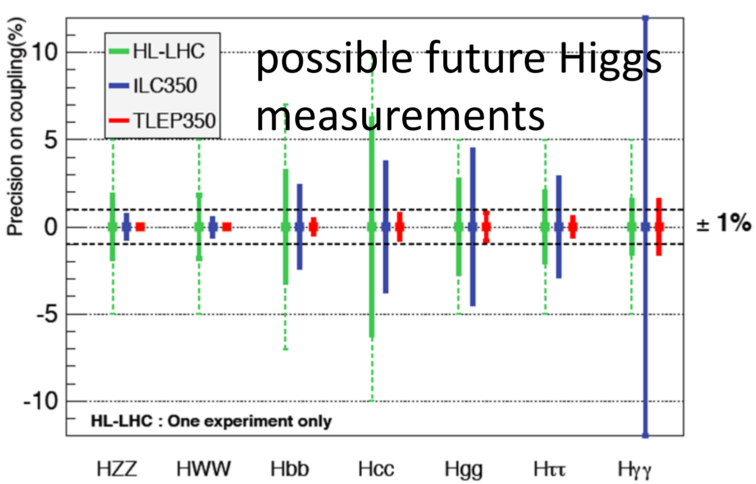
Precision Measurements

- Springboard for sensitivity to new physics
- Theoretical issues:
  - Higher-order QCD
  - Higher-order EW
  - Mixed QCD + EW

Rare Decays

- Direct searches for new physics
- Many opportunities
- Z: 10^{12}
- b, c, τ: 10
- W: 10^8
- H: 10^6
- t: 10^6

***FCC-ee* promises much higher precision & and many more rare decays than any competitors**

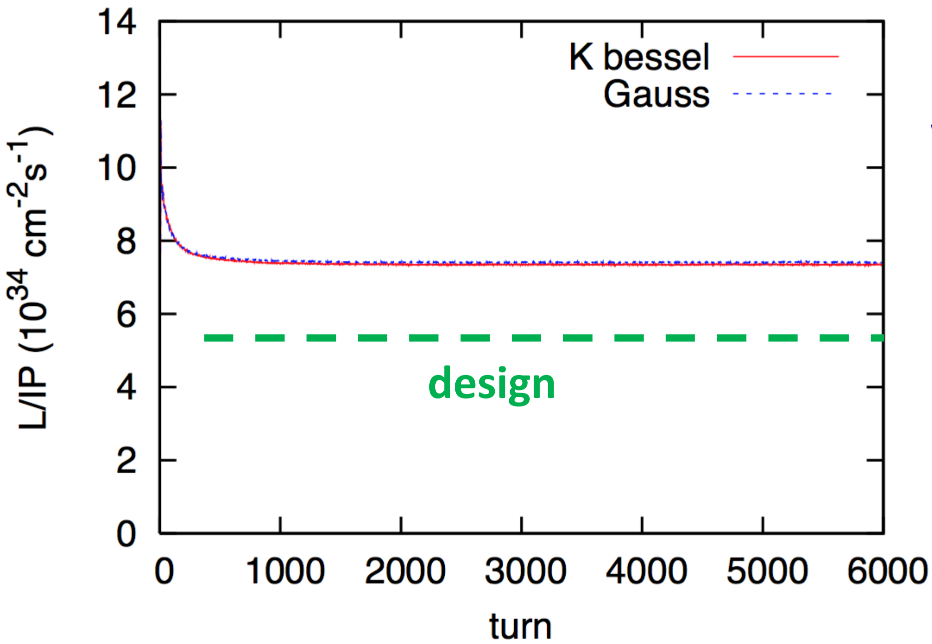


possible future Higgs measurements

M. Bicer et al., "First Look at the Physics Case of TLEP," JHEP 01, 164 (2014)

J. Ellis

simulations confirm tantalizing performance

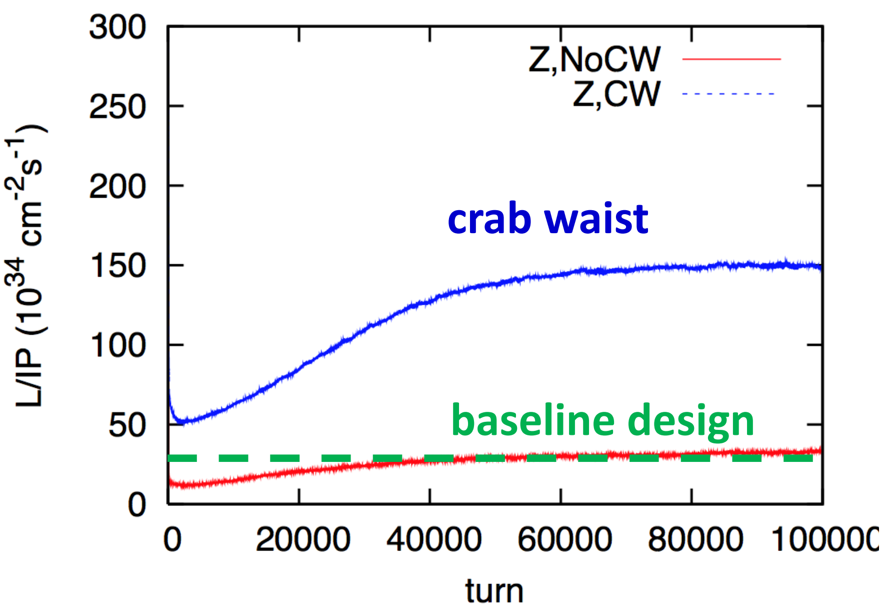


BBSS strong-strong simulation
w beamstrahlung

FCC-ee in Higgs production mode (240 GeV c.m.):
L≈7.5x10^{34} cm^{-2}s^{-1} per IP

BBWS crab-strong simulation
w beamstrahlung

FCC-ee in crab-waist mode at the Z pole (91 GeV c.m.):
L≈1.5x10^{36} cm^{-2}s^{-1} per IP



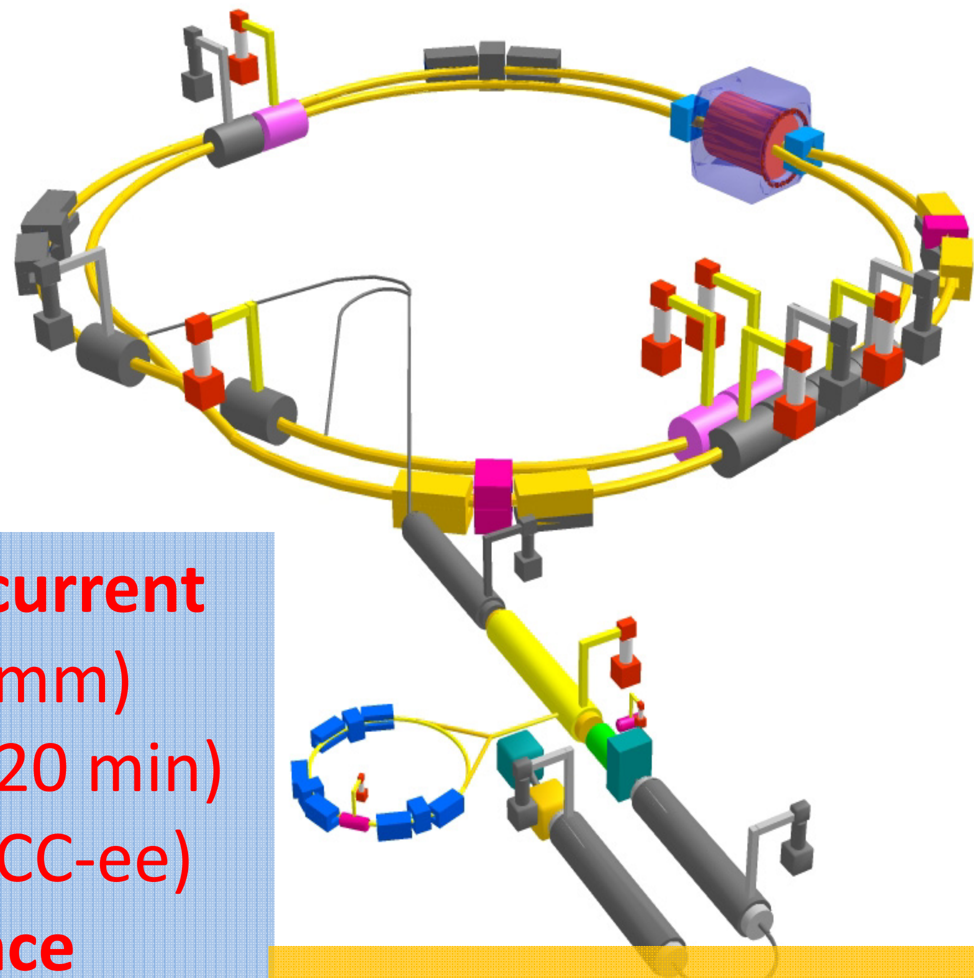
K. Ohmi et al., IPAC2014, THPRI003 & THPRI004

A. Bogomyagkov, E. Levichev, P. Piminov, IPAC2014, THPRI008

SuperKEKB = *FCC-ee* demonstrator

beam commissioning will start in early 2015

N. Ohuchi et al., IPAC2014, WEOCA01



top up injection at high current

β_y^* =300 μm (FCC-ee: 1 mm)

lifetime 5 min (FCC-ee: ≥20 min)

$\varepsilon_y/\varepsilon_x$ =0.25% (similar to FCC-ee)

off momentum acceptance

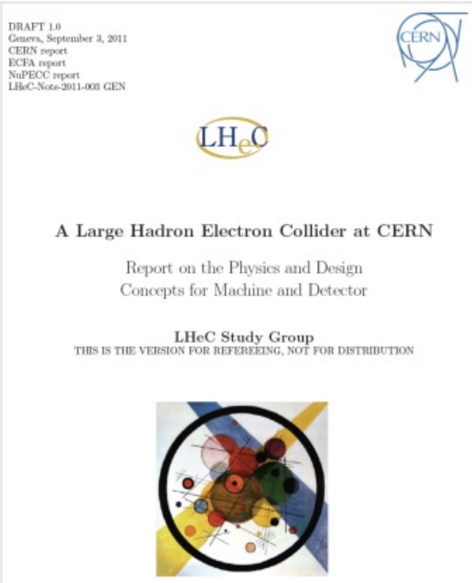
(±1.5%, similar to FCC-ee)

***e*$^+$ production rate** (2.5x10^{12}/s,

FCC-ee: <1.5x10^{12}/s (*Z* cr.waist)

***SuperKEKB* goes beyond *FCC-ee*, testing all concepts**

FCC-he: high-energy lepton-hadron collider


DRAFT 1.0
Geneva, September 3, 2011
CERN report
ECFA report
NuPECC report
LHeC-Note-2011-003 GEN

LHeC

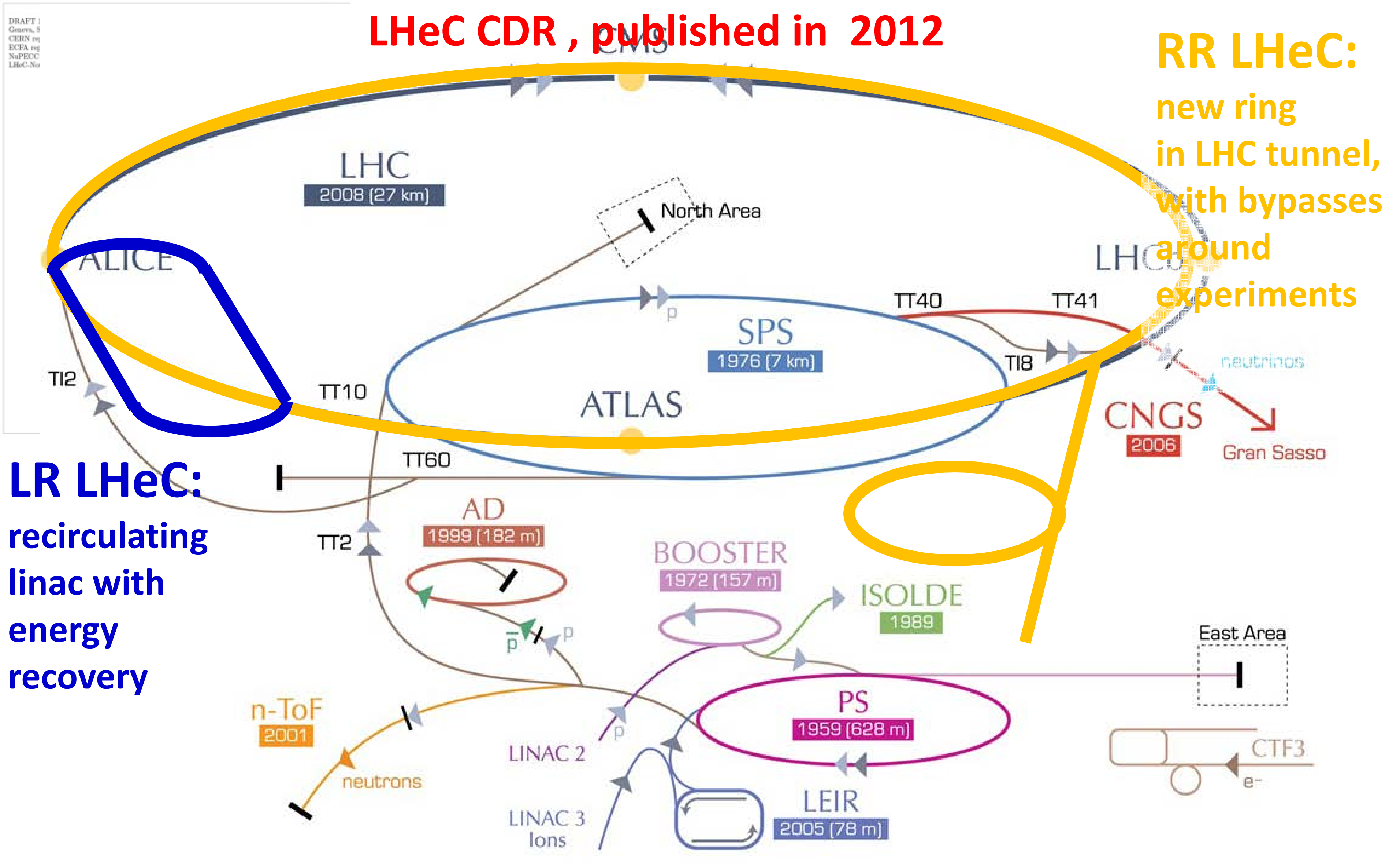
A Large Hadron Electron Collider at CERN

Report on the Physics and Design
Concepts for Machine and Detector

LHeC Study Group
THIS IS THE VERSION FOR REFEREEING, NOT FOR DISTRIBUTION

FCC-he: high-energy lepton-hadron collider

LHeC CDR , published in 2012

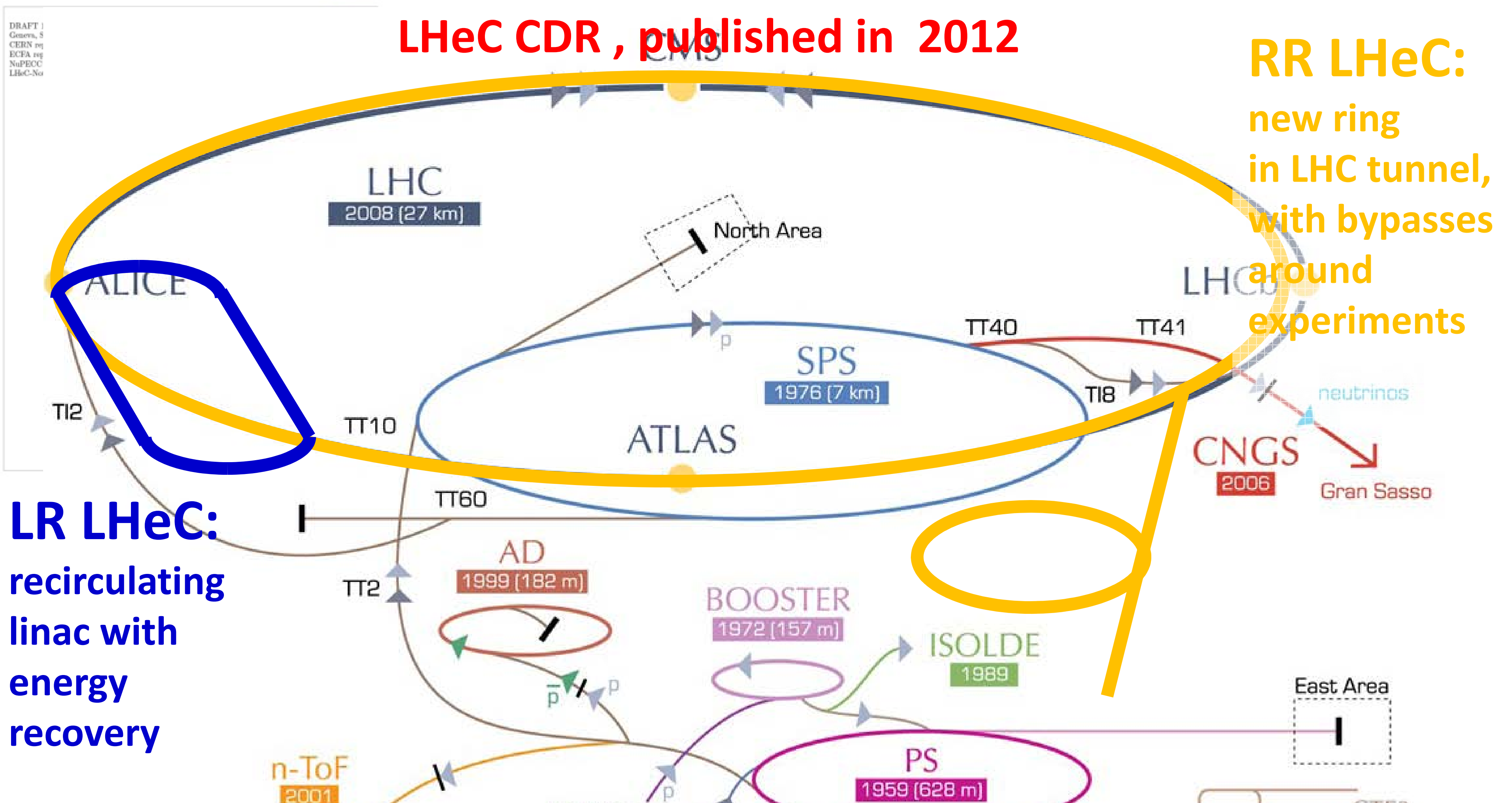


RR LHeC:
new ring
in LHC tunnel,
with bypasses
around
experiments

LR LHeC:
recirculating
linac with
energy
recovery

FCC-he: high-energy lepton-hadron collider

LHeC CDR , published in 2012



RR LHeC:

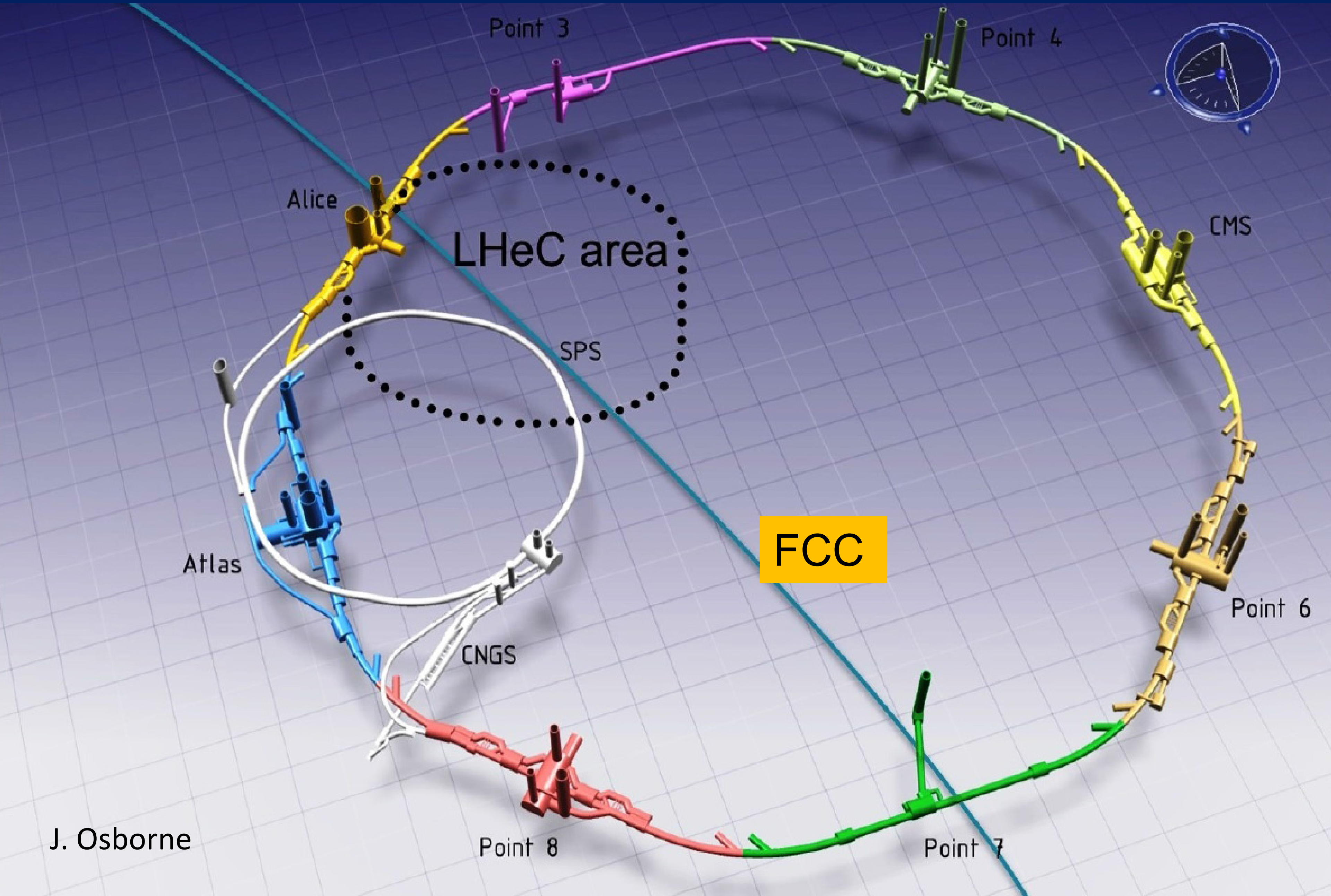
new ring
in LHC tunnel,
with bypasses
around
experiments

LR LHeC:

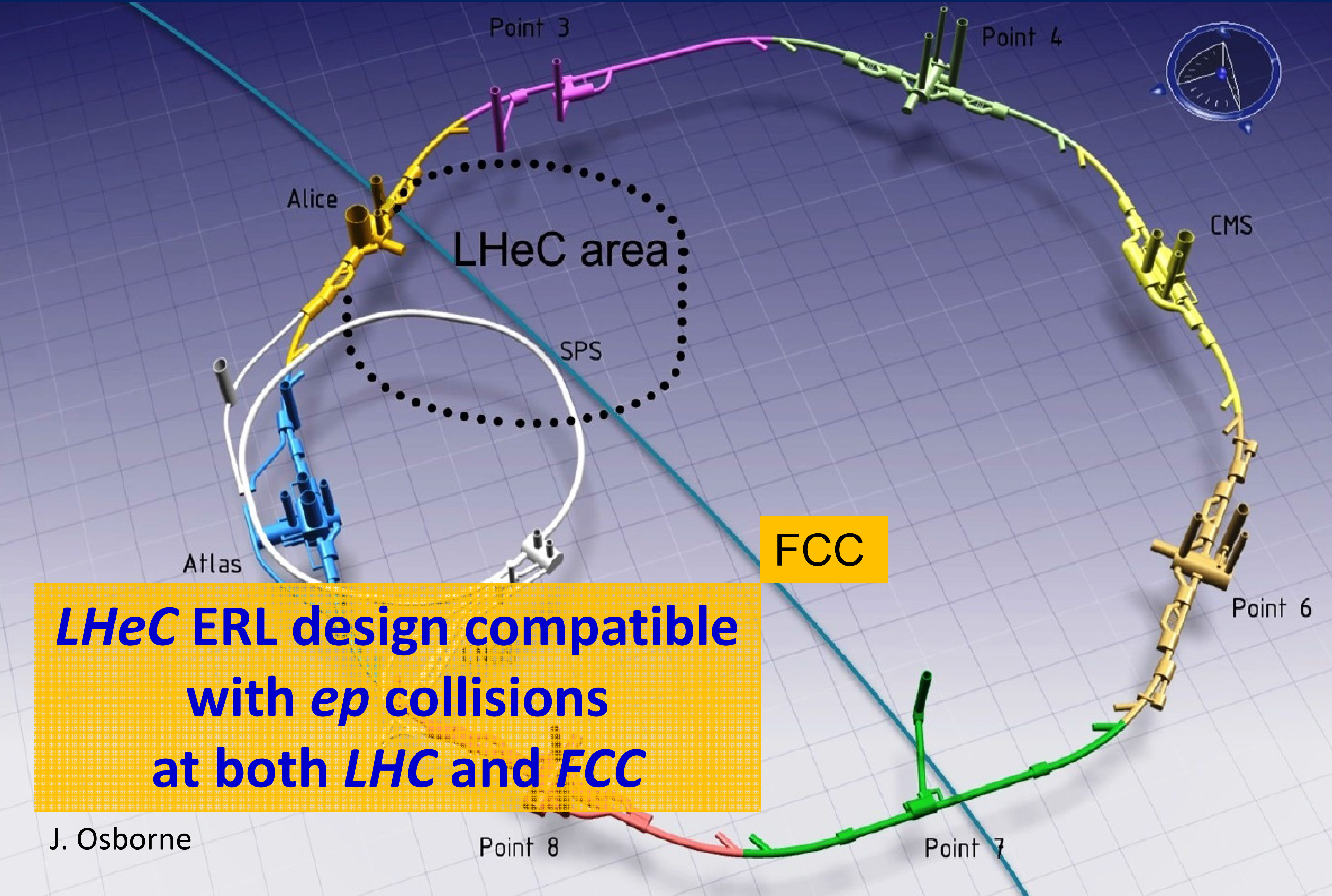
recirculating
linac with
energy
recovery

similar two options for *FCC*:
(1) *FCC-ee* ring, (2) ERL – from *LHeC* or new

FCC-he – 2nd option: based on *LHeC*



FCC-he – 2nd option: based on *LHeC*



LHeC **ERL design compatible with *ep* collisions at both *LHC* and *FCC***

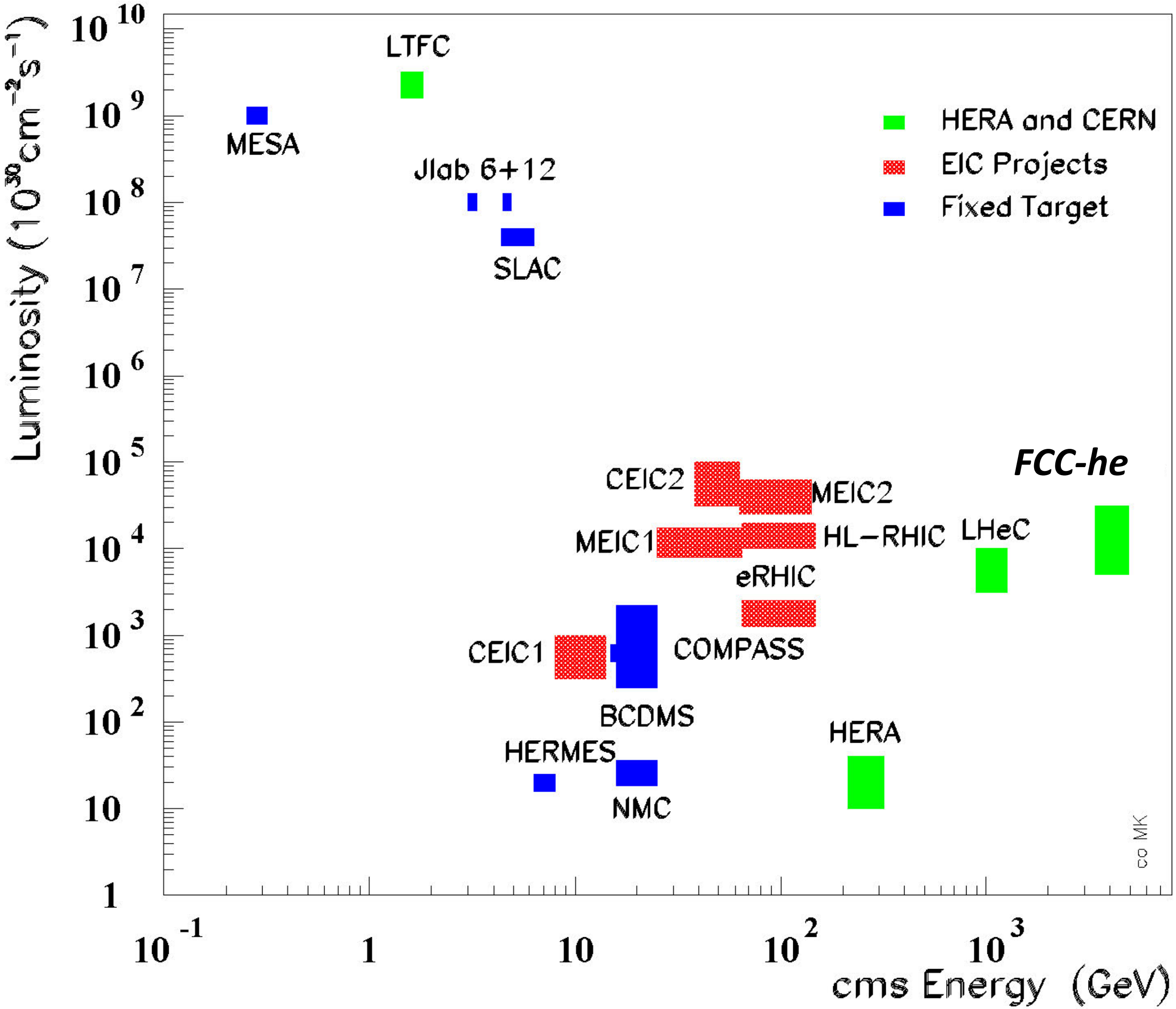
J. Osborne

collider parameters	FCC ERL	FCC-ee ring		protons
species	e^- (e^+?)	$e^\pm$	$e^\pm$	p
beam energy [GeV]	60	80	120	50000
bunches / beam	-	4490	1360	10600
bunch intensity [10^{11}]	0.04	0.7	0.46	1.0
beam current [mA]	25.6	152	30	500
rms bunch length [cm]	0.02	0.15	0.12	8
rms emittance [nm]	0.17	3.3 (*x*)	0.94 (*x*)	0.04 [0.02 *y*]
$\beta_{x,y}$*[mm]	1000	6.0, 3.0	22, 11	500 [250 *y*]
$\sigma_{x,y}$* [μm]	4.0	4.5, 2.3		equal
beam-b. parameter ξ	(D=32)	0.05	**0.13**	0.017 (0.0002)
hourglass reduction	0.94 (H_D=1.35)	**~0.24**	~0.60	
CM energy [TeV]	3.5	4.0	4.9	
luminosity[10^{34}cm^{-2}s^{-1}]	**1.0**	**2.3**	**1.2**	

collider parameters	FCC ERL	FCC-ee ring		protons
species	e^- (e^+?)	$e^\pm$	$e^\pm$	p
beam energy [GeV]	60	80	120	50000
bunches / beam	-	4490	1360	10600
bunch intensity [10^{11}]	0.04	0.7	0.46	1.0
beam current [mA]	25.6	152	30	500
rms bunch length [cm]	0.02	0.15	0.12	8
rms emittance [nm]	0.17	3.3 (*x*)	0.94 (*x*)	0.04 [0.02 *y*]
$\beta_{x,y}$*[mm]	1000	6.0, 3.0	22, 11	500 [250 *y*]
$\sigma_{x,y}$* [μm]	4.0	4.5, 2.3		equal
beam-b. parameter ξ	(*D*=32)	0.05	**0.13**	0.017 (0.0002)
hourglass reduction	0.94 (H_D=1.35)	**~0.24**	~0.60	
CM energy [TeV]	3.5	4.0	4.9	
luminosity[10^{34}cm^{-2}s^{-1}]	**1.0**	**2.3**	**1.2**	

preliminary

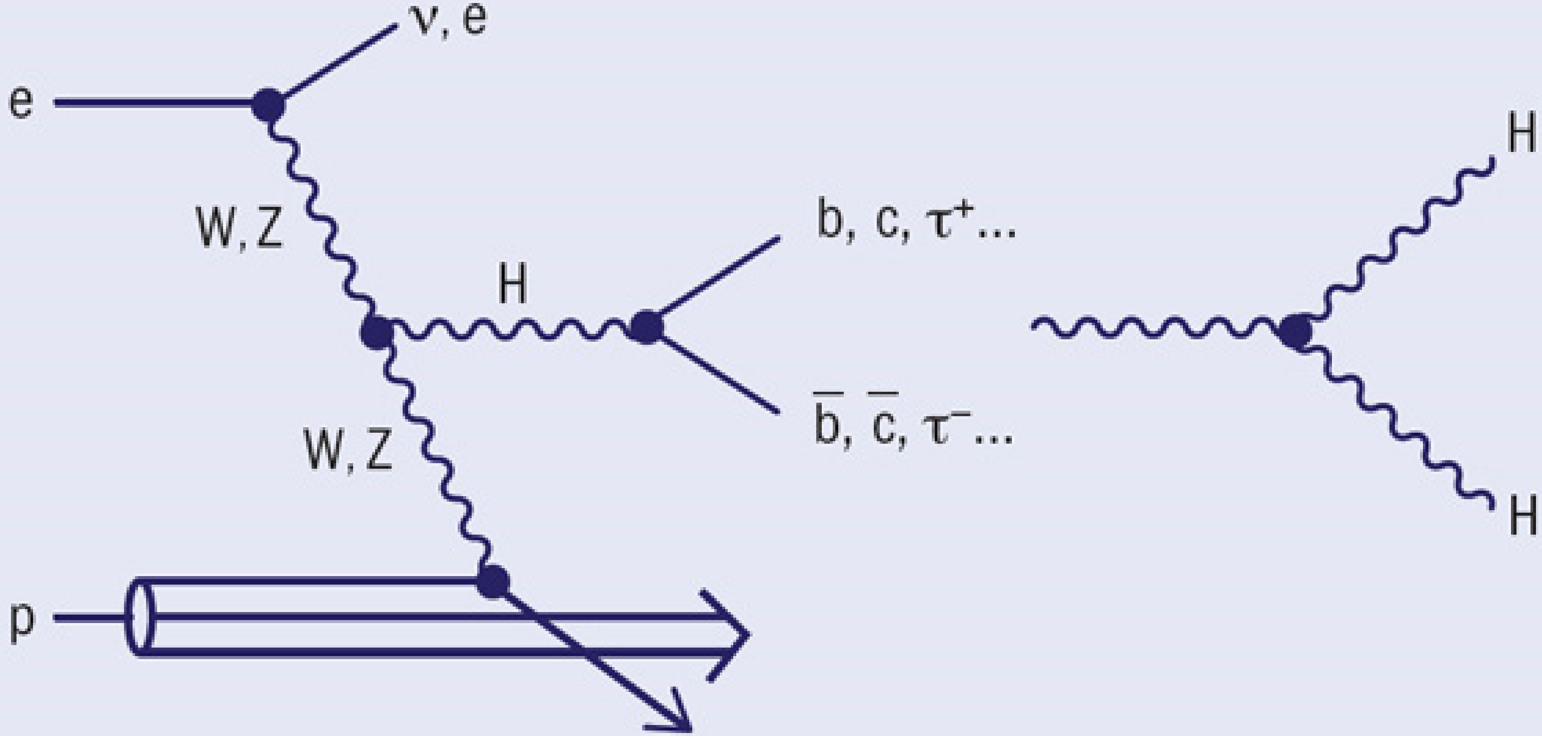
lepton-hadron scattering facilities till *FCC-he*



M. Klein and H. Schopper

CERN Courier June 2014

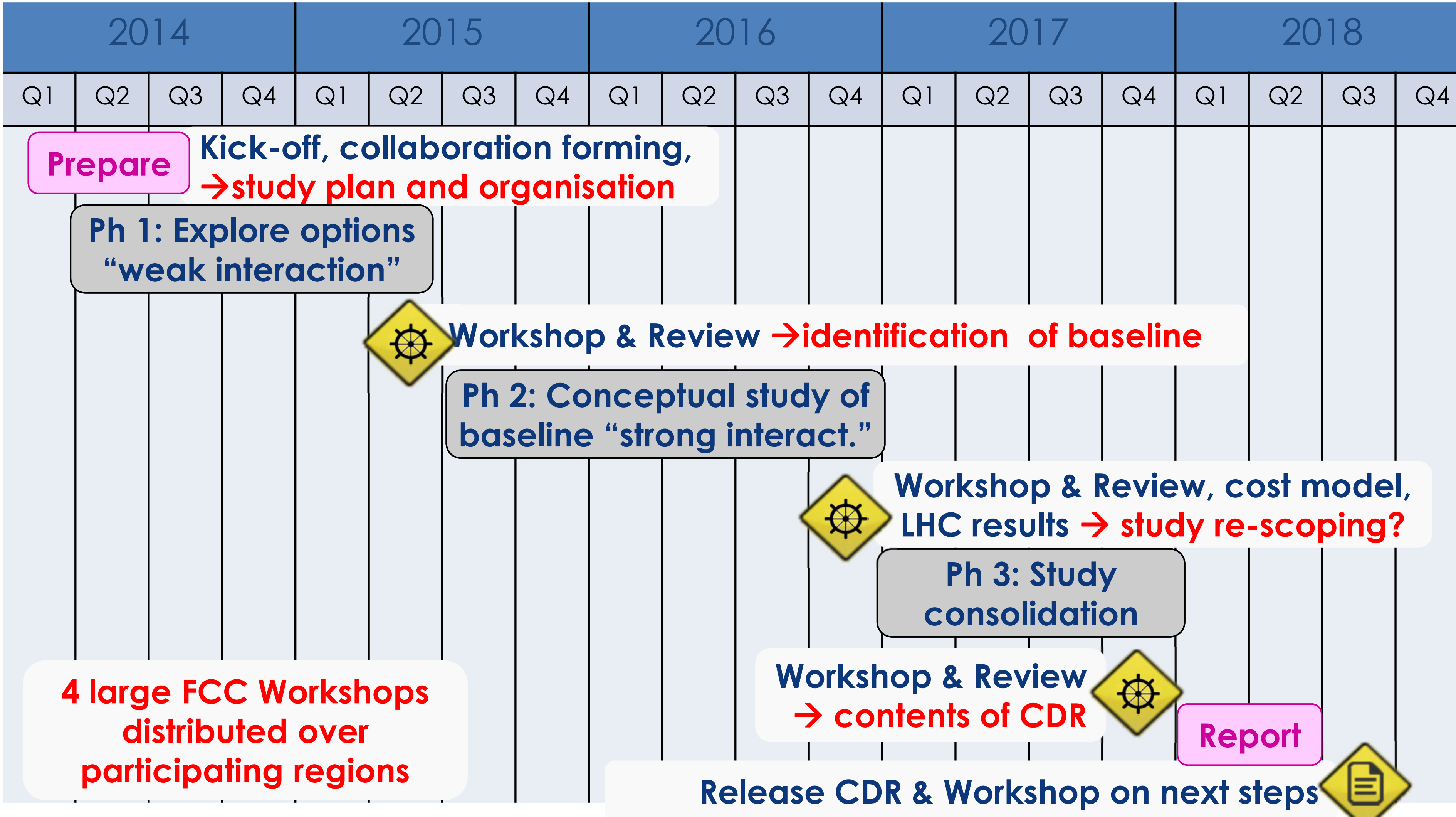
Higgs physics at *LHeC & FCC-he*



h-e* Higgs-boson production and decay**; and precision measurements of the ***H–bb* coupling** in ***WW–H* production**; *FCC-he* also gives access to **Higgs self-coupling *H–HH (<10% precision!? - under study), to **lepto-quarks up to ≈4TeV** & to **Bjorken *x* as low as 10^{-7} - 10^{-8}** [of interest for ultra high energy ν scattering]

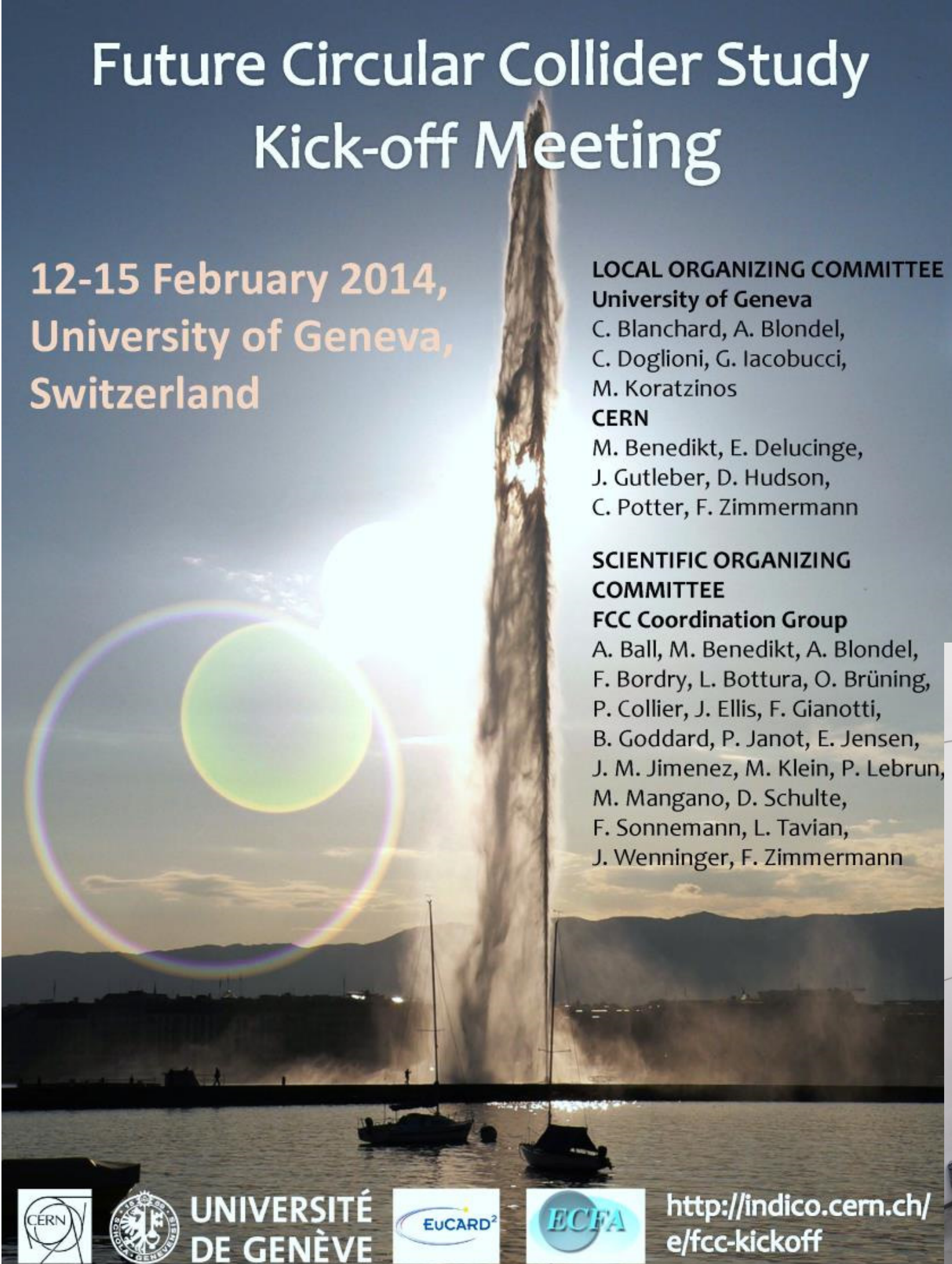
M. Klein and H. Schopper, CERN Courier June2014

FCC global design study – time line



- → **presently discussions with potential partners (MoUs)**
- → **first international collaboration board meeting at CERN on 9 & 10 September 2014**

M. Benedikt

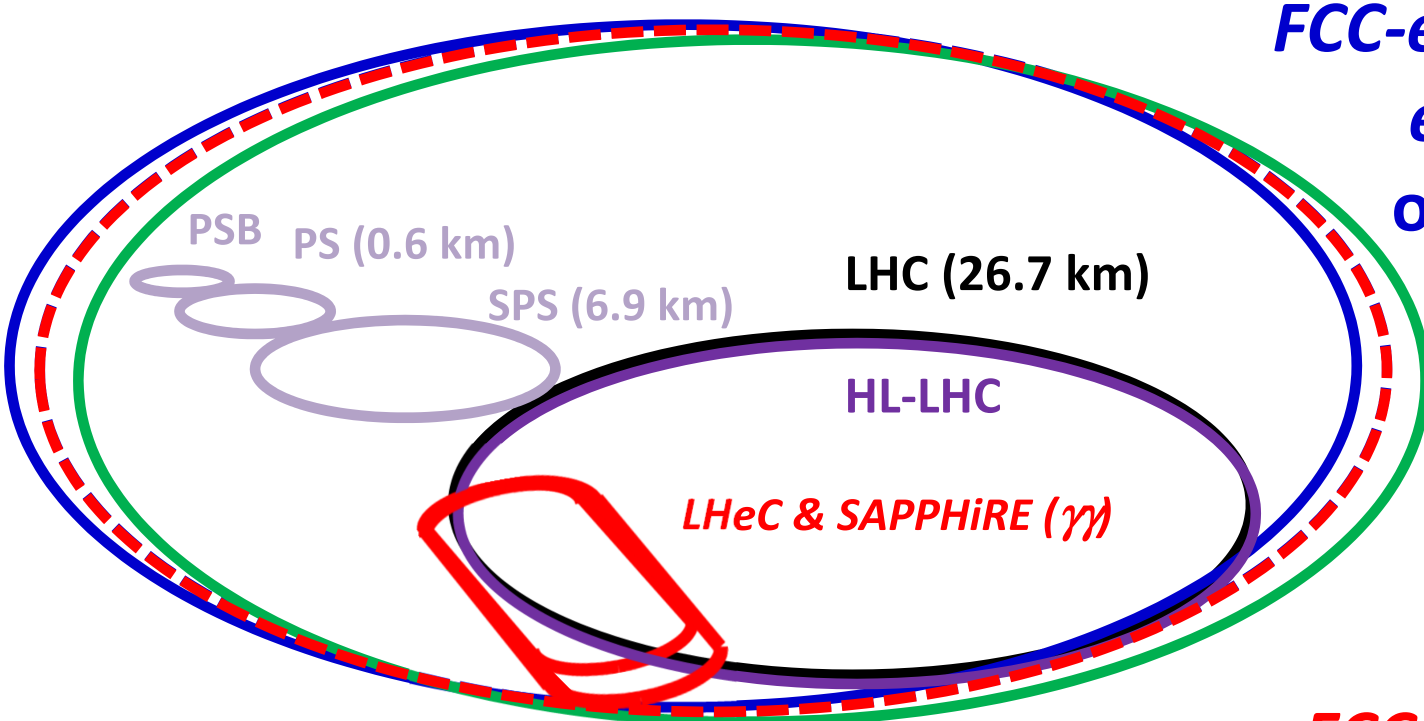


http://indico.cern.ch/e/fcc-kickoff
http://cern.ch/fcc

FCC Kick-off Meeting
University of Geneva
12-15 February 2014

>340 participants

possible evolution of FCC complex



FCC-ee **(80-100 km, e^+e^-, up to 350 or 500 GeV c.m.)**

FCC-hh **(*pp* up to 100 TeV c.m. & *AA*)**

LHeC as FCC-ee injector?

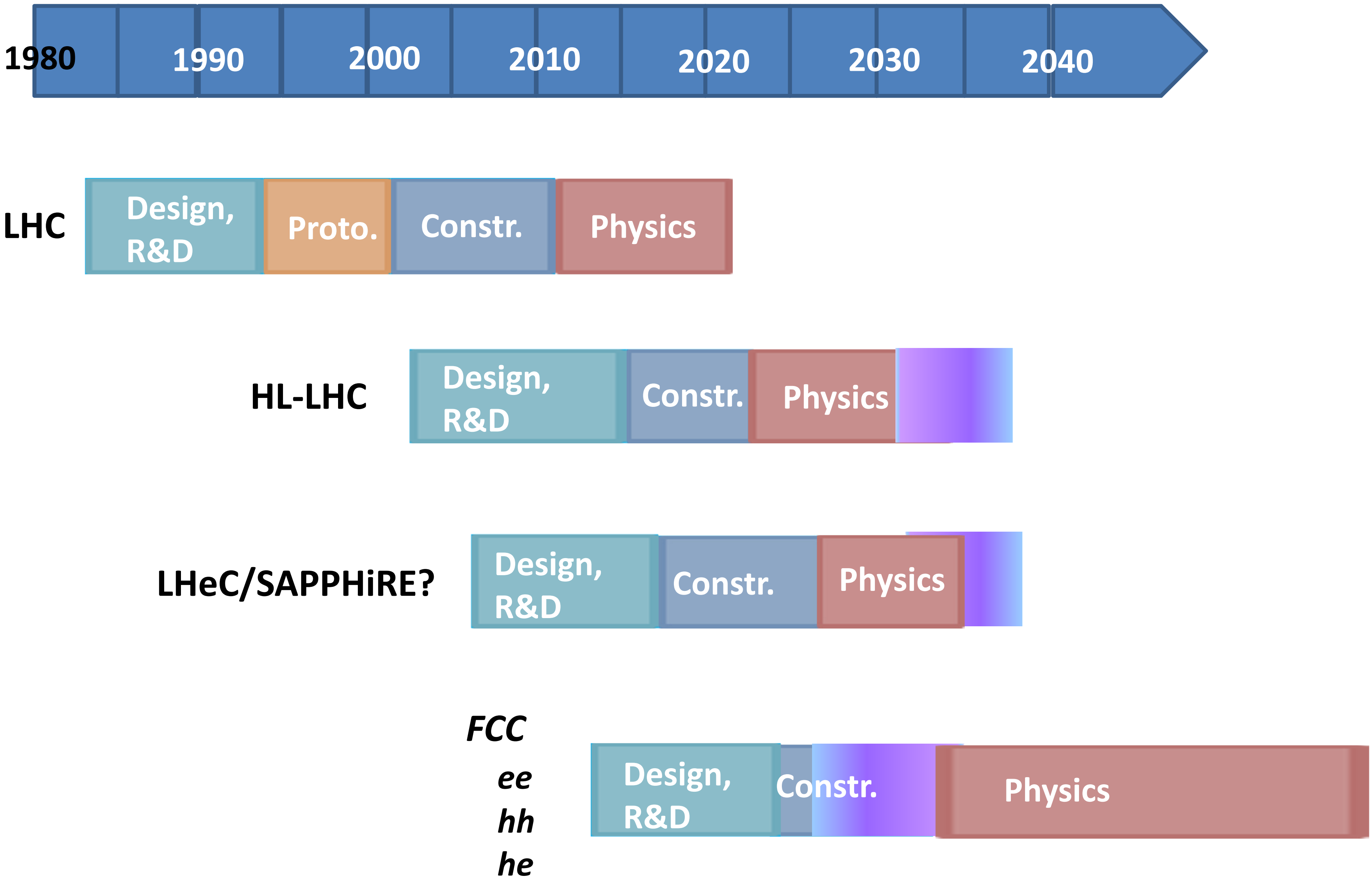
FCC-he **as ring-ring collider ?!**

LHeC-based FCC-he collider?!

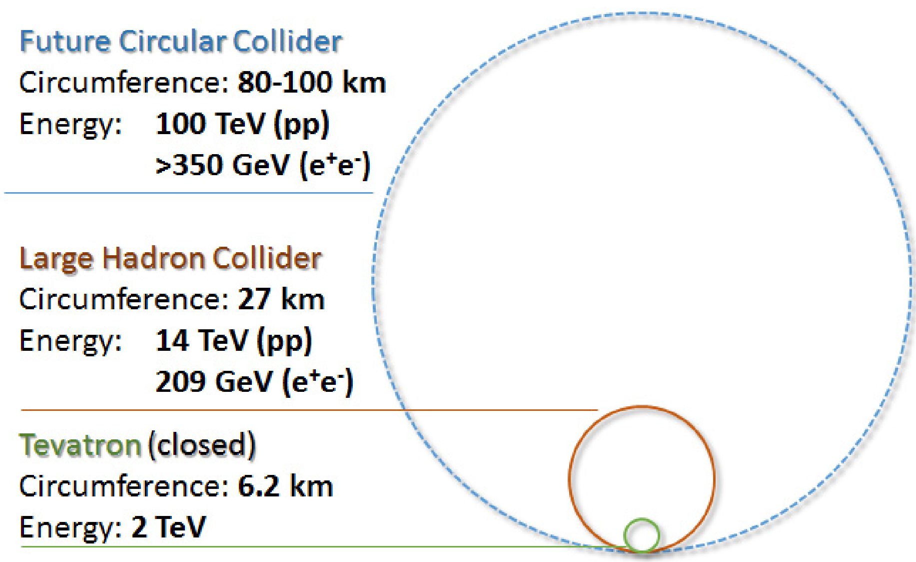
FCC-he: $e^\pm$ (60-250 GeV) – *p*(50 TeV)/A collisions

≥50 years e^+e^-, *pp*, $e^\pm p/A$ physics at highest energies

tentative time line



„Willst du ins Unendliche schreiten, Geh nur im Endlichen nach allen Seiten.“



Johann Wolfgang von Goethe

Werke – Hamburger Ausgabe Bd. 1, Gedichte und Epen I, Sprüche

(Weimar - 169 km from Dresden)

FCC-related IPAC'14 talks on Tuesday:

G. Apollinari, *High-field Magnet Development toward Higher Luminosity Performance of the LHC*, **TUOCB02**

A. Milanese, H. Piekarz, L. Rossi, *Concept of a Hybrid (Normal and Super-conducting) Bending Magnet based on Iron Magnetization for 80-100 km Lepton/Hadron Colliders*, **TUOCB01**

FCC-related IPAC'14 posters on Thursday:

K. Ohmi, Y. Zhang, D. Shatilov, D. Zhou, *Beam-Beam Simulation Study for CepC*, **THPIR003**

K. Ohmi, F. Zimmermann, *Beam-Beam Simulations with Beamstrahlung for FCC-ee and CepC*, **THPRI004**

A. Bogomyagkov, E. Levichev, P. Piminov, *Interaction Region Lattice for FCC-ee (TLEP),* **THPRI008**

H. Garcia, L. Medina, R. Tomas, *FCC-ee/TLEP Final Focus with Chromaticity Correction*, **THPRI010**

L. Lari, F. Cerutti, A. Ferrari, A. Mereghetti, *Beam-Machine Interaction at TLEP: First Evaluation & Mitigation of the Synchrotron Radiation Impact*, **THPRI011**