HEP and Collider Activities in Asia

FCC Week, Amsterdam

9-13 April, 2018

Geoffrey Taylor, ACFA
CoEPP, University of Melbourne

ACFA (Asian Committee for Future Accelerators) - some background-

- Set up in 1996.
- Directors of KEK, IHEP (and Pohang, Korea) sought a solution for Asian support of large future accelerator projects. - in a parallel to ECFA
- Whilst aim was to support, an ILC for example, it was soon realised that Asia not like Europe. Many small countries, with small accelerators, lights sources - introduced AsiaHEP (2012) with HEP focus.
- Will push to recombine ACFA/AsiaHEP in coming months - aimed at supporting ILC and CEPC.

Collider Activities - Asia

- Brief overview of Asian colliders:
  - KEK (Japan) - past and present
  - IHEP (China)- Past and present
  - BINP (Russia - Novosibirsk)
- Brief description of Asian Participation at LHC
- In view of the FCC focus:

  Concentrate on Future Asian Colliders

  (Will not discuss status of Asian neutrino projects nor non-accelerator physics -
  a large part of Asian HEP activities, but time/FCC focus preclude it)

KEK Colliders

- Tristan
  - Operated from 1987 to 1995.
  - Main objective to detect the top quark.
  - CoM energy 30 GeV.
  - 3 detectors: TOPAZ, VENUS and AMY
  - KEKB was built in TRISTAN tunnel
- KEKB
- Super KEKB

SuperKEKB/Belle II

Toru Iijima, ICFA Seminar 2017

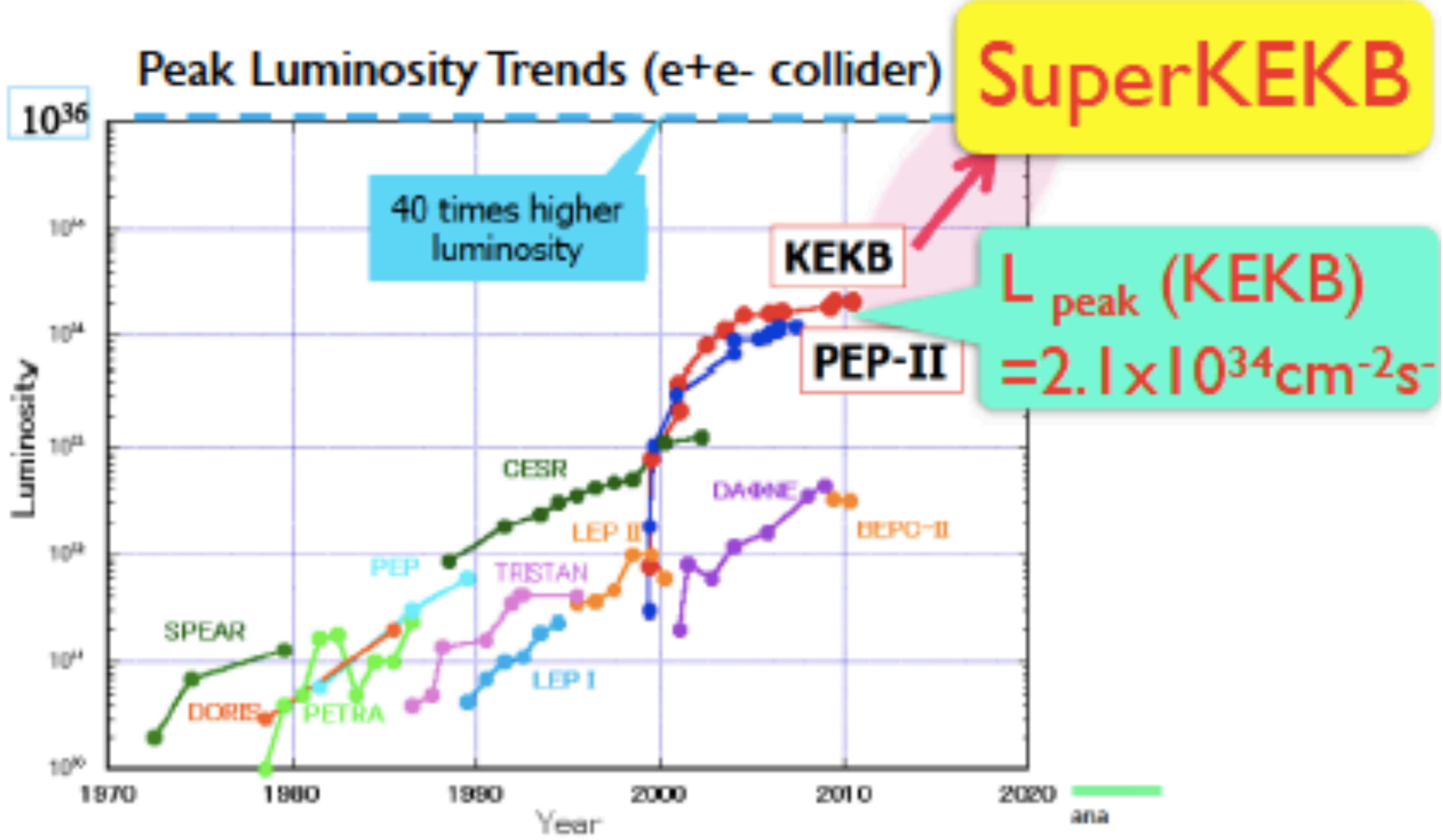
New intensity frontier facility at KEK

- Target luminosity ; $L_{peak} = 8 \times 10^{35} cm^{-2}s^{-1}$

  $\Rightarrow \sim 10^{10}$ $B\bar{B}$, $\tau^+\tau^-$ and charms per year !

  $L_{int} > 50\ ab^{-1}$

- Rich physics program
  - Search for New Physics through processes sensitive to virtual heavy particles.
  - New QCD phenomena (XYZ, new states including heavy flavors) + more



The first particle collider after the LHC !

SuperKEKB Accelerator

Toru Iijima, ICFA Seminar 2017

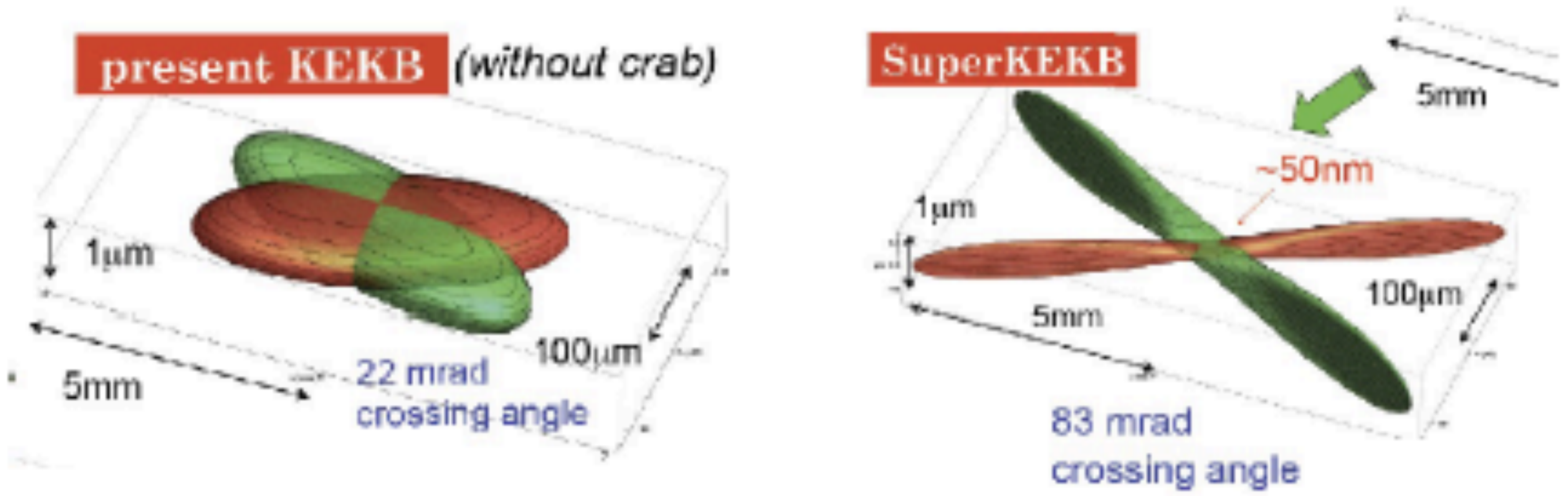
- Low emittance ("nano-beam") scheme employed (originally proposed by P. Raimondi)

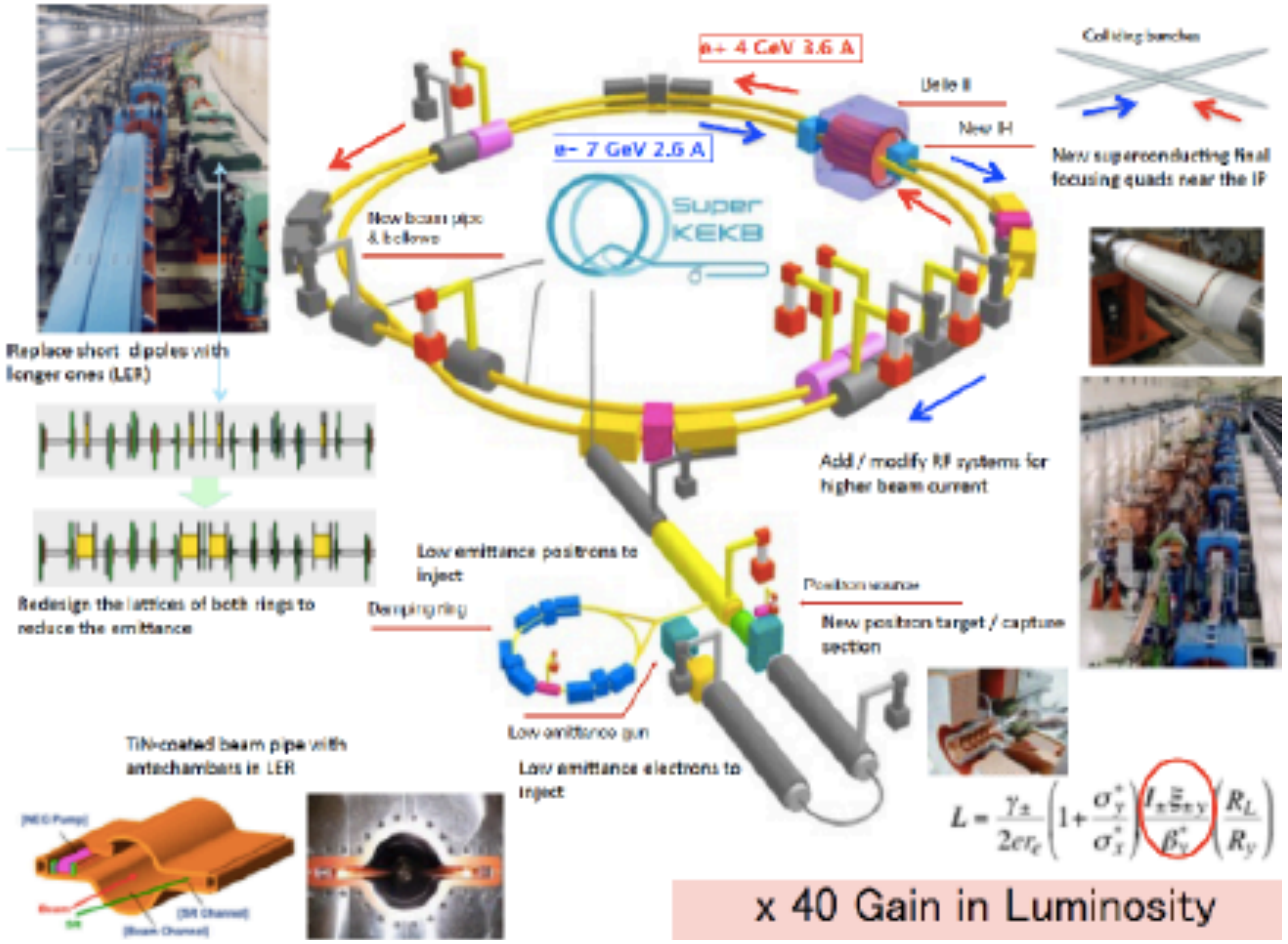
Machine parameters

	SuperKEKB LER/HER	KEKB LER/HER
E(GeV)	4.0/7.0	3.5/8.0
ε_x (nm)	3.2/4.6	18/24
βy at IP(mm)	0.27/0.30	5.9/5.9
βx at IP(mm)	32/25	120/120
Half crossing angle(mrad)	41.5	11
I(A)	3.6/2.6	1.6/1.2
Lifetime	~10min	130min/200min
L(cm^{-2}s^{-1})	80×10^{34}	2.1×10^{34}

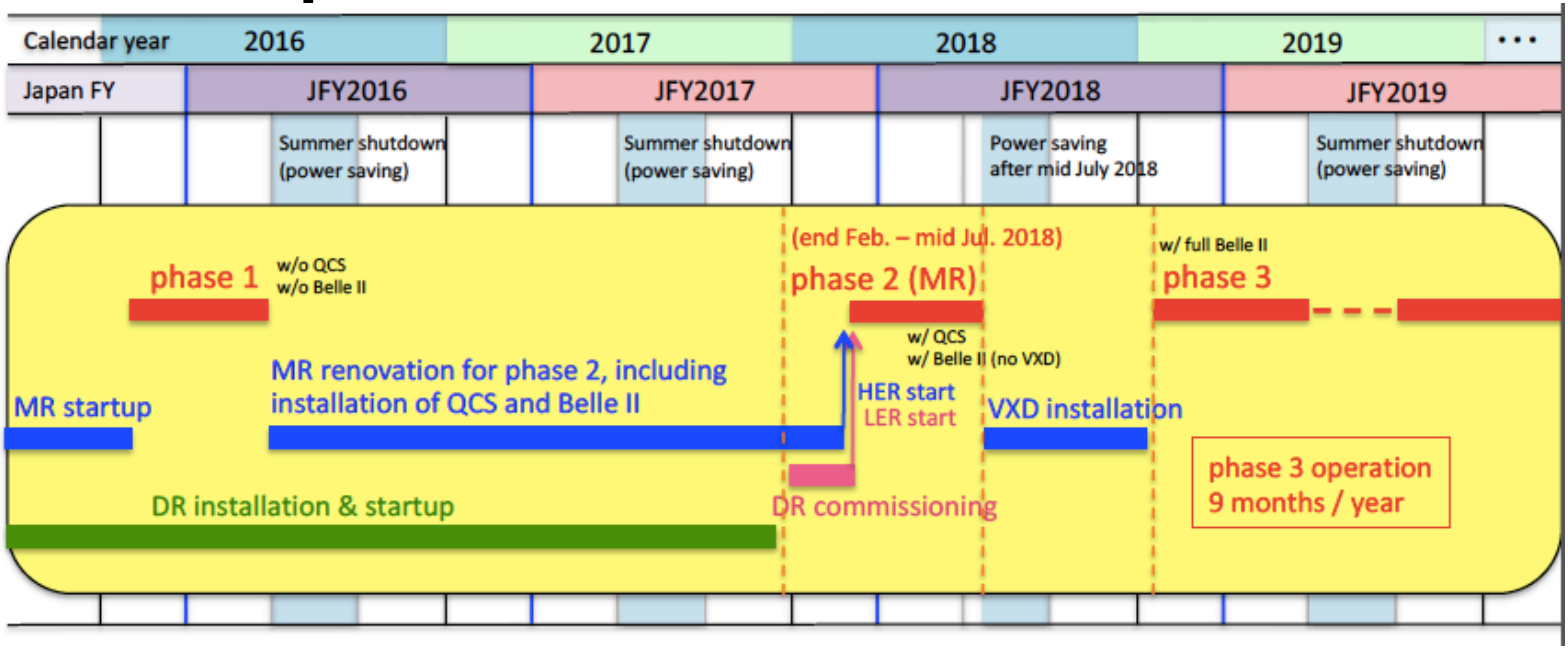
x20

x2





SuperKEKB/Belle II Schedule



- Electrons stored 21 March, 2018
- Positrons to follow
- Collisions ~early May

Belle II Collaboration

As of Oct. 2017

25countries/regions
105 institutions
~750 researchers

Europe	300
Austria	13
Czechia	6
France	14
Germany	110
Israel	3
Italy	76
Poland	13
Russia	42
Slovenia	16
Spain	4
Ukraine	3

+ France from mid-2017

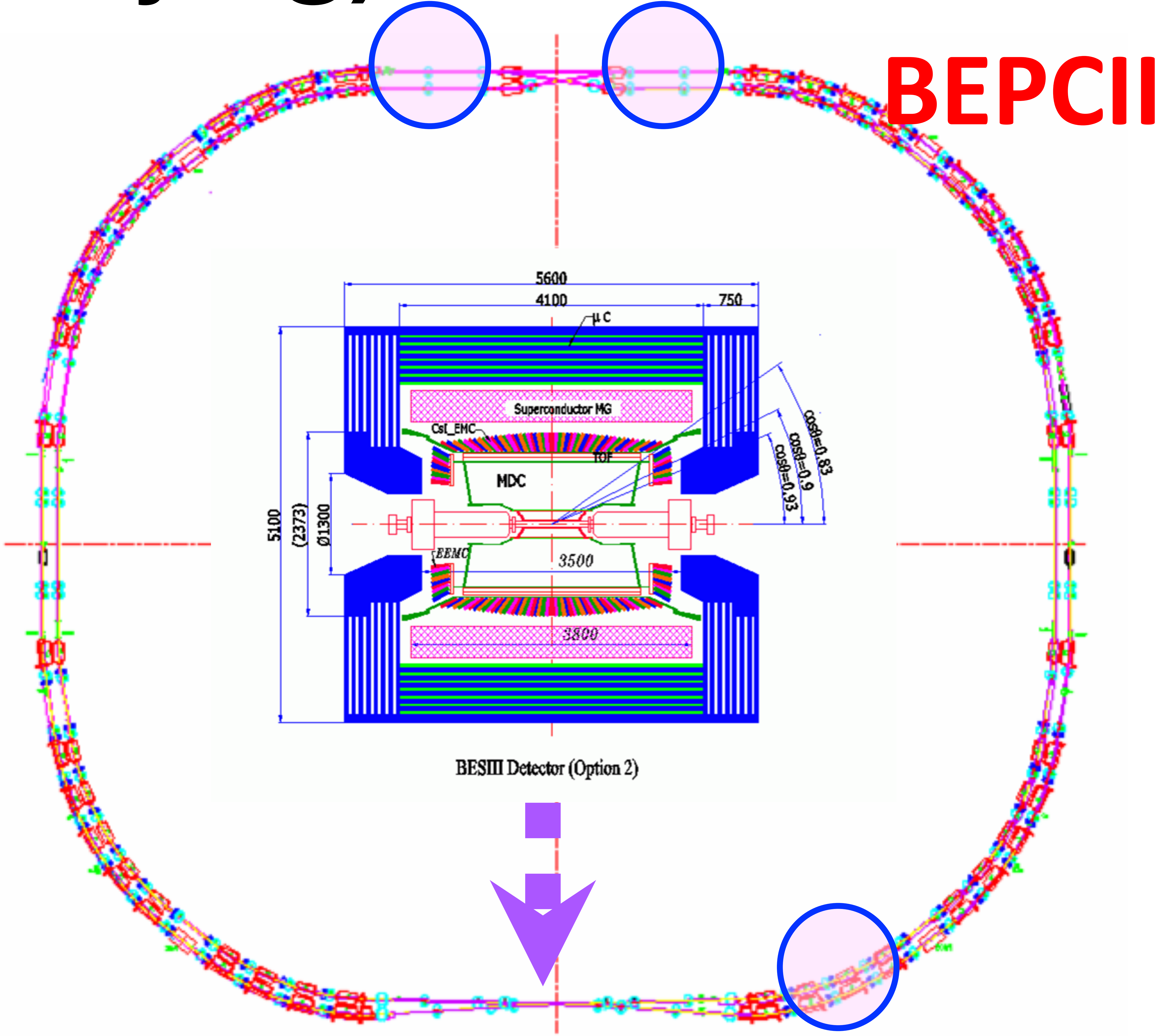
Asia			346
Saudi Arabia	1	Korea	43
Australia	33	Malaysia	6
China	33	Vietnam	3
India	44	Taiwan	28
Japan	150	Thailand	2
		Turkey	3

America	129
Canada	28
Mexico	12
USA	89

Toru Iijima, ICFA Seminar 2017

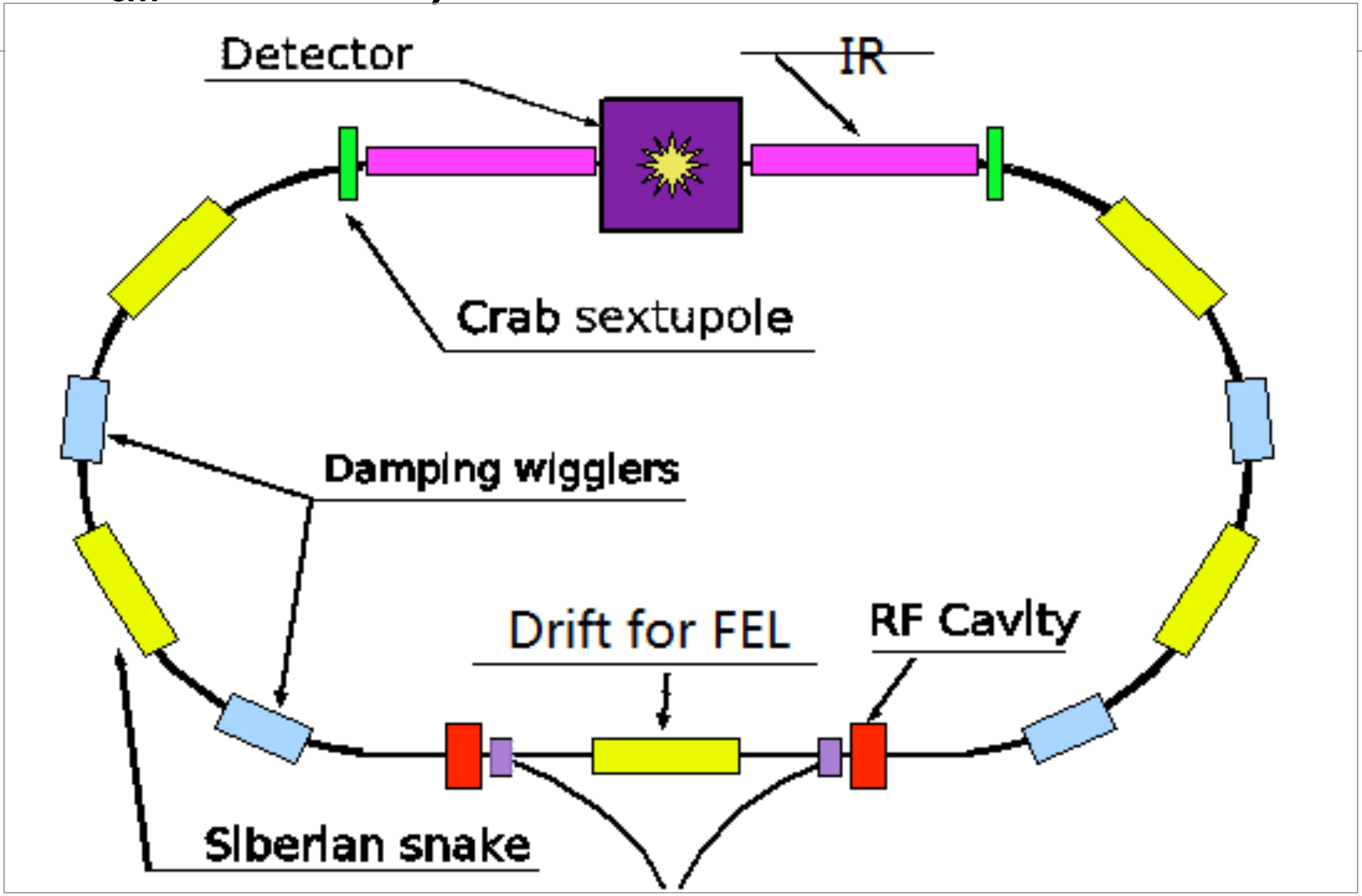
IHEP (Beijing) Colliders

BEPCII/BESSIII



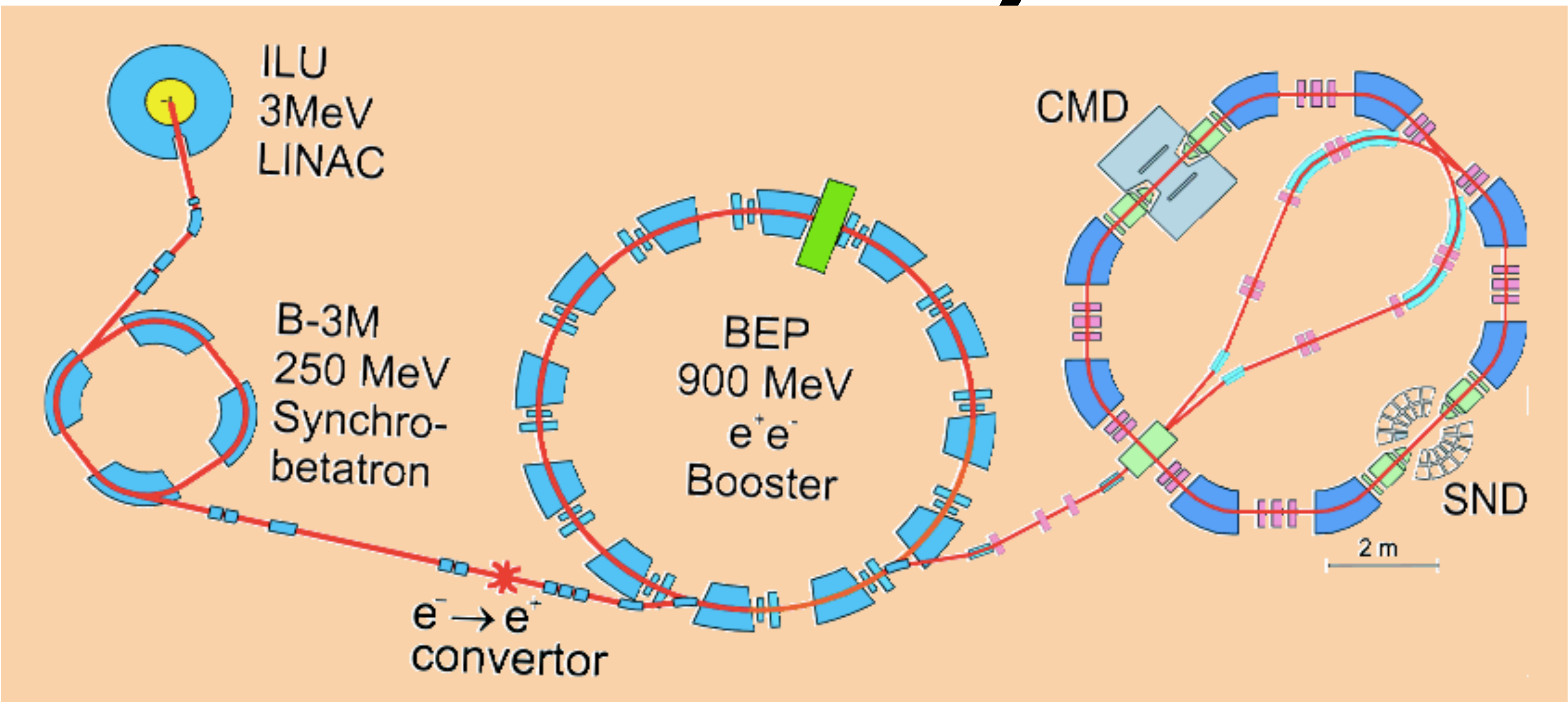
High Intensity Electron Positron Accelerator
- Super tau-charm factory (STCF) -

E_{cm} = 2 -7 GeV, L = 0.5-1 x 10^{35} $cm^{-2}s^{-1}$ at 4 GeV

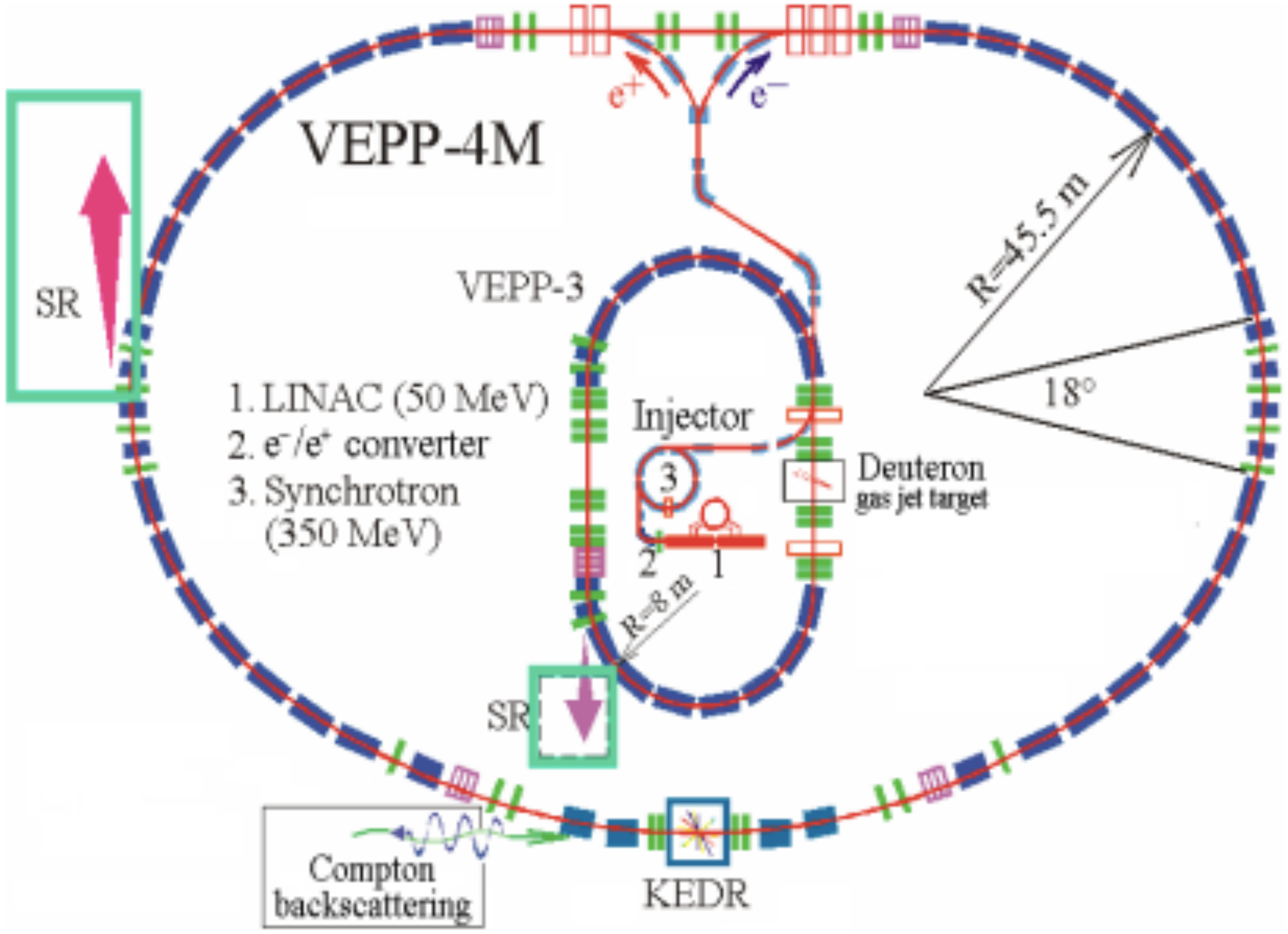


BINP (Novosibirsk) Colliders

- VEPP-2000
  1-2 GeV

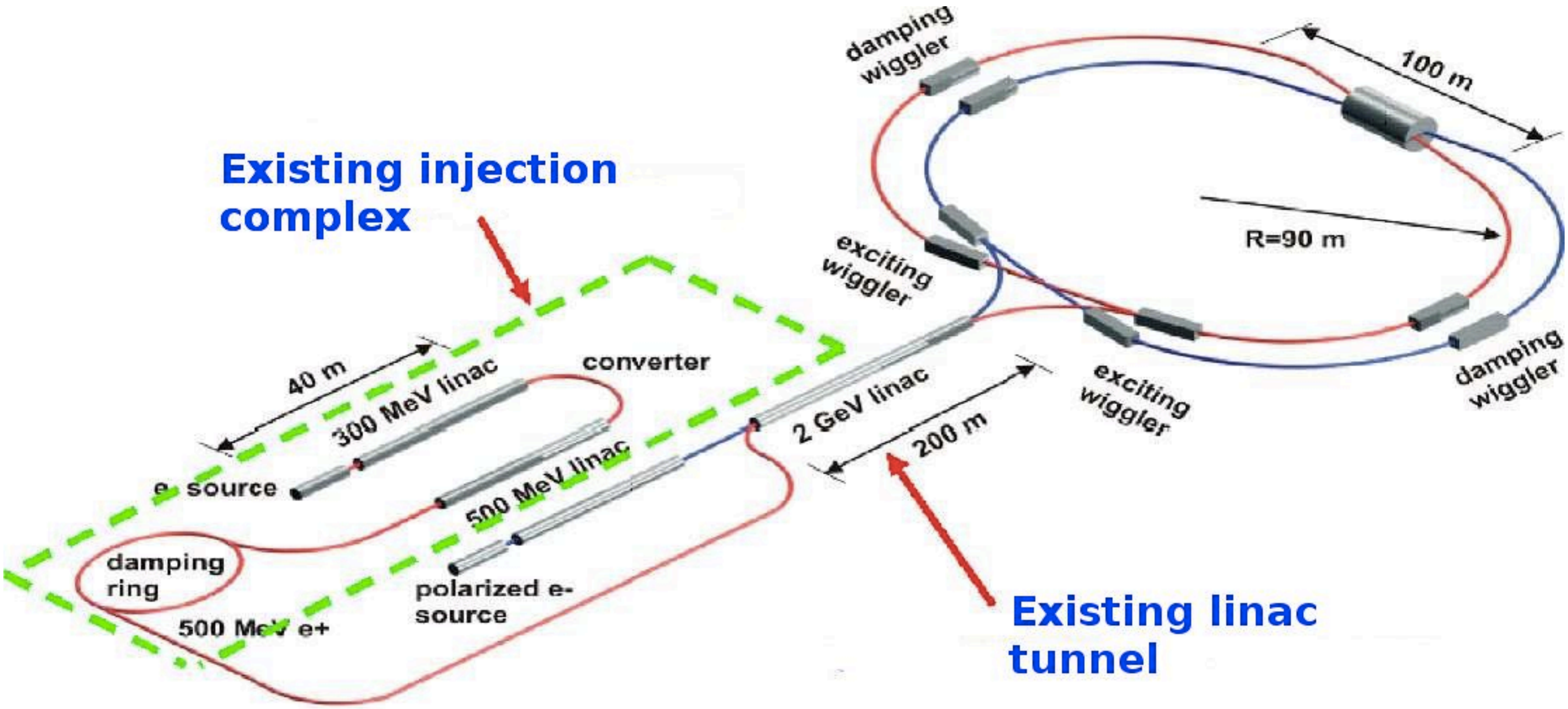


- VEPP-4M - 1.5-5 GeV
  (c-tau threshold studies)



http://accelconf.web.cern.ch/AccelConf/rupac2014/papers/tuz01.pdf

BINP Proposed charm-tau Factory

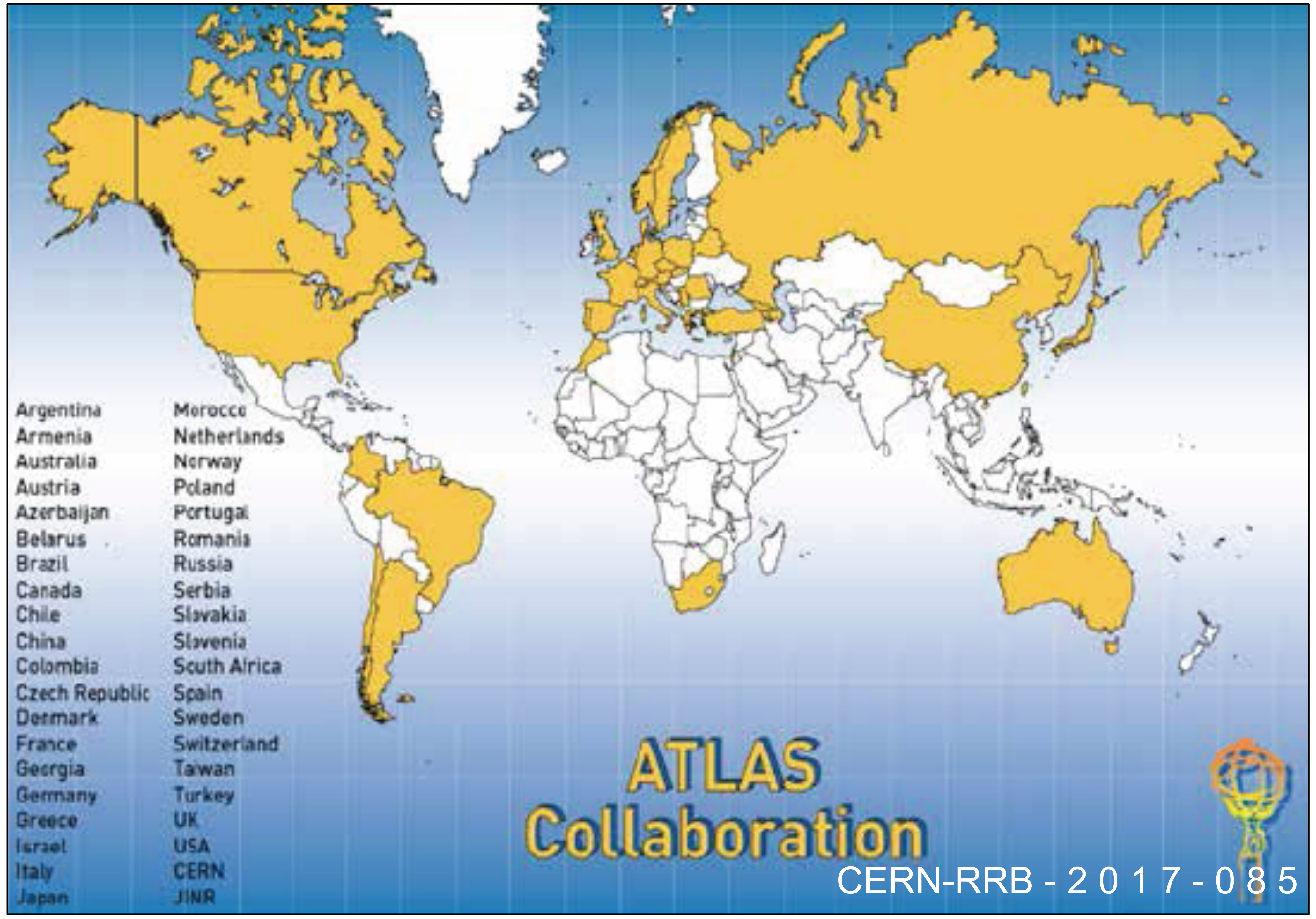


https://ctd.inp.nsk.su/c-tau/

BINP Super c-tau Factory

https://ctd.inp.nsk.su/c-tau/

- CoM energies from 2 to 5 GeV
- Luminosity: 10^{35} $cm^{-2}s^{-1}$
- Longitudinal polarized electrons
- Main physics goals:
  - search for effects of CP-violation in the decays of charmed particles
  - tests of the Standard Model in the decay of the tau lepton
  - search and study glueballs, hybrids, etc.
- Data increase by 3-4 orders



Asian Activities at LHC

Asian Participation in:

- ATLAS
- ALICE
- CMS
- LHCb

Much detector development and supply across Asia

Future High Energy Asian Colliders

- ILC - Japan
- CEPC/SppC - China

International Linear Collider

- Future e+e- linear collider R&D started in 1990's in 3 regions.
- By early 2000's, consensus in world HEP community:
  - e+e- linear collider CM energy ~500 GeV should be the next collider beyond the LHC.
- ICFA chose S/C RF for LC as a global project in 2004 -global team (GDE) for design and coordination of R&D for the ILC.
- Higgs boson discovery at CERN in the summer of 2012.
- ILC-TDR was published in June 2013. ICFA set up the Linear Collider Collaboration for engineering design phase.

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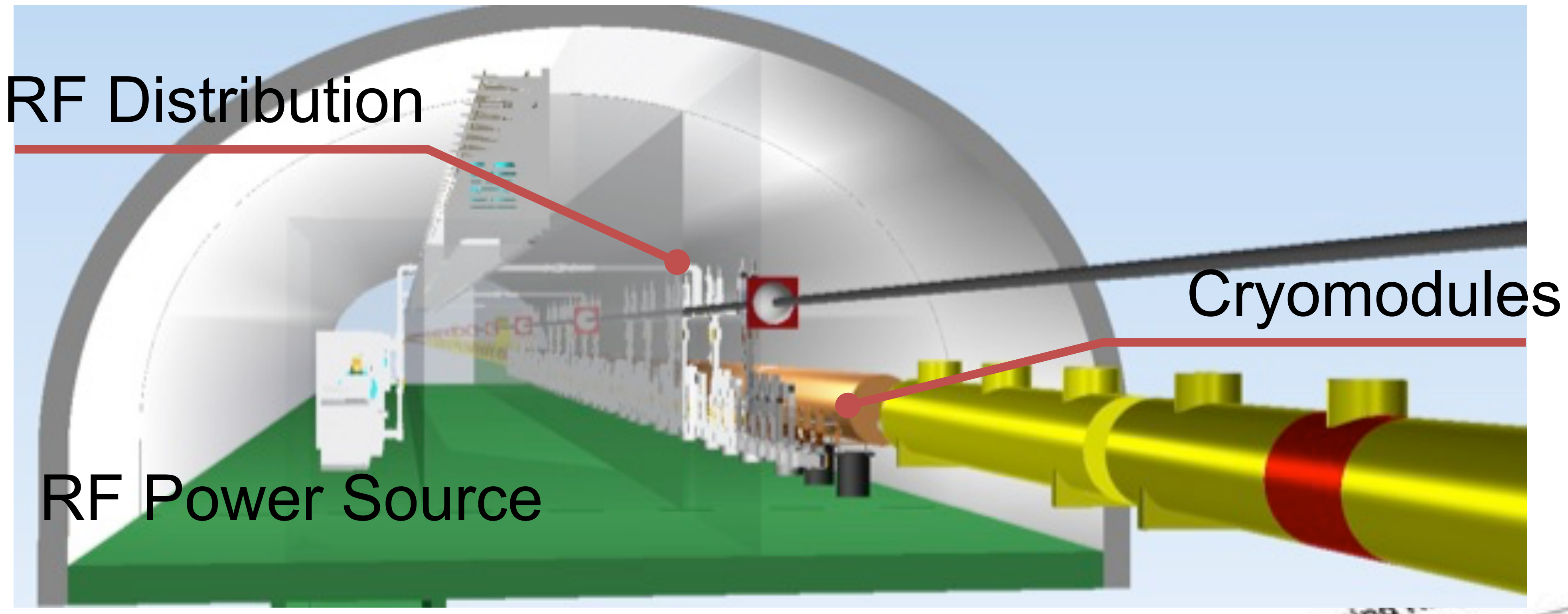
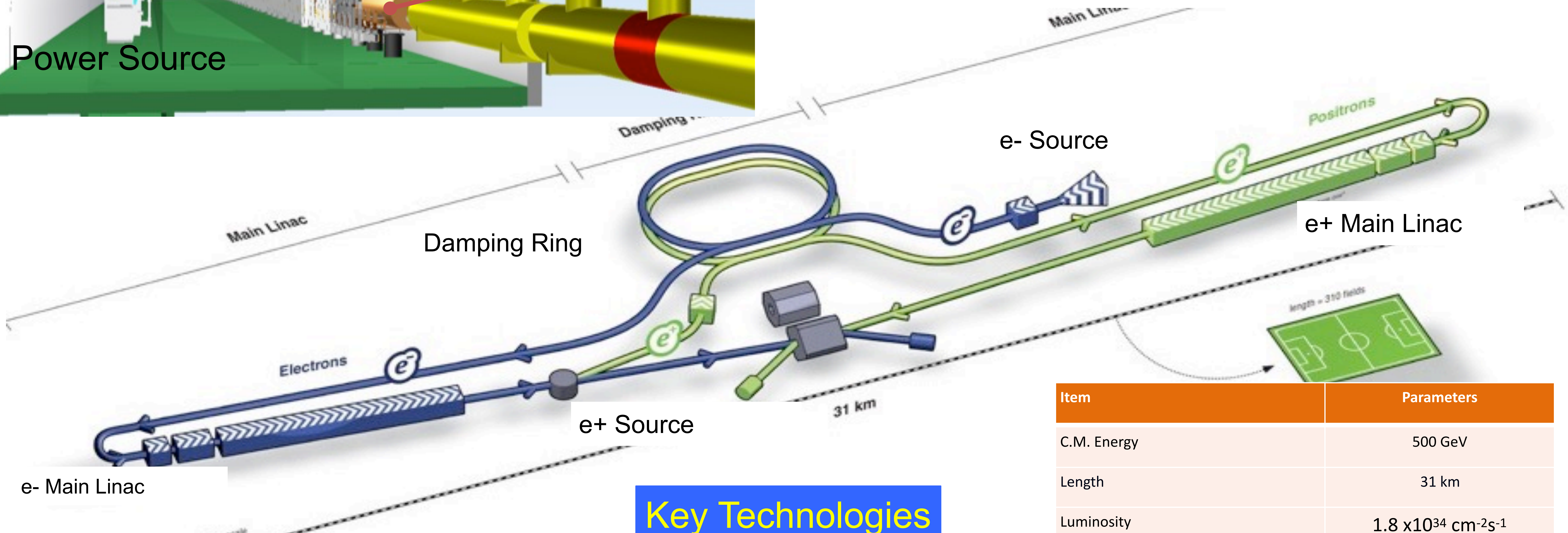
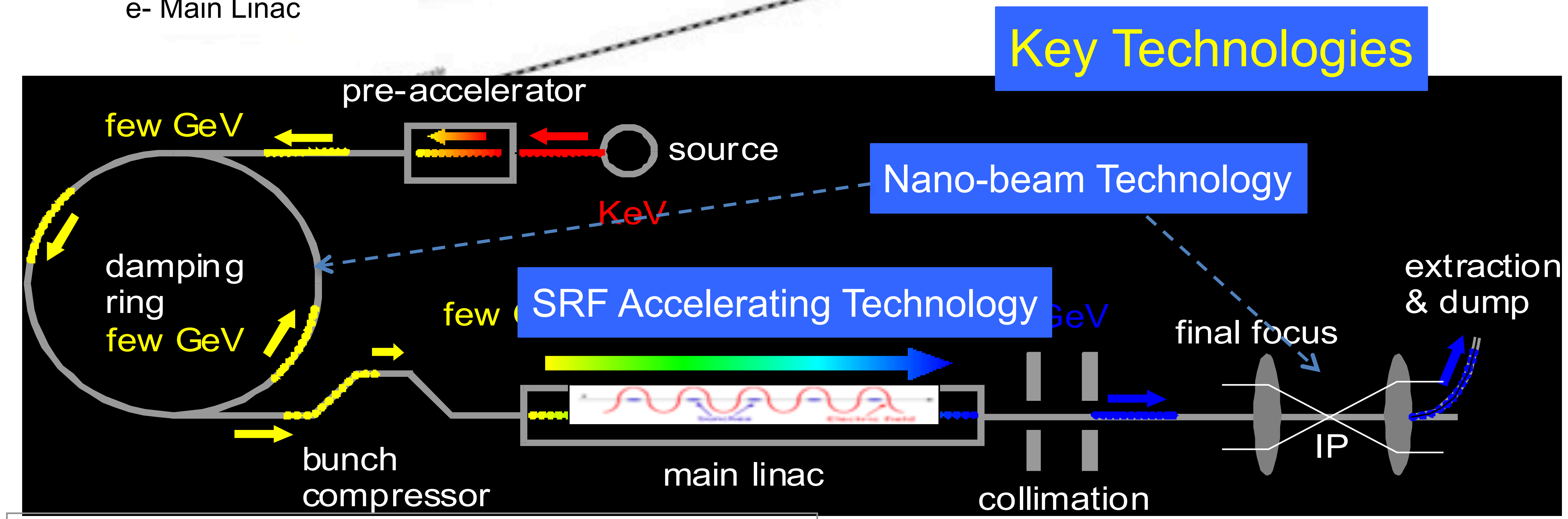
ILC accelerator à la TDR







Item	Parameters
C.M. Energy	500 GeV
Length	31 km
Luminosity	1.8×10^{34} $cm^{-2}s^{-1}$
Repetition	5 Hz
Beam Pulse Period	0.73 ms
Beam Current	5.8 mA (in pulse)
Beam size (y) at FF	5.9 nm
SRF Cavity G. Q_0	31.5 MV/m $Q_0 = 1 \times 10^{10}$

S. MICHIZONO (KEK/LCC) ICFA Seminar, Nov. 2017

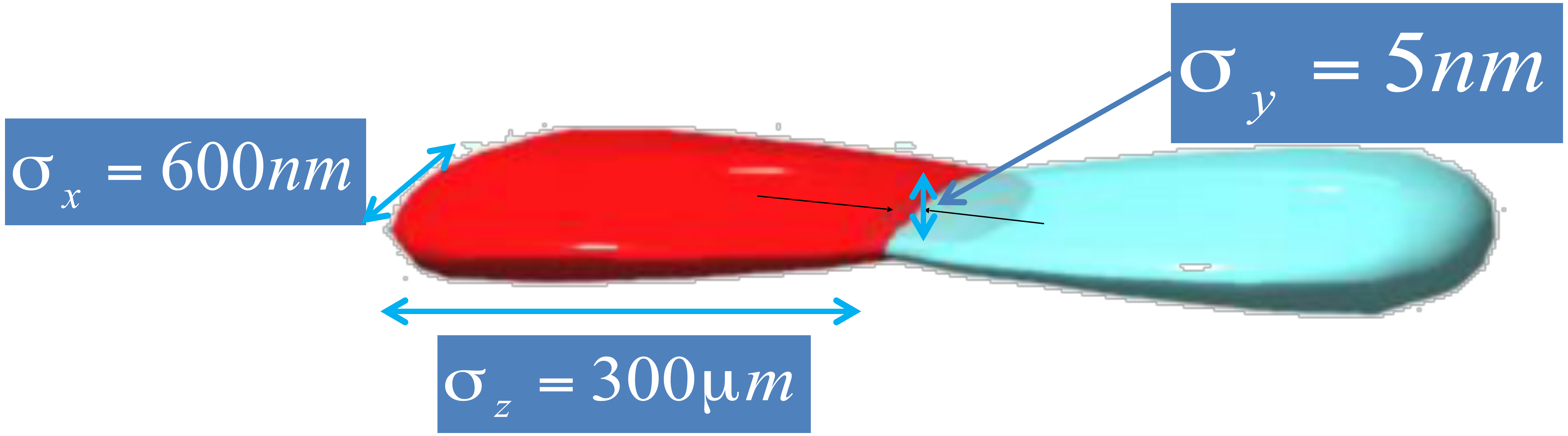
M.Yamauchi (KEK), LP2017

Nano beams

$$L \propto \frac{fN^2}{\pi\sigma_x\sigma_y}$$

Beam power ~ cost

smaller beam cross section



Final Focus system → Focusing beam
Stable Collision

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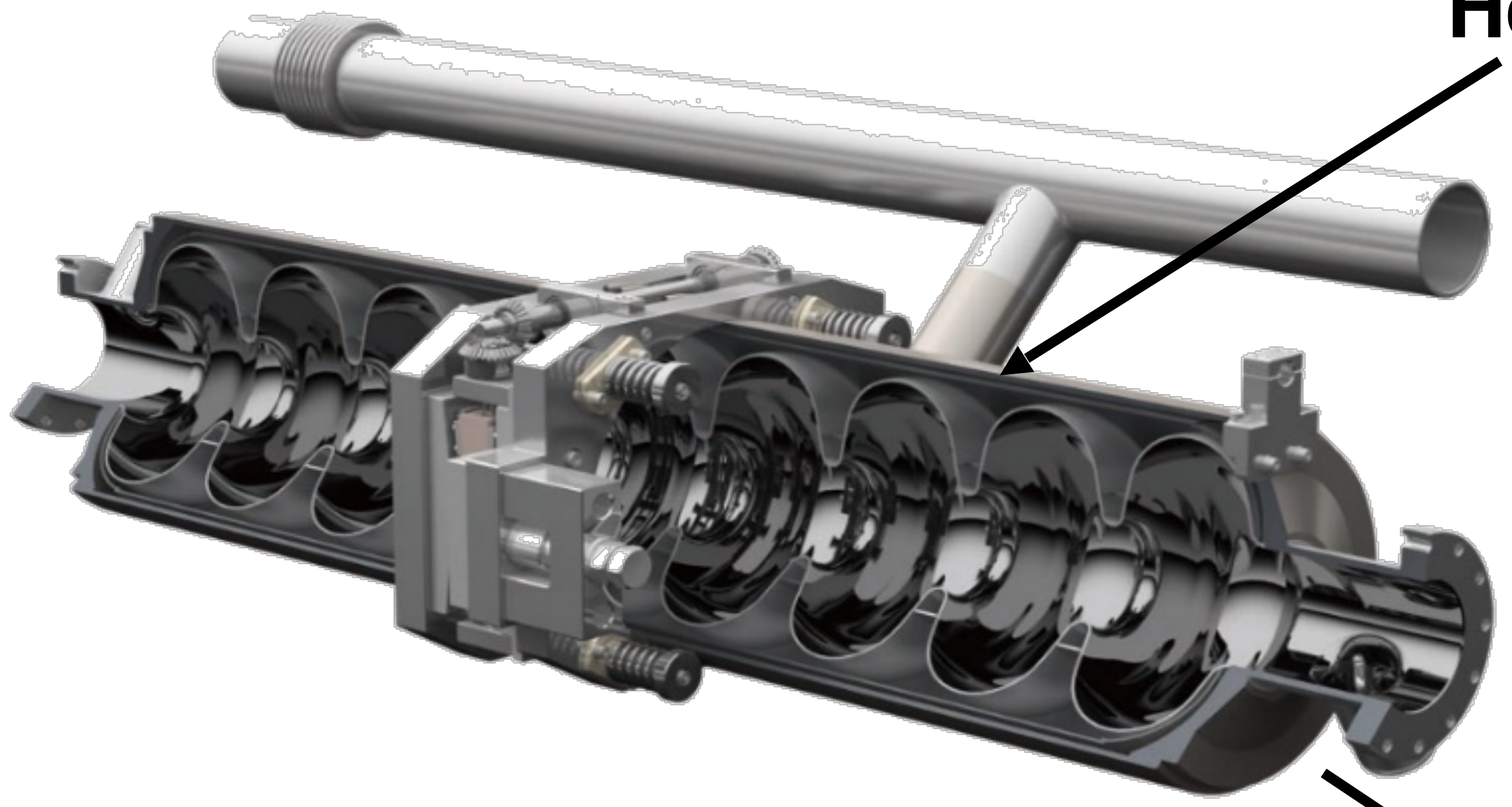
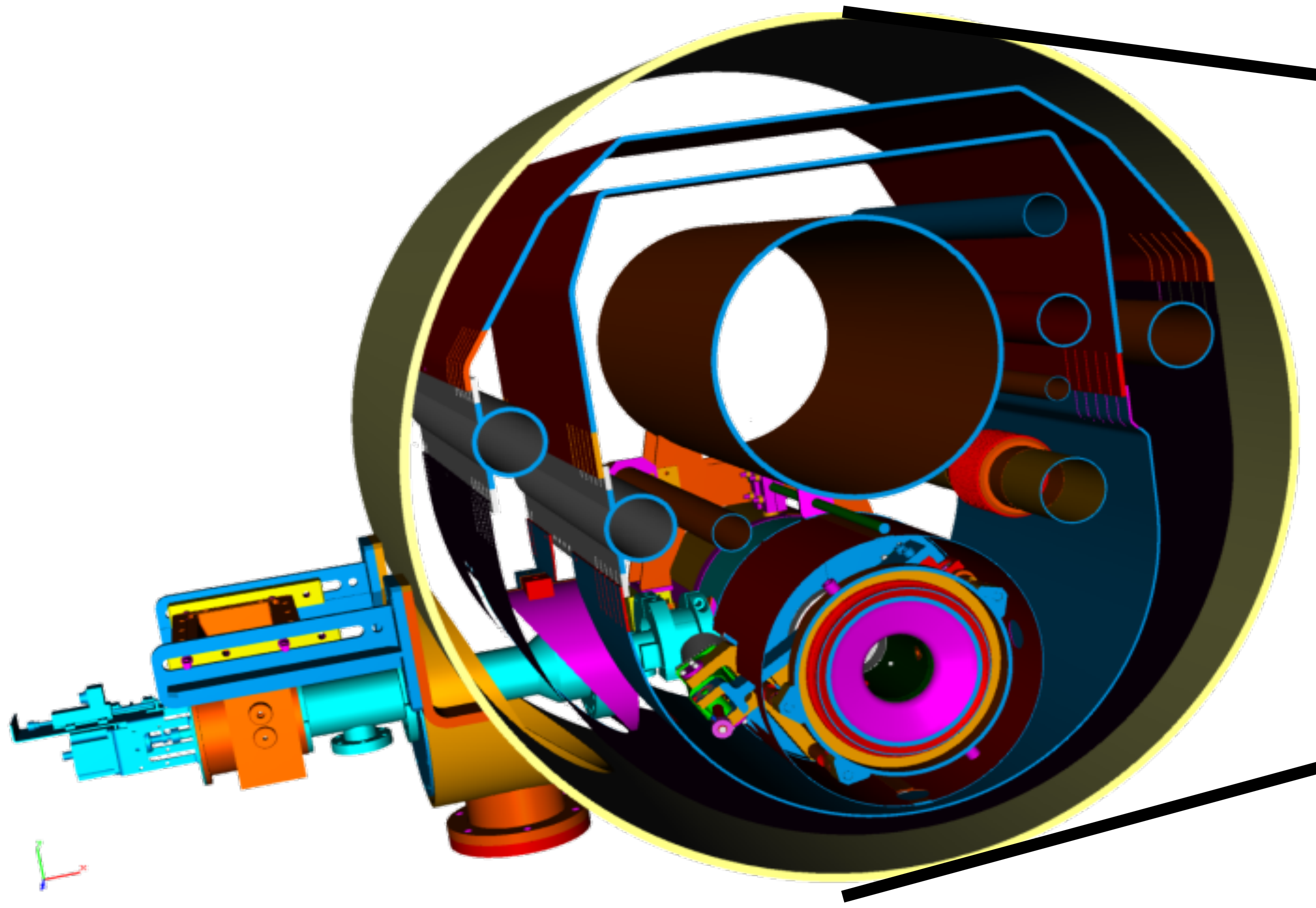
Accelerator complex

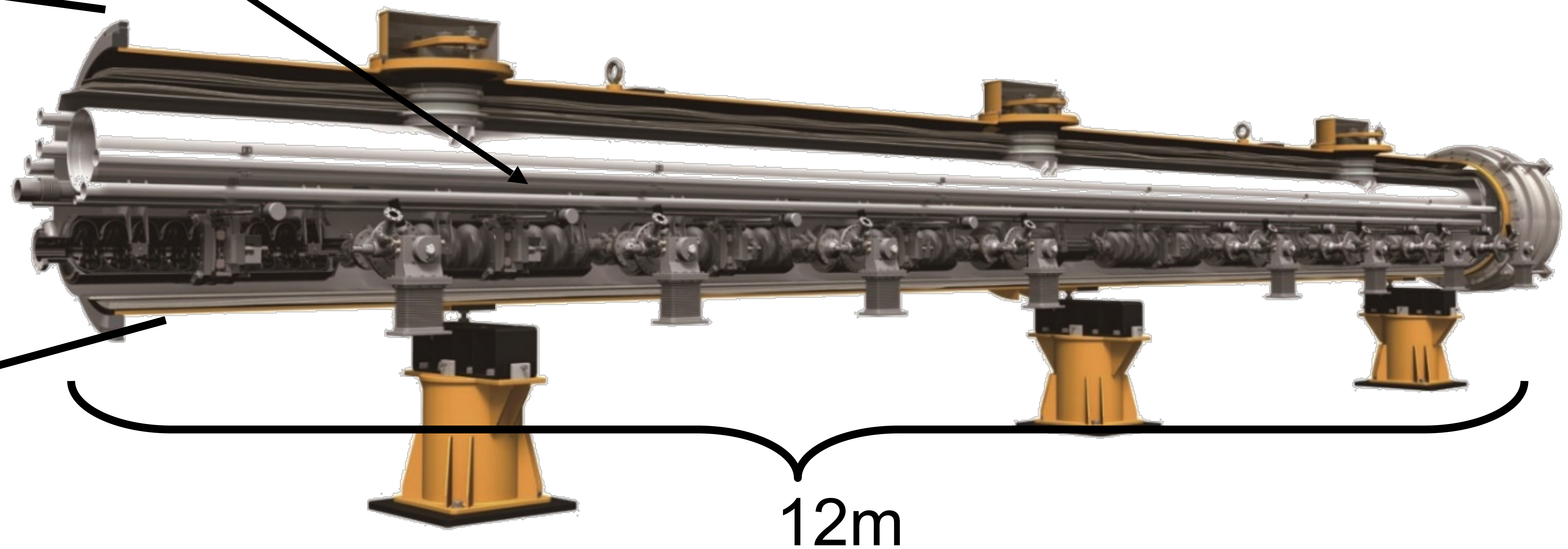


1m

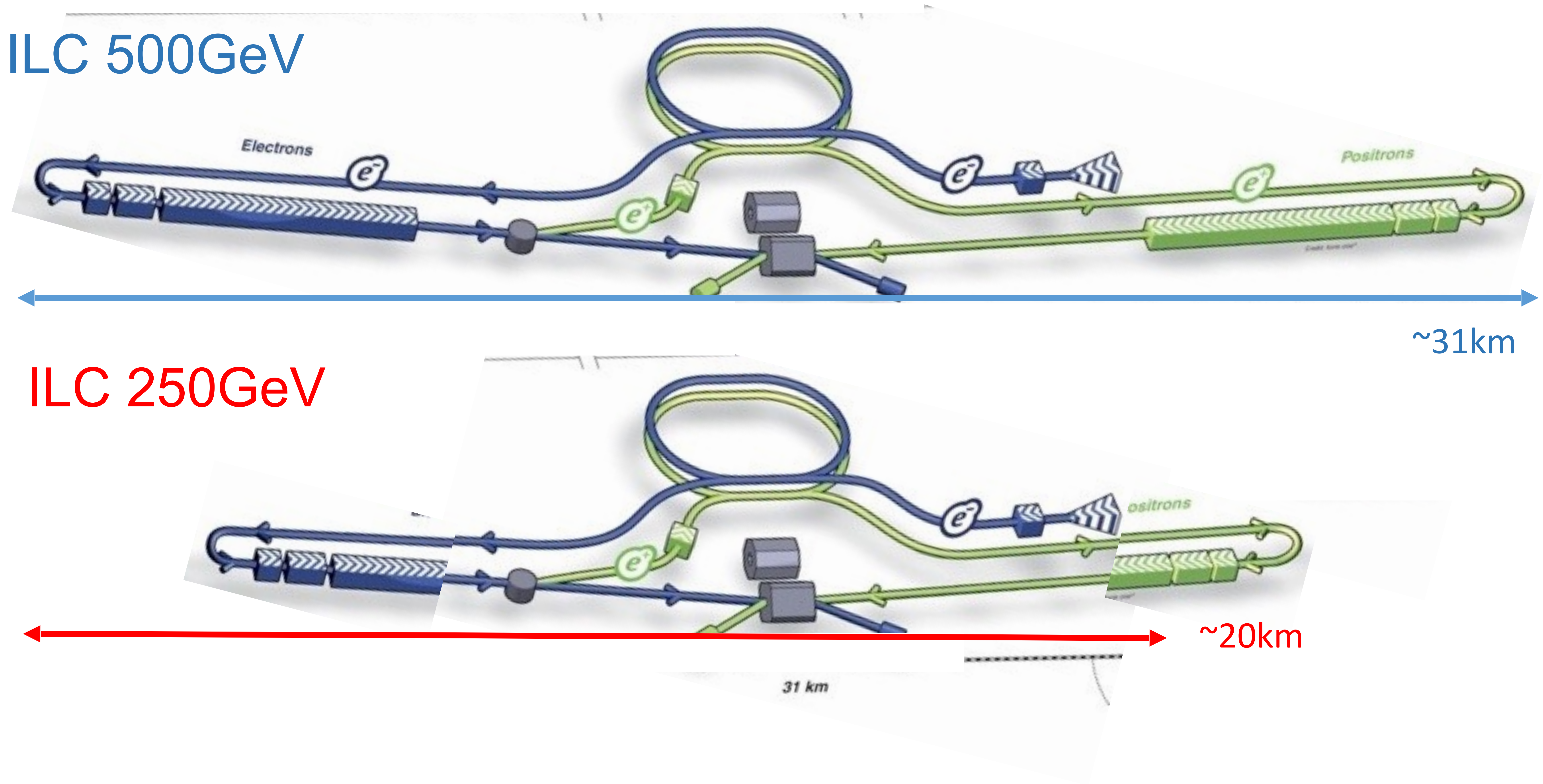
15,764

Cryomodules
1824





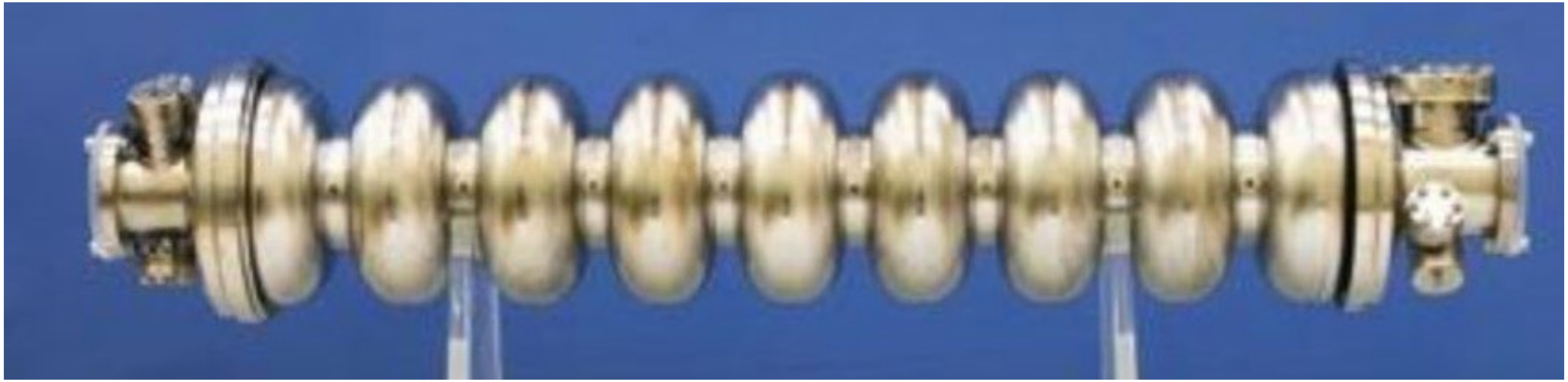
12m



- ***Dominant Cost: Superconducting RF Cavities***
- ***Initial cost reduction by reduced size***
- ***Maintain capacity to increase energy in future***

Cost reduction via technology improvement

- US-Japan Superconducting Nb Cavity Production
  - *Innovation of Nb (superconducting) material process: decrease in material cost*
  - *Innovative surface process for high efficiency cavity (N-infusion): decrease in number of cavities*



World wide Labs for SRF system

Shin Michizono @ LCWS2017

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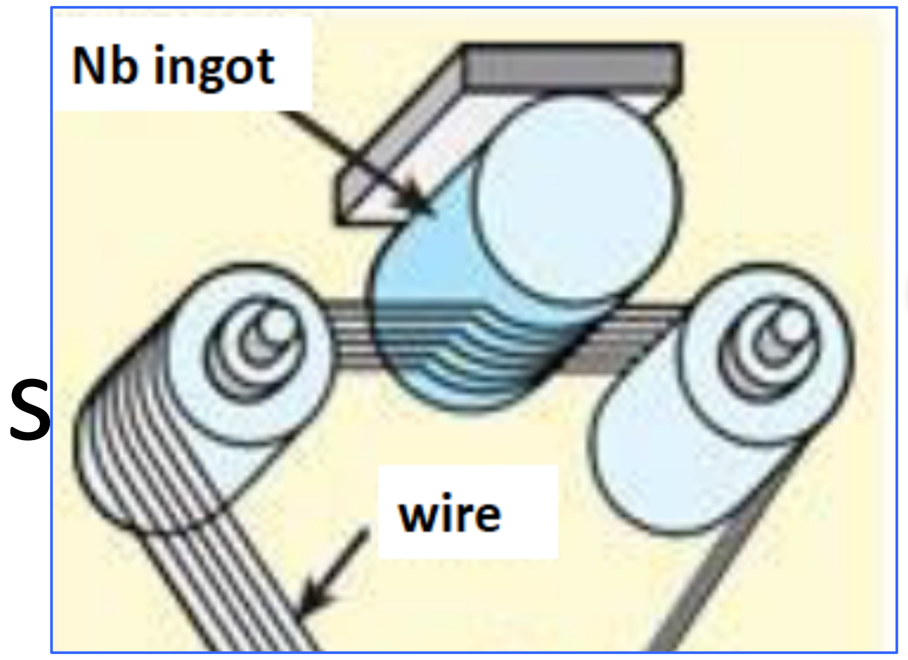
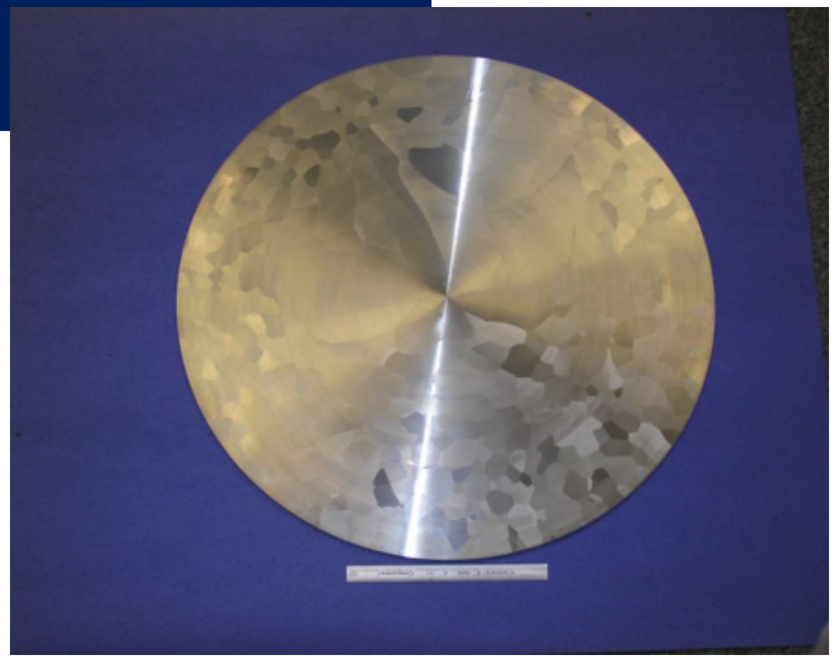
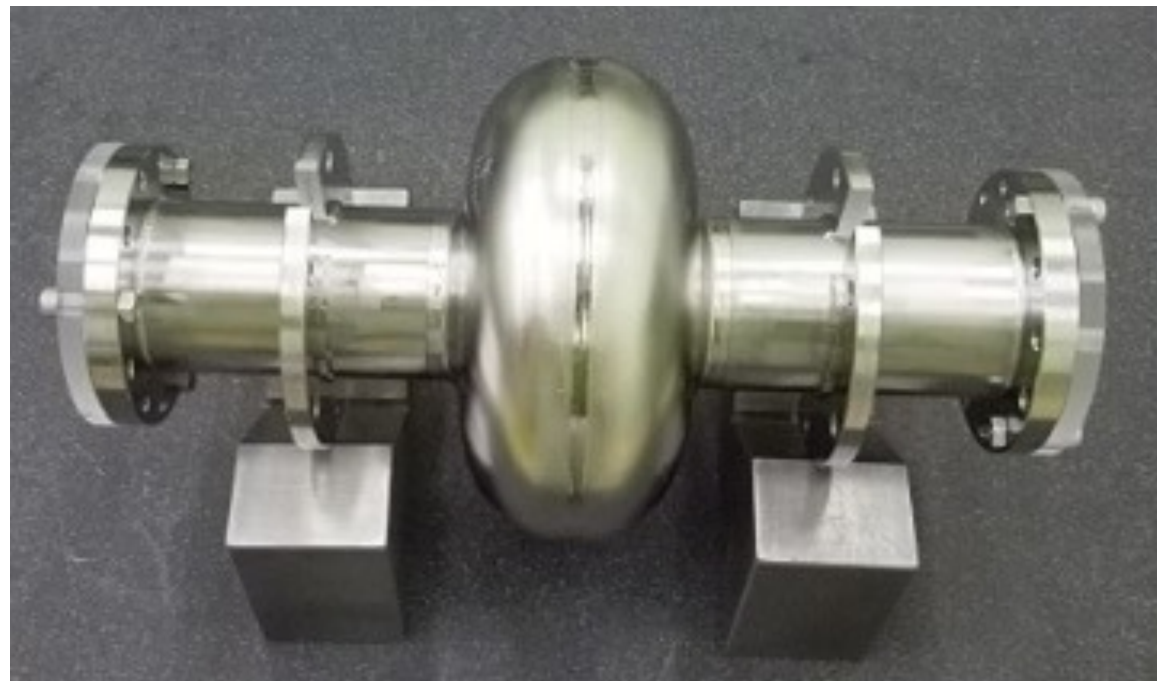
High Energy Accelerator Research Organization

Cost reduction in Nb material preparation

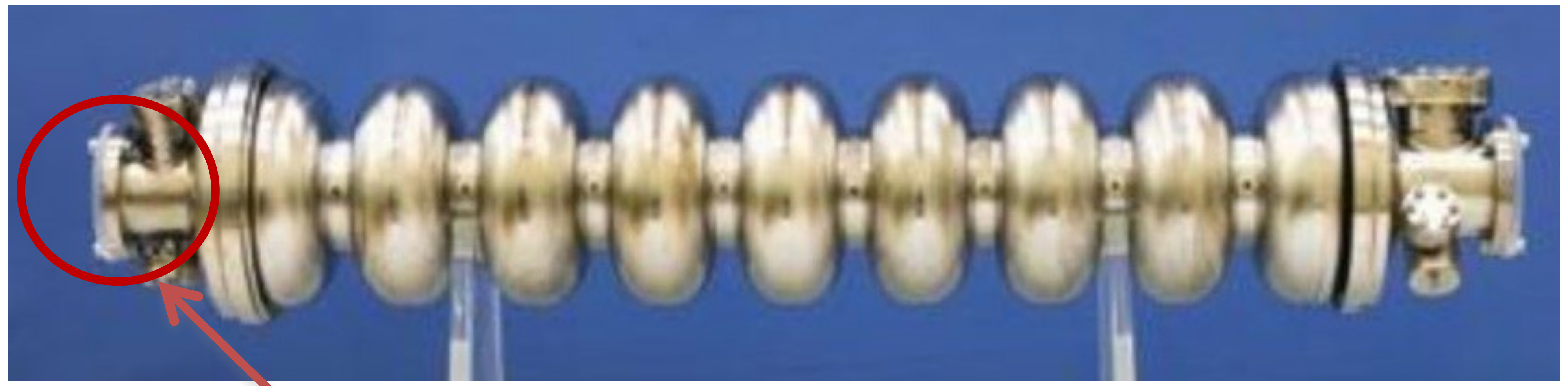
- Optimize the ingot purity with a lower residual resistivity ratio (RRR).
- Simplify the manufacturing method such as forging, rolling, slicing and tube forming.







	2016	2017	2018	2019
KEK Masashi Yamanaka	Feasibility study using 3-cell cavities (ongoing)		Preparing materials Manufacture 8x9-cell cavities	Evaluation (Vertical&Horizontal tests)



Medium or High RRR sheet for cells

Low RRR tube for stiffener and beam pipe

Quality of Nb for the end part will be optimized at this stage.

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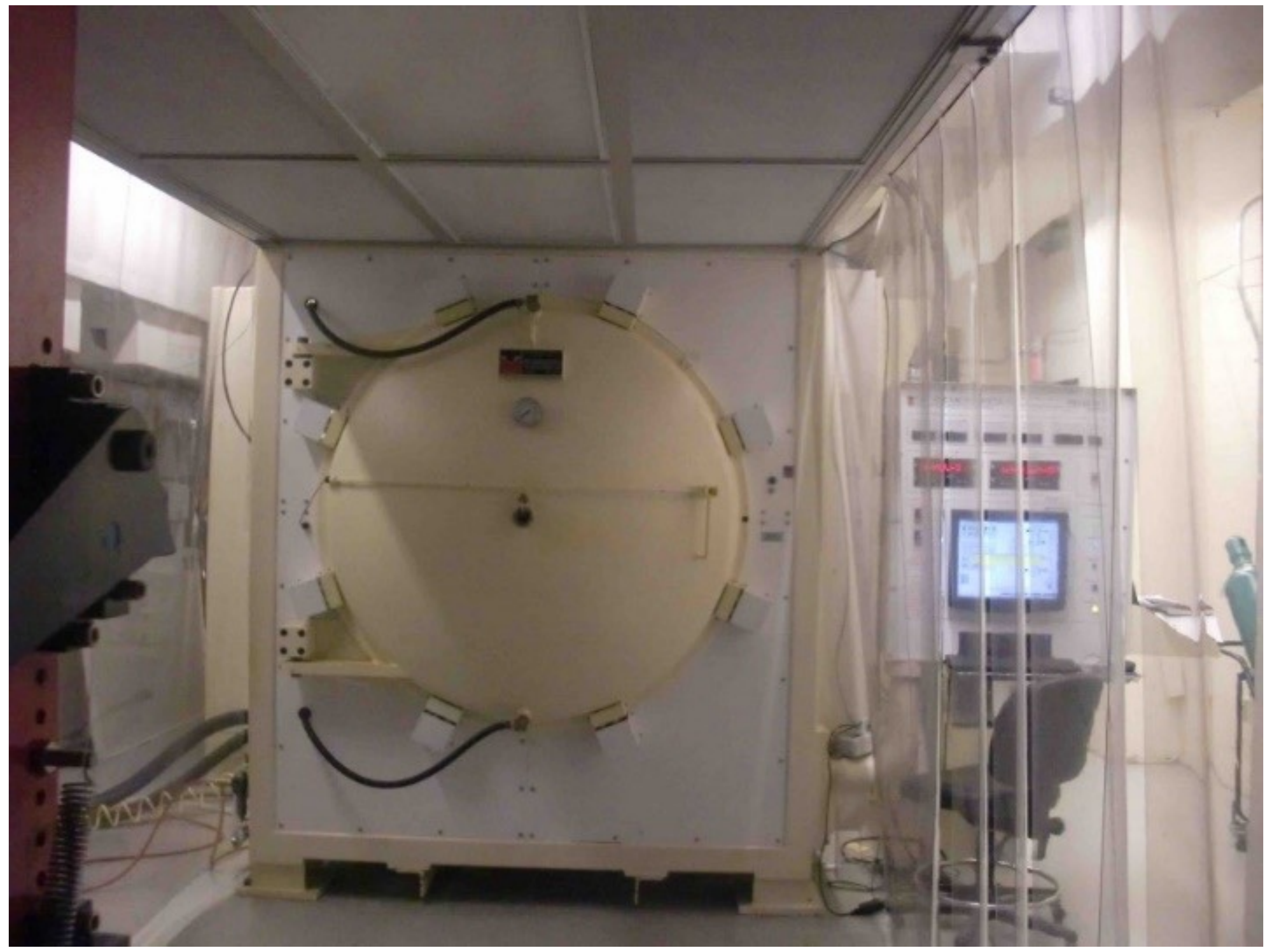
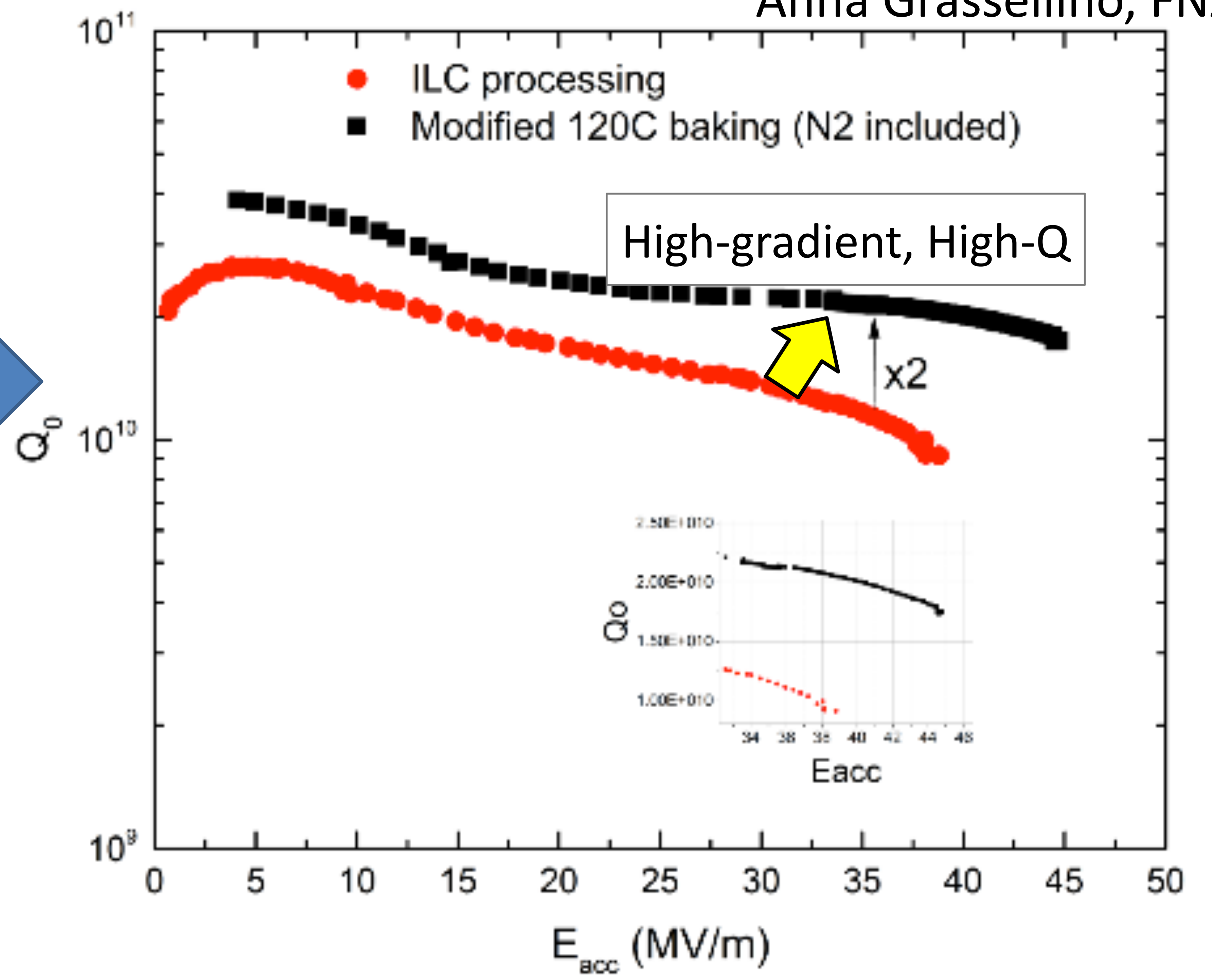
- Confirm reproducibility of the nitrogen infusion method to improve Q and field gradient of SC RF cavity.
- High statistics test of the yield by fabricating 8 9-cell cavities.



Anna Grassellino, FNAL



	2016	2017	2018	2019
KEK Hitoshi HAYANO	FNAL process Preparation of vacuum furnace	1 cell processing	Performance test 3-9cell performance 8 - 9cell cavities fabrication	Preparation for cryomodule Performance test

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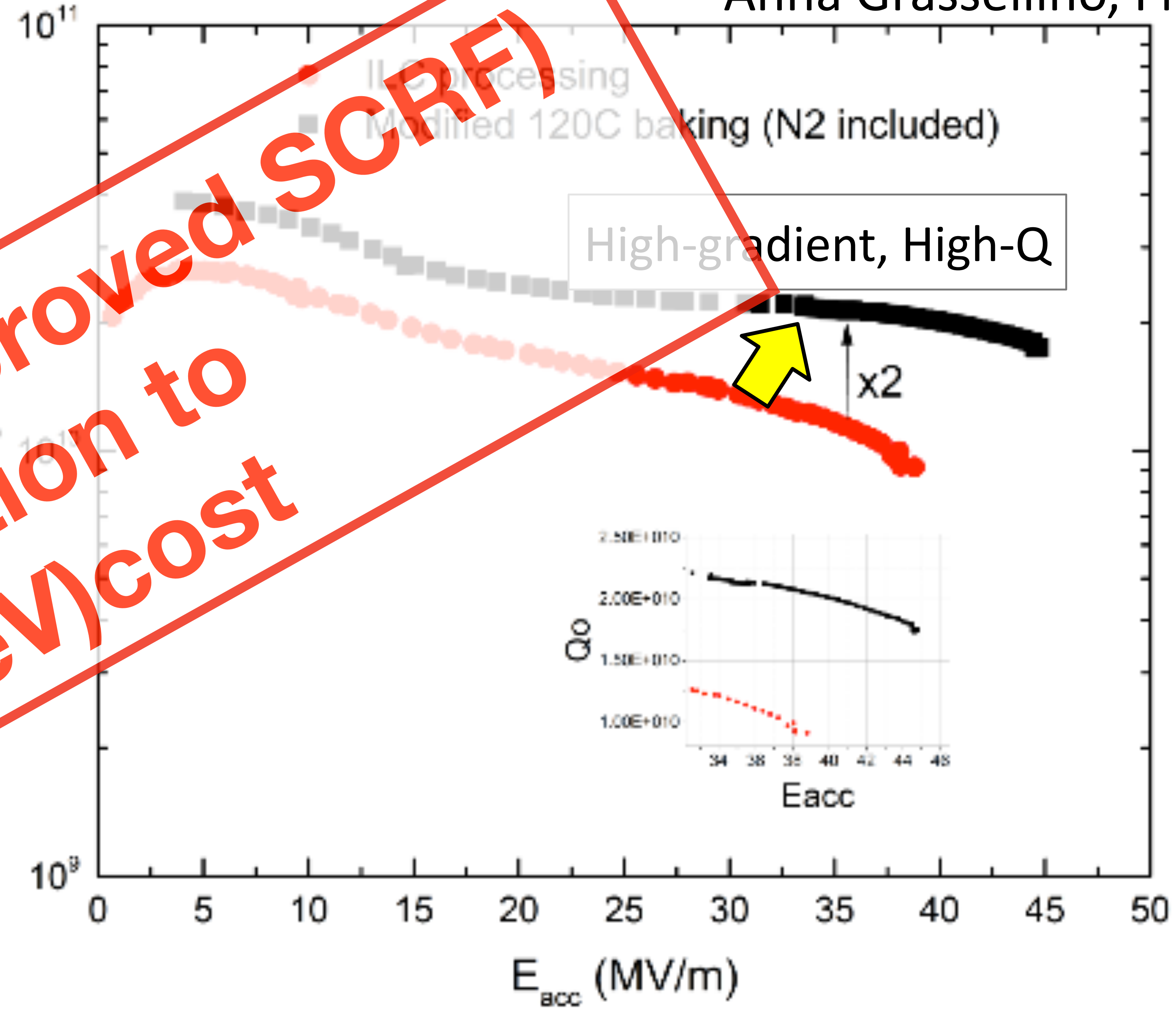
High Energy Accelerator Research Organization

- Confirm reproducibility of the nitrogen infusion method to improve Q and field gradient of SC RF cavity.
- High statistics test of the yield by fabricating 8 9-cell cavities.

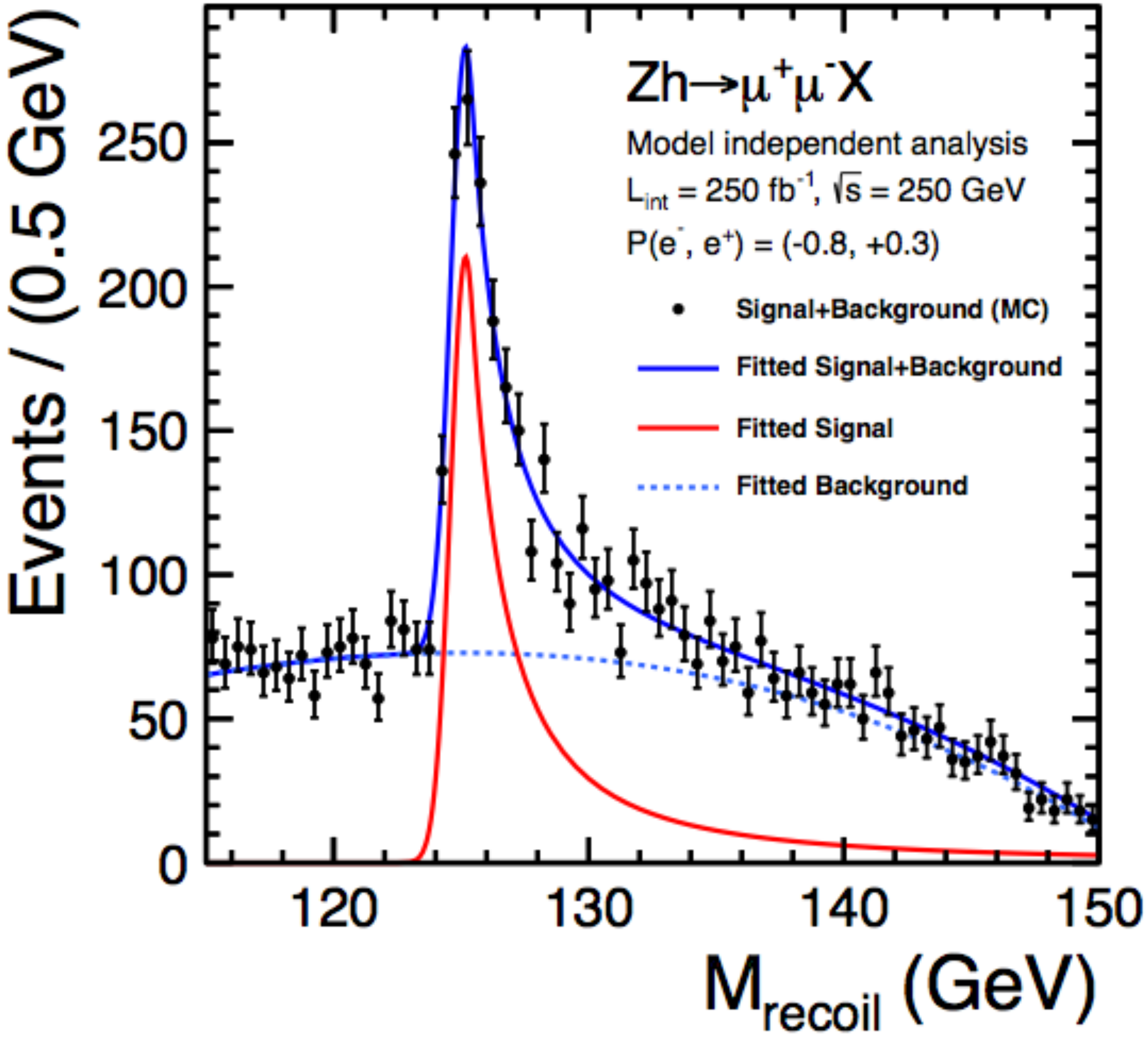
Anna Grassellino, FNAL

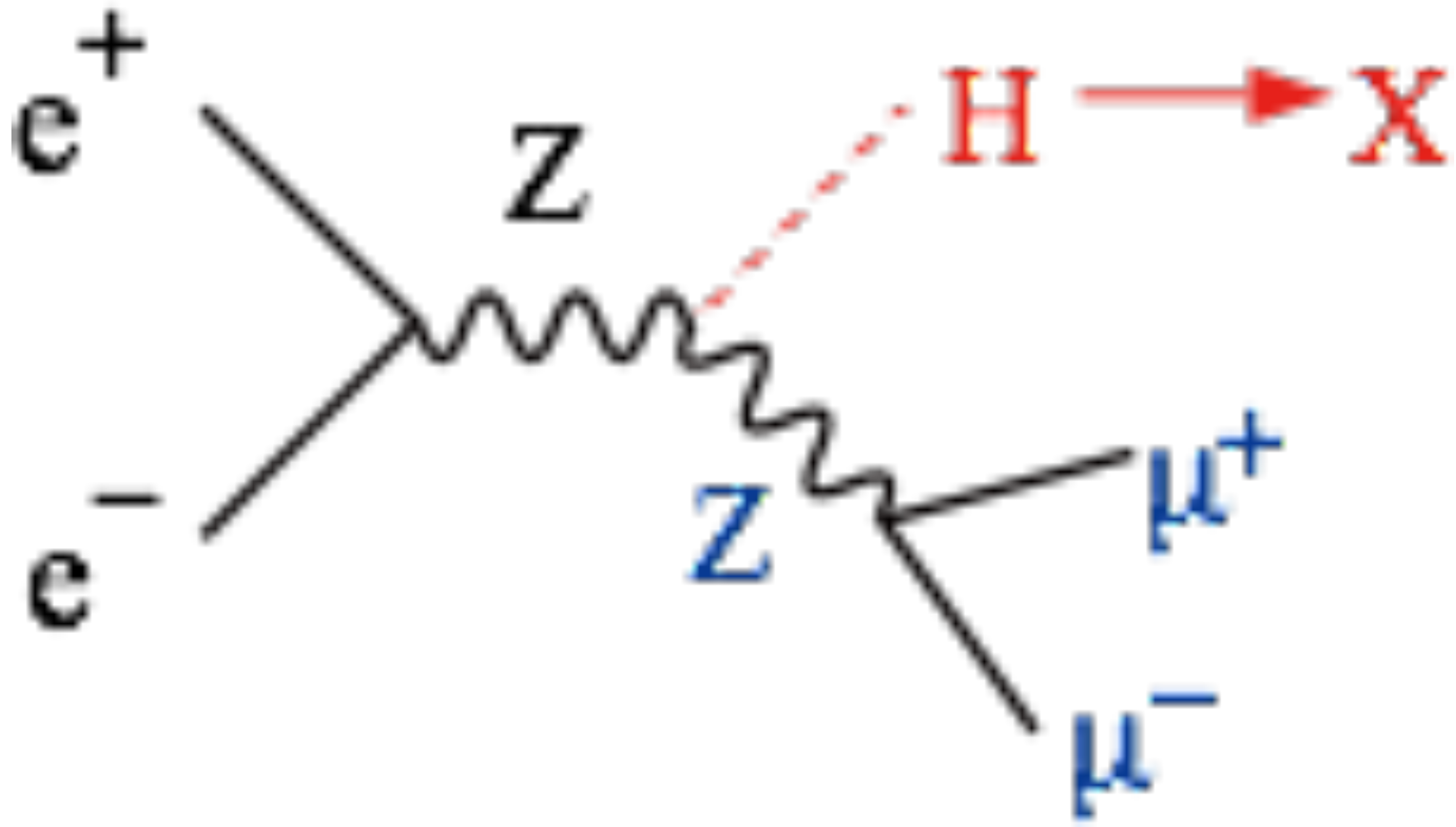


Combination (250GeV, Improved SCRF) leads to expected reduction to 60% of ILC-TDR (500GeV)cost

	2016	2017	2018	2019
KEK Hitoshi HAYANO	FNAL process; Preparation of vacuum furnace	1 cell processing; Preparation of vacuum furnace	Performance test; 3-9cell performance; 8 - 9cell cavities fabrication	Preparation for cryomodule; Performance test

“ILC250” - 250 GeV ILC
- the initial stage? -

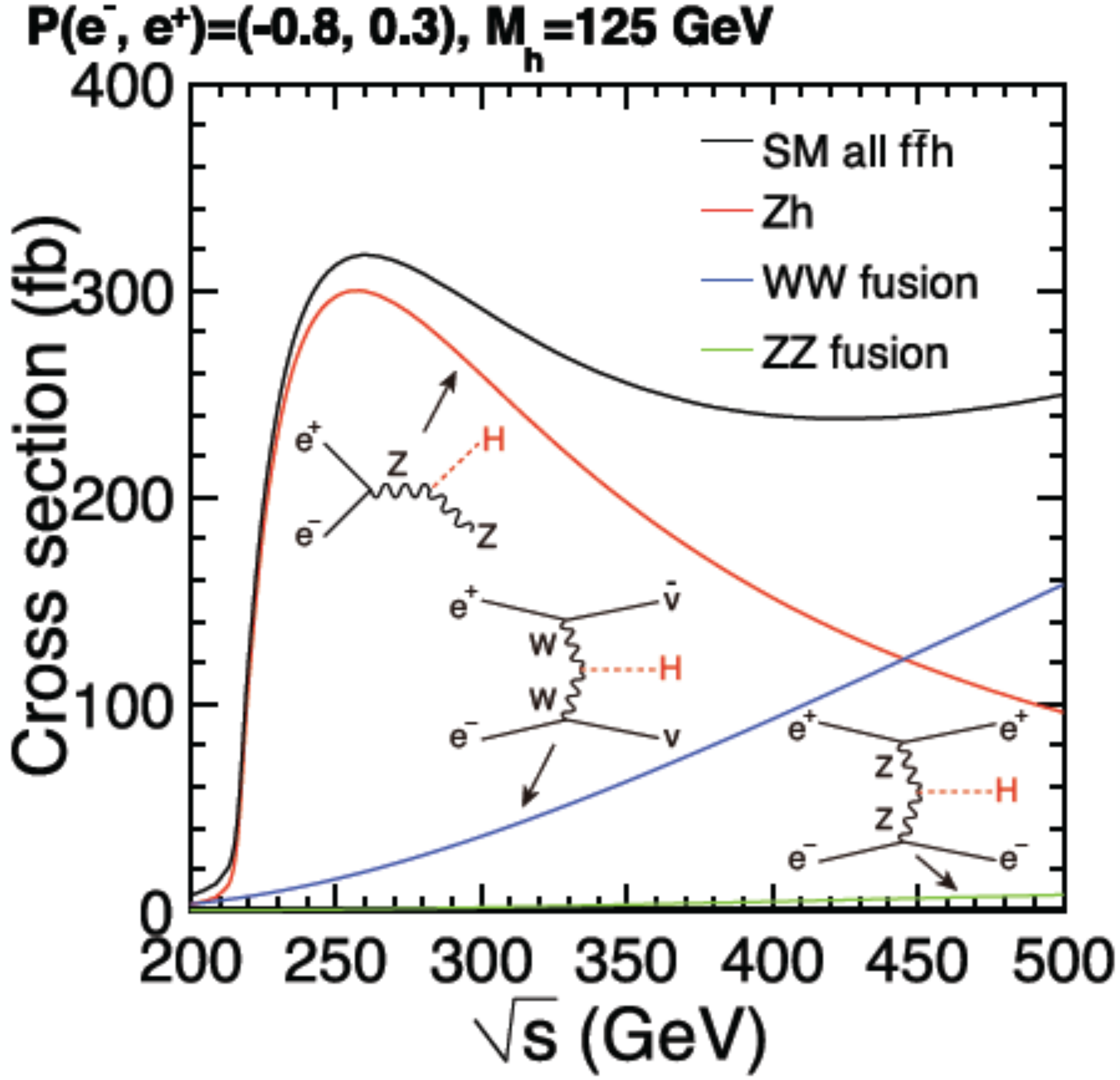


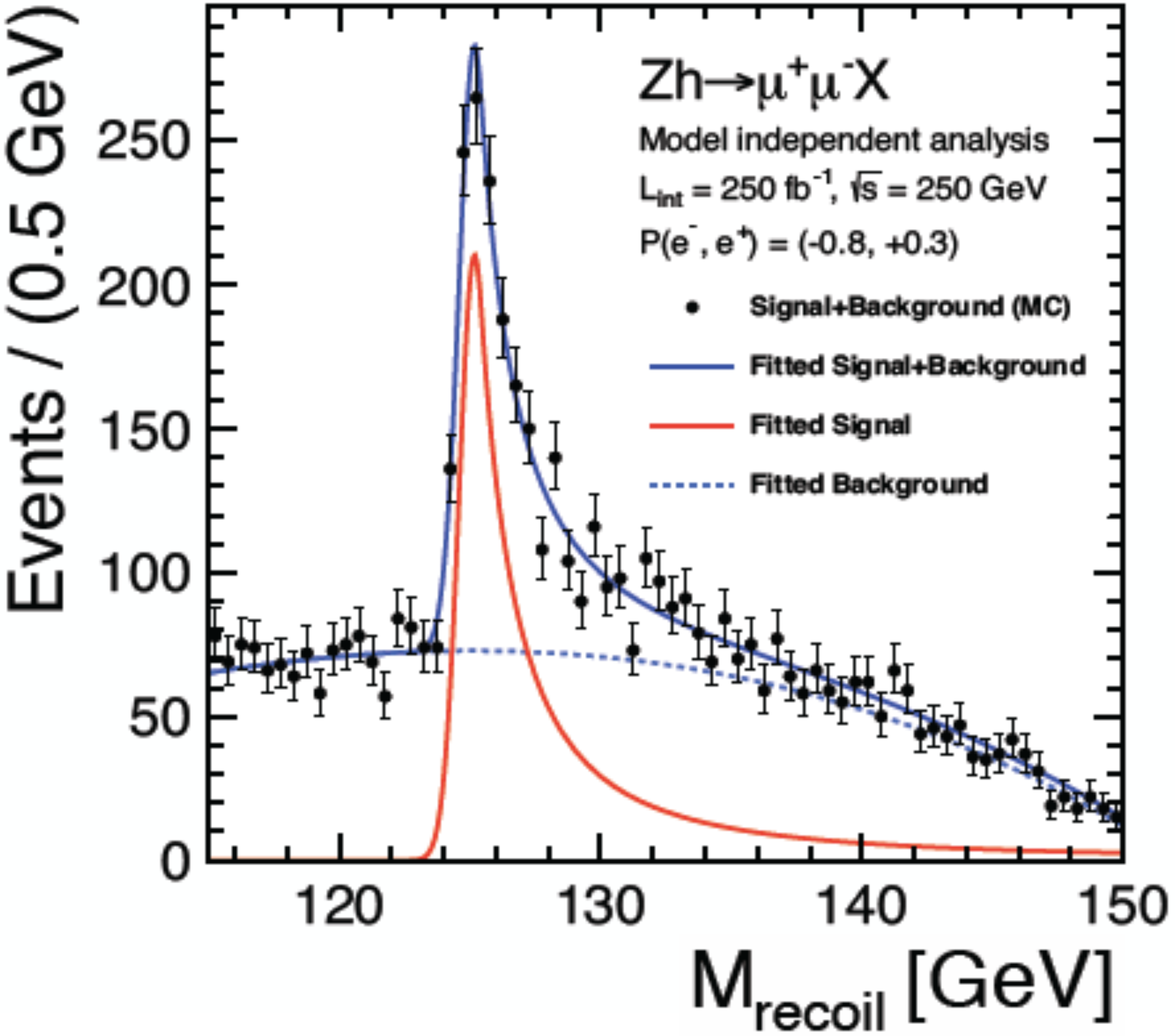


$$M_X^2 = \left(p_{CM} - (p_{\mu^+} + p_{\mu^-})\right)^2$$

Can detect the Higgs without looking at it!

.. much can be done at 250GeV





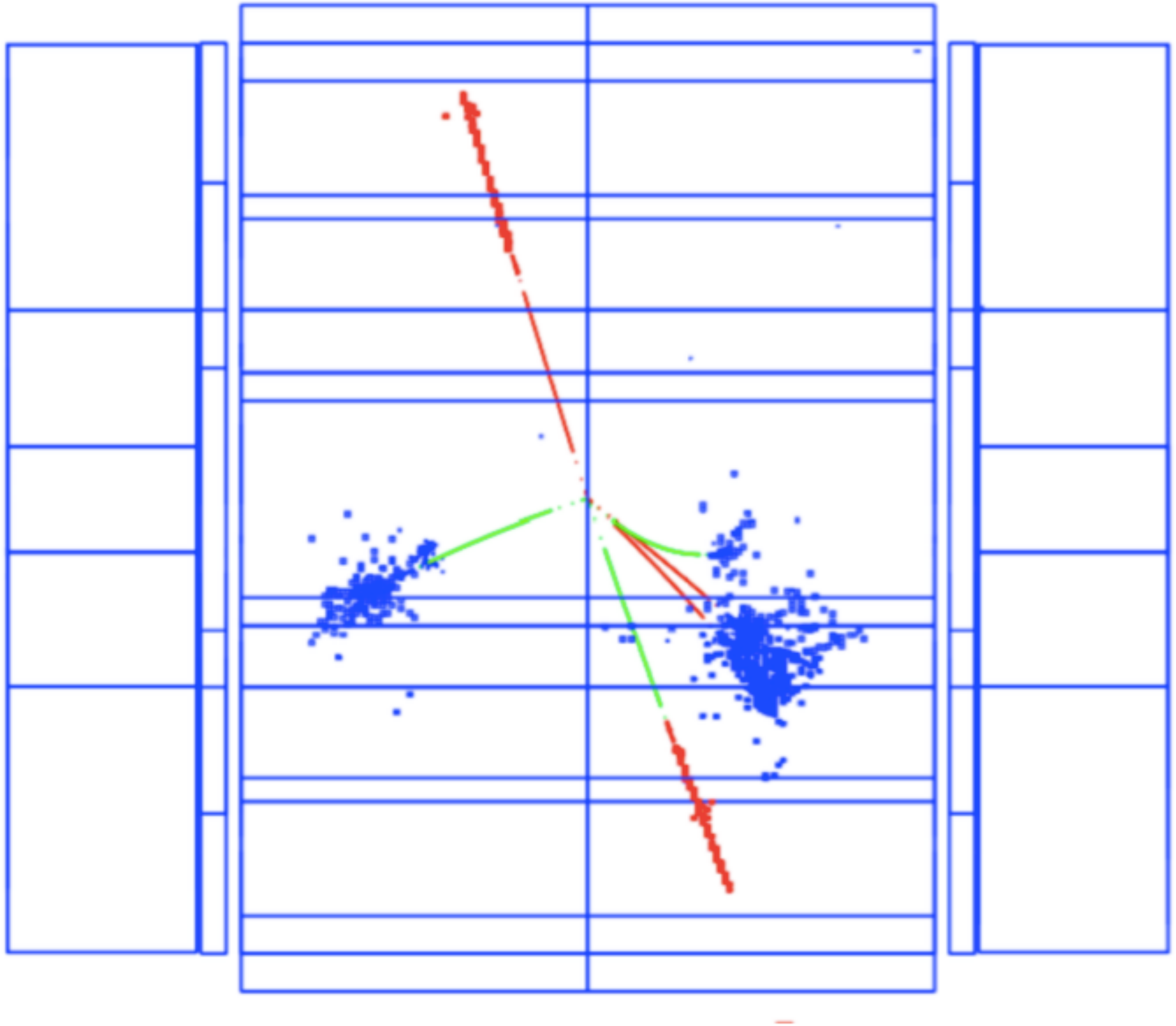
Higgs events are readily isolated from background.
All standard Higgs decay modes are visible.

Measurement accuracies are such that 1% coupling measurements are feasible.

The absolute cross section for $e^+e^- \to Zh$ can be measured.

At 250 GeV, to first approximation, any Z boson with $E_{lab} = 110$ GeV is recoiling against a Higgs boson.

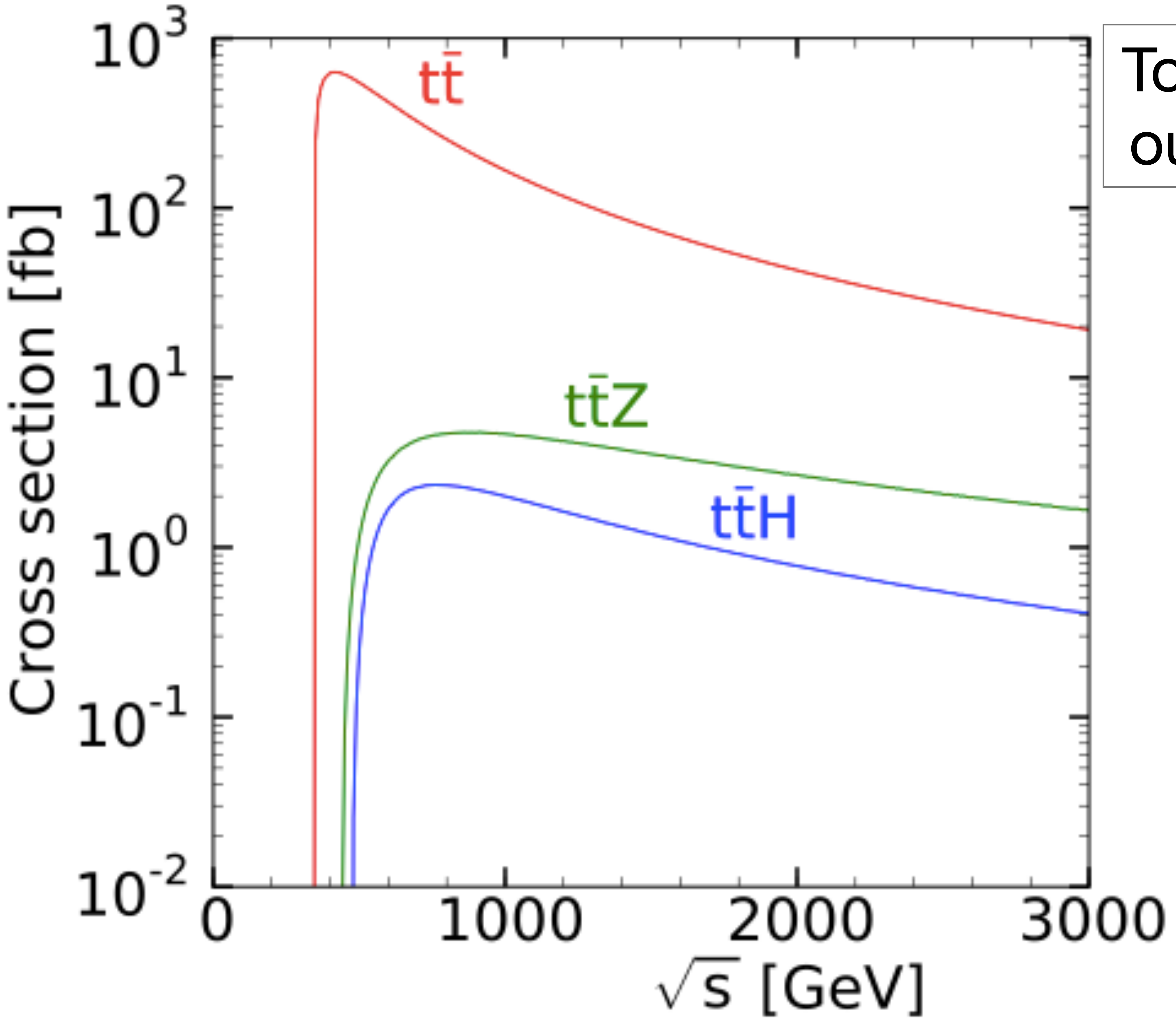
Physics Case for the 250 GeV Stage of the ILC arXiv:1710.07621
also, M. Peskin, ICFA Seminar, Nov 2017,



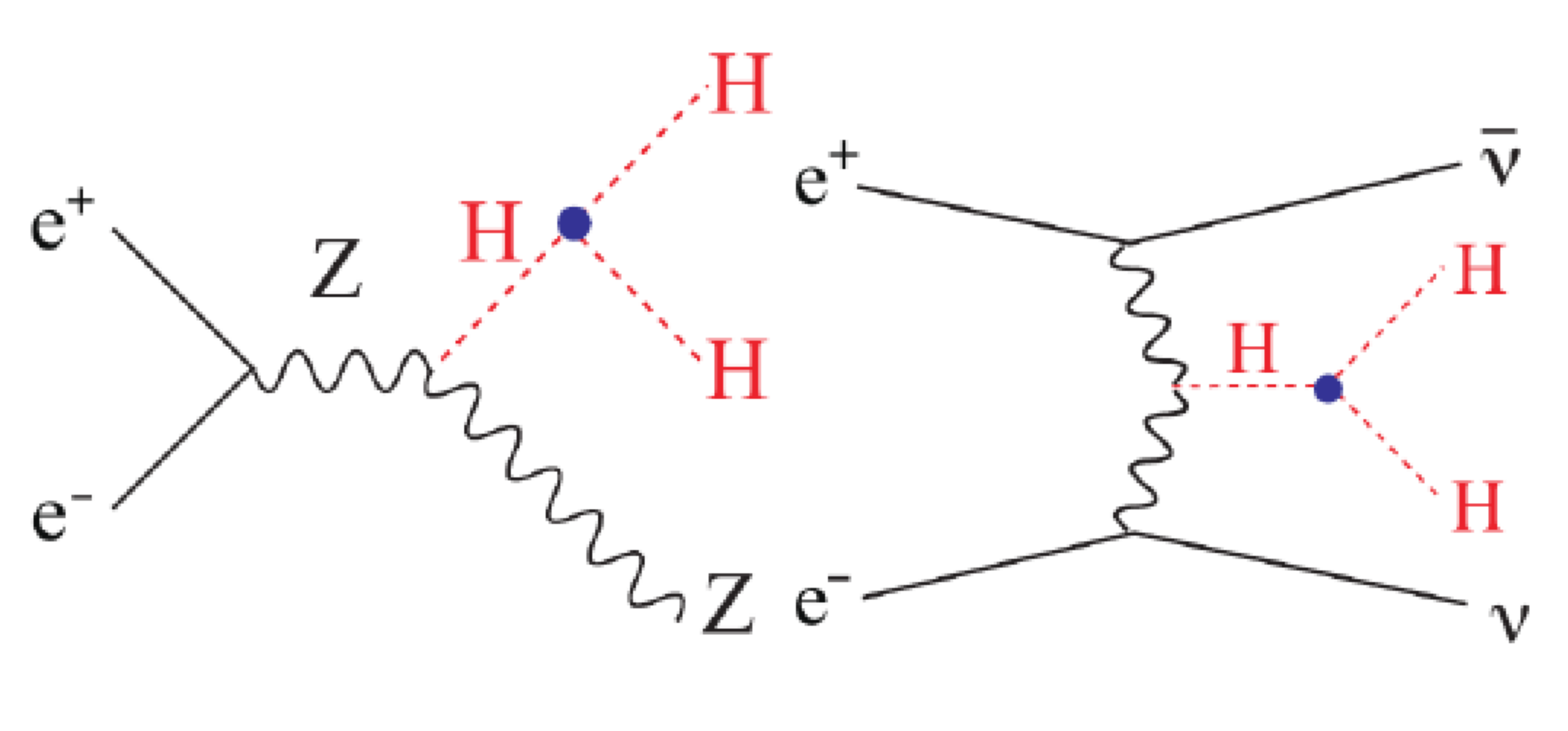
(thanks to Manqi Ruan)

M. Peskin, ICFA Seminar, Nov 2017,

… but with *initial* trade-off

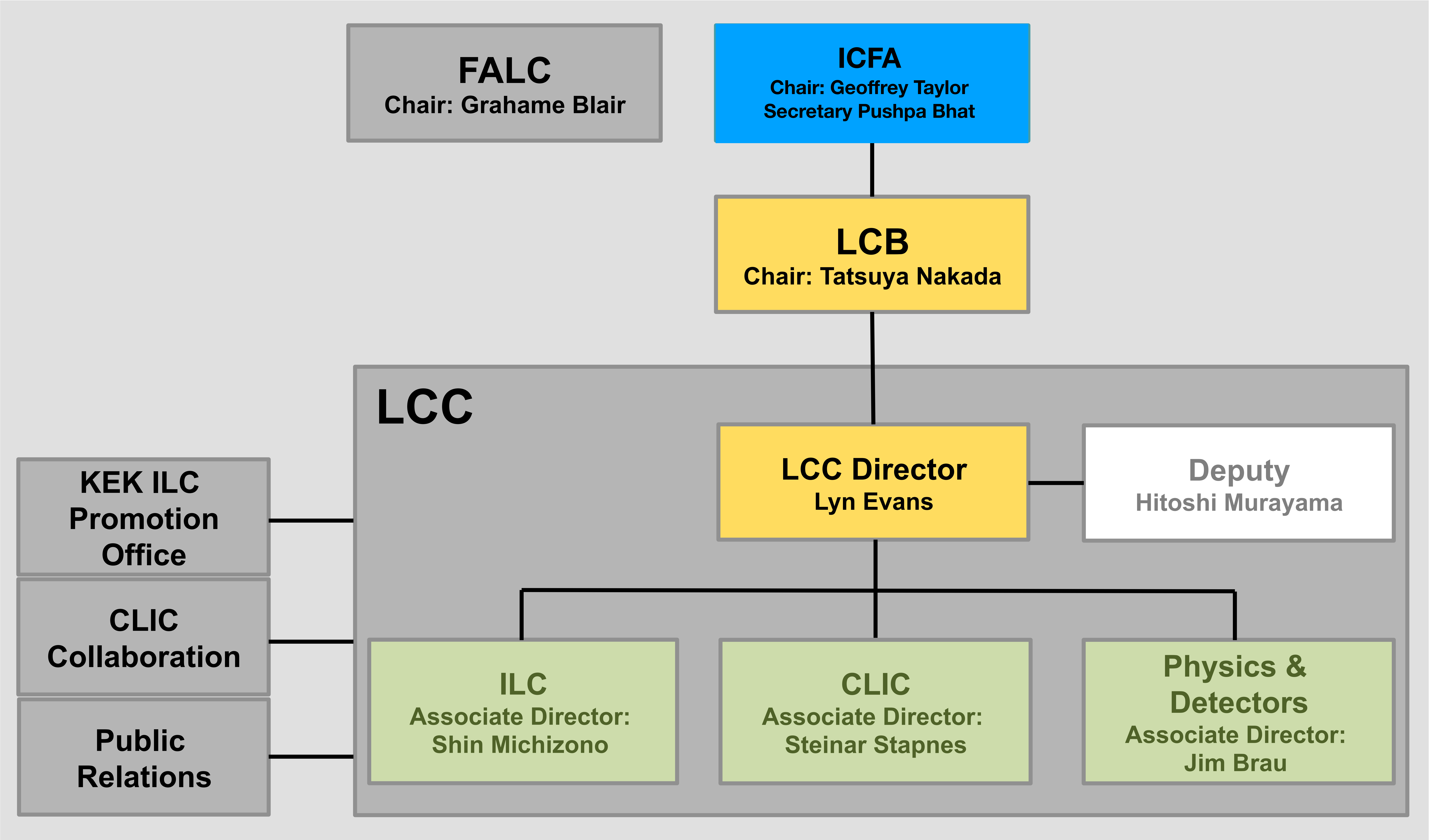


Top physics, including H-t coupling, out of reach (350-500 GeV)



Higher energies required for direct Higgs self-coupling

ICFA LC Organisation Structure (from 2016)



250 GeV ILC as a Higgs factory

- In LCWS 2016, Morioka, November 2016 - consider staging ILC
- LCC studied physics at 250 GeV ILC and technical and cost issues of the staging scenario, (arXiv:1710.07621 [hep-ex])
- In July 2017, the Japanese HEP community (JAHEP) released a statement :"Scientific Significance of ILC and Proposal of its Early Realization in light of the Outcomes of LHC Run 2 " based on its subcommittee's report on the scientific significance of the 250GeV ILC (http://www.jahep.org/files/JAHEP-ILCstatement-170816-EN.pdf)
- LCB and ICFA released their conclusions and statement supporting 250 GeV ILC.

"ICFA thus supports the conclusions of the Linear Collider Board (LCB) in their report presented at this meeting and very strongly encourages Japan to realize the ILC in a timely fashion as a Higgs boson factory with a center-of-mass energy of 250 GeV as an international project, led by Japanese initiative."

ICFA STATEMENT ON THE ILC OPERATING AT 250 GEV AS A HIGGS BOSON FACTORY

The discovery of a Higgs boson in 2012 at the Large Hadron Collider (LHC) at CERN is one of the most significant recent breakthroughs in science and marks a major step forward in fundamental physics. Precision studies of the Higgs boson will further deepen our understanding of the most fundamental laws of matter and its interactions.

The International Linear Collider (ILC) operating at 250 GeV center-of-mass energy will provide excellent science from precision studies of the Higgs boson. Therefore, ICFA considers the ILC a key science project complementary to the LHC and its upgrade.

ICFA welcomes the efforts by the Linear Collider Collaboration on cost reductions for the ILC, which indicate that up to 40% cost reduction relative to the 2013 Technical Design Report (500 GeV ILC) is possible for a 250 GeV collider.

ICFA emphasises the extendibility of the ILC to higher energies and notes that there is large discovery potential with important additional measurements accessible at energies beyond 250 GeV.

ICFA thus supports the conclusions of the Linear Collider Board (LCB) in their report presented at this meeting and very strongly encourages Japan to realize the ILC in a timely fashion as a Higgs boson factory with a center-of-mass energy of 250 GeV as an international project[1] , led by Japanese initiative.

1 In the LCB report the European XFEL and FAIR are mentioned as recent examples for international projects.

Ottawa, November 2017

MEXT ILC Advisory Panel after the ICFA statement

The 8th Meeting on December 5, 2017

- Report on the revised plan of the ILC by Tatsuya Nakada, LCB Chair
- Report on the status of the LHC experiment by Eckhard Elsen (CERN)
- The panel decides to reconvene the Physics and TDR validation WGS to validate physics and technical/cost conclusions of the 250 GeV ILC plan.
- The activities of these two working groups are expected to be concluded by May, 2018. Reporting to ILC Advisory Panel in MEXT
- Science Council of Japan (SCJ) will assess the report. Favourable outcome puts Japanese decision on ILC ~end of 2018.
- In parallel, discussions between the Japanese Government and major foreign partners.
- Serious pressure for decision for input to Update of the European Strategy for Particle Physics

Circular Electron-Positron Collider (China)

- CEPC

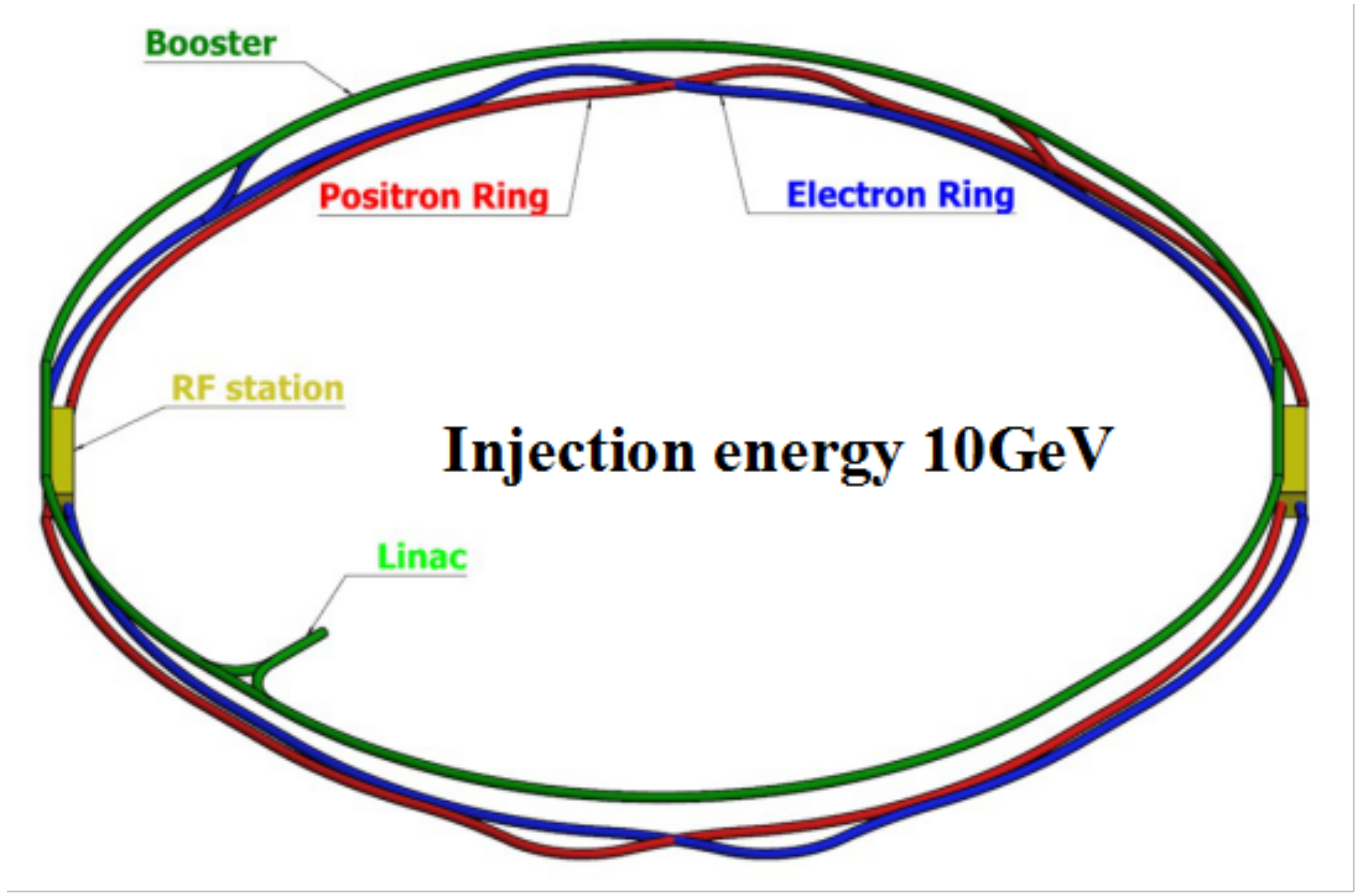
  (and SppC beyond)

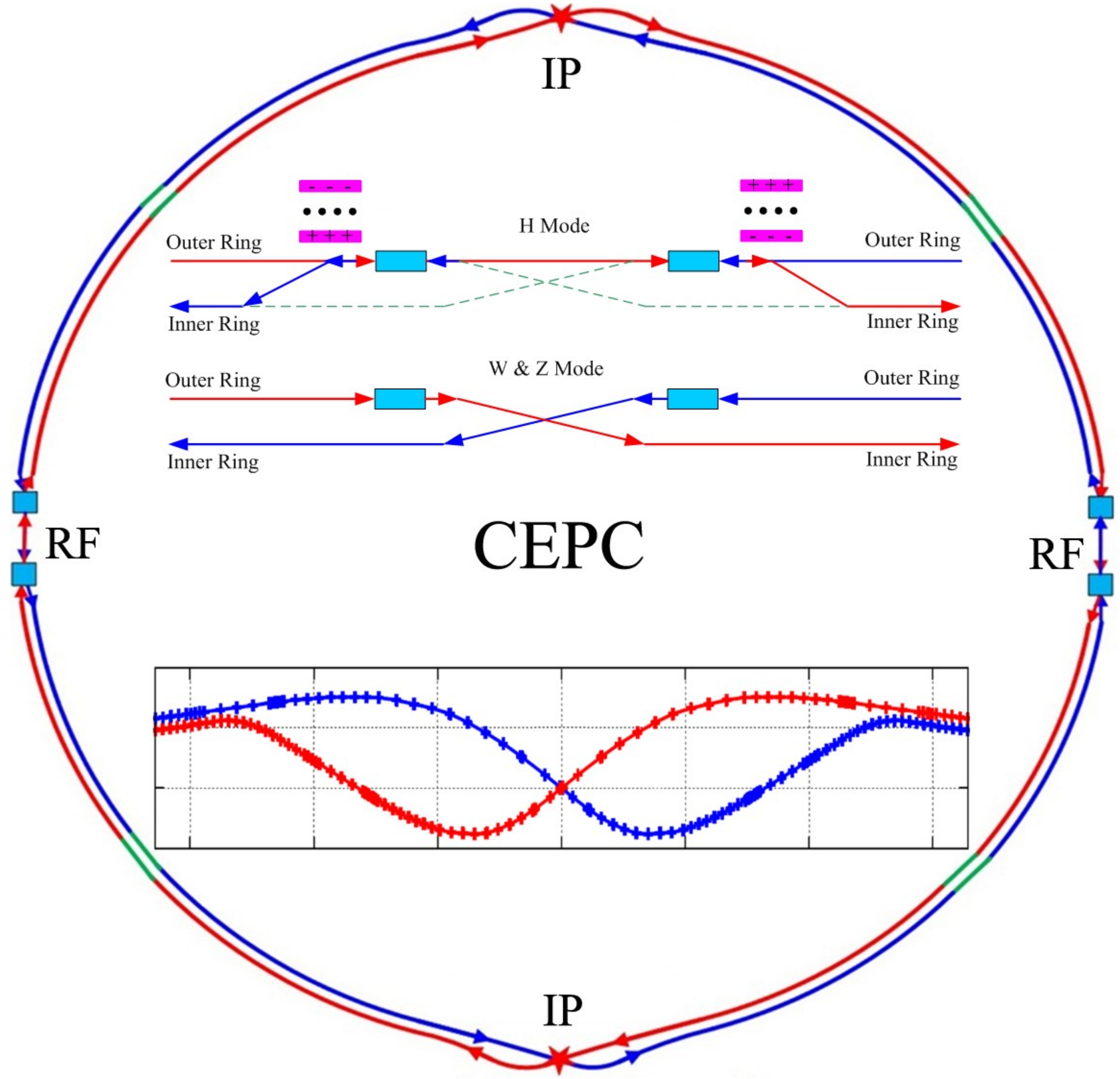
Physics Goals of CEPC-SppC

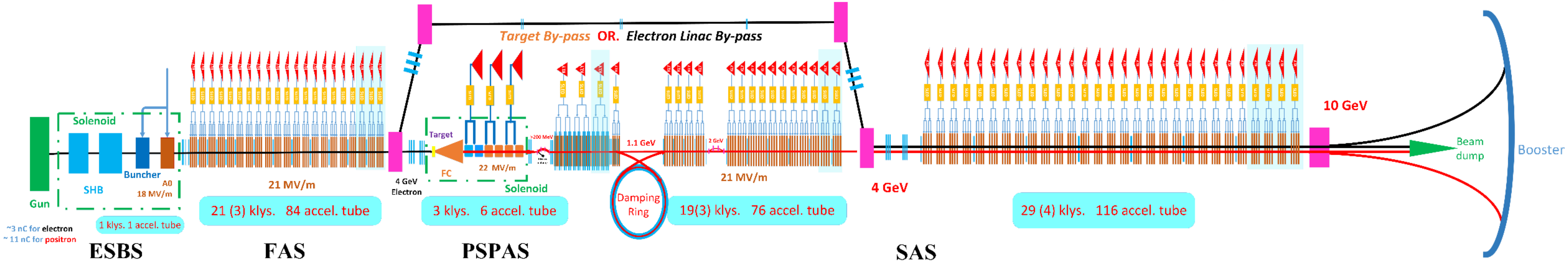
- **Electron-positron collider (90, 160, 250 GeV)**
  - **Higgs Factory（10^6 Higgs）:**
    - Precision study of Higgs(m_H, J^{PC}, couplings), Similar & complementary to ILC
    - Looking for hints of new physics
  - **Z & W factory（10^{10} Z^0）:**
    - precision test of SM
    - Rare decays ?
  - **Flavor factory: b, c, τ and QCD studies**
- **Proton-proton collider(~100 TeV)**
  - **Directly search for new physics beyond SM**
  - **Precision test of SM**
    - e.g., h^3 & h^4 couplings

Precision measurement + searches:
Complementary with each other !

CEPC CDR Layout



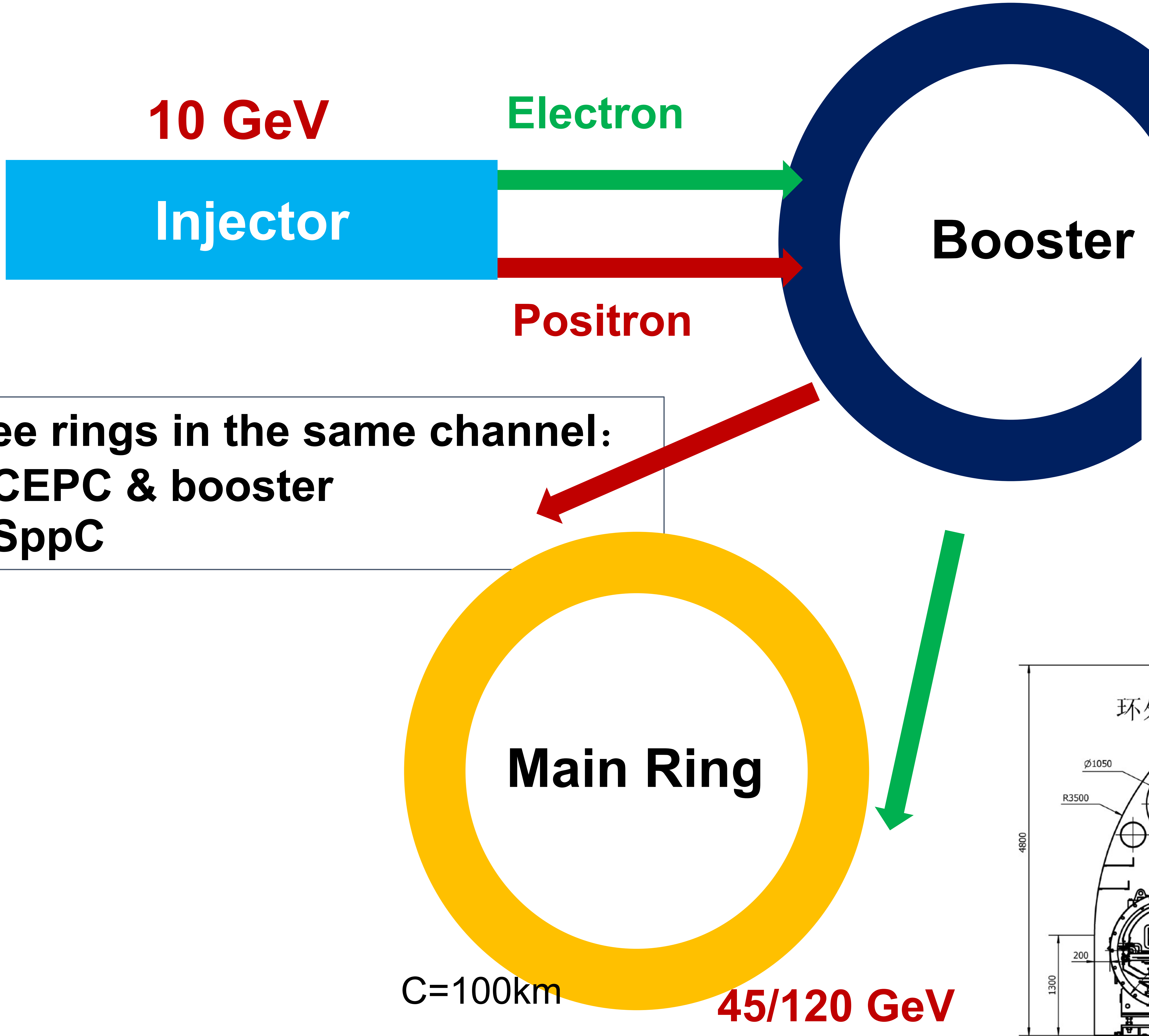




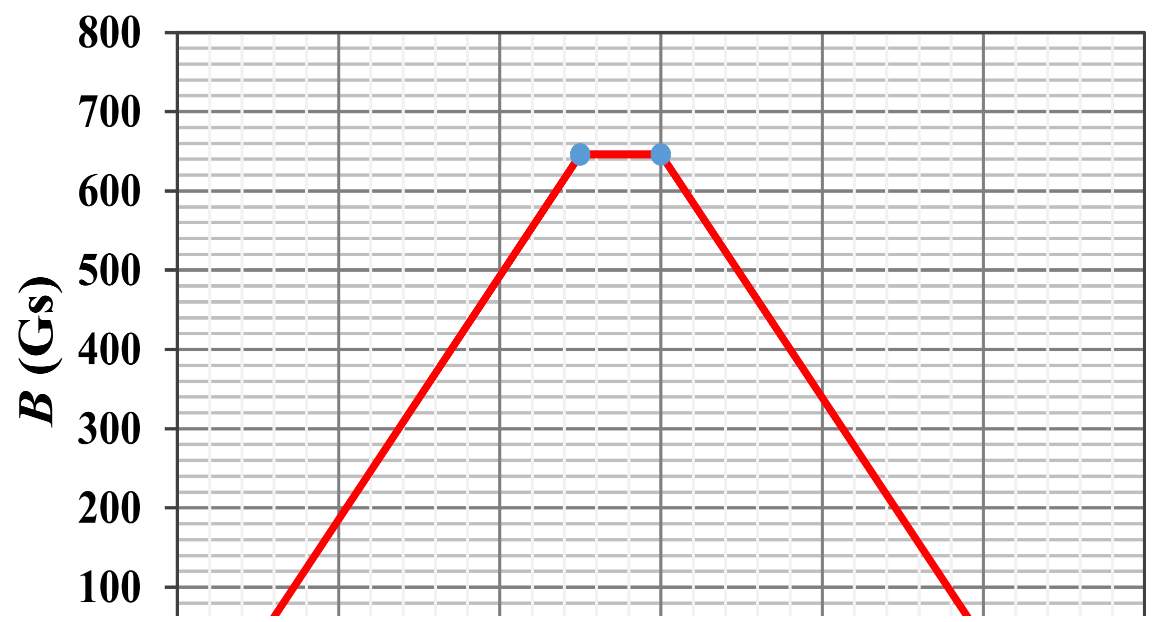
J. Gao IHEP, Beijing

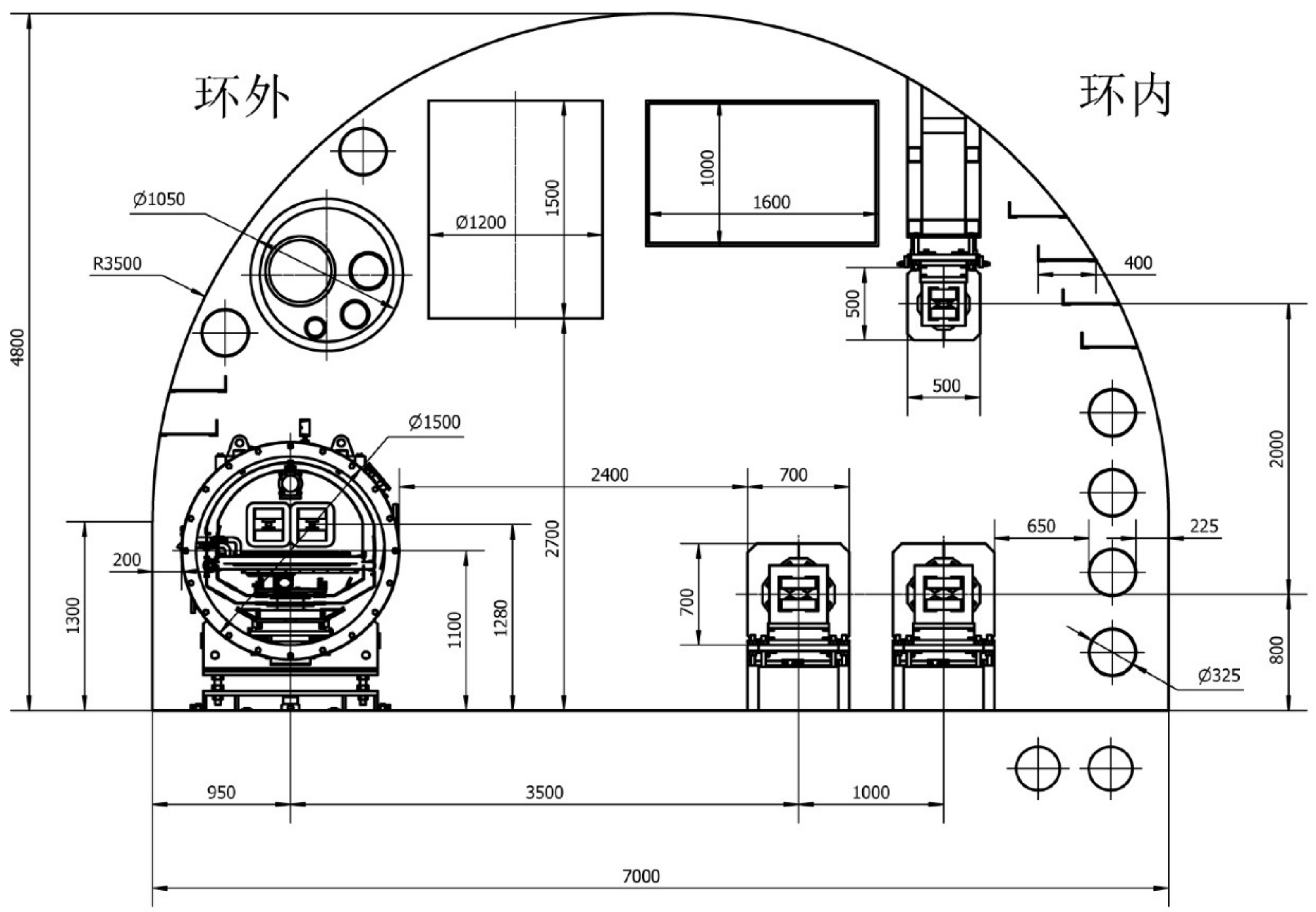
CEPC CDR Accelerator Chain

J. Gao IHEP, Beijing



Three rings in the same channel：
- ➢ CEPC & booster
- ➢ SppC





CEPC Design – Higgs Parameters

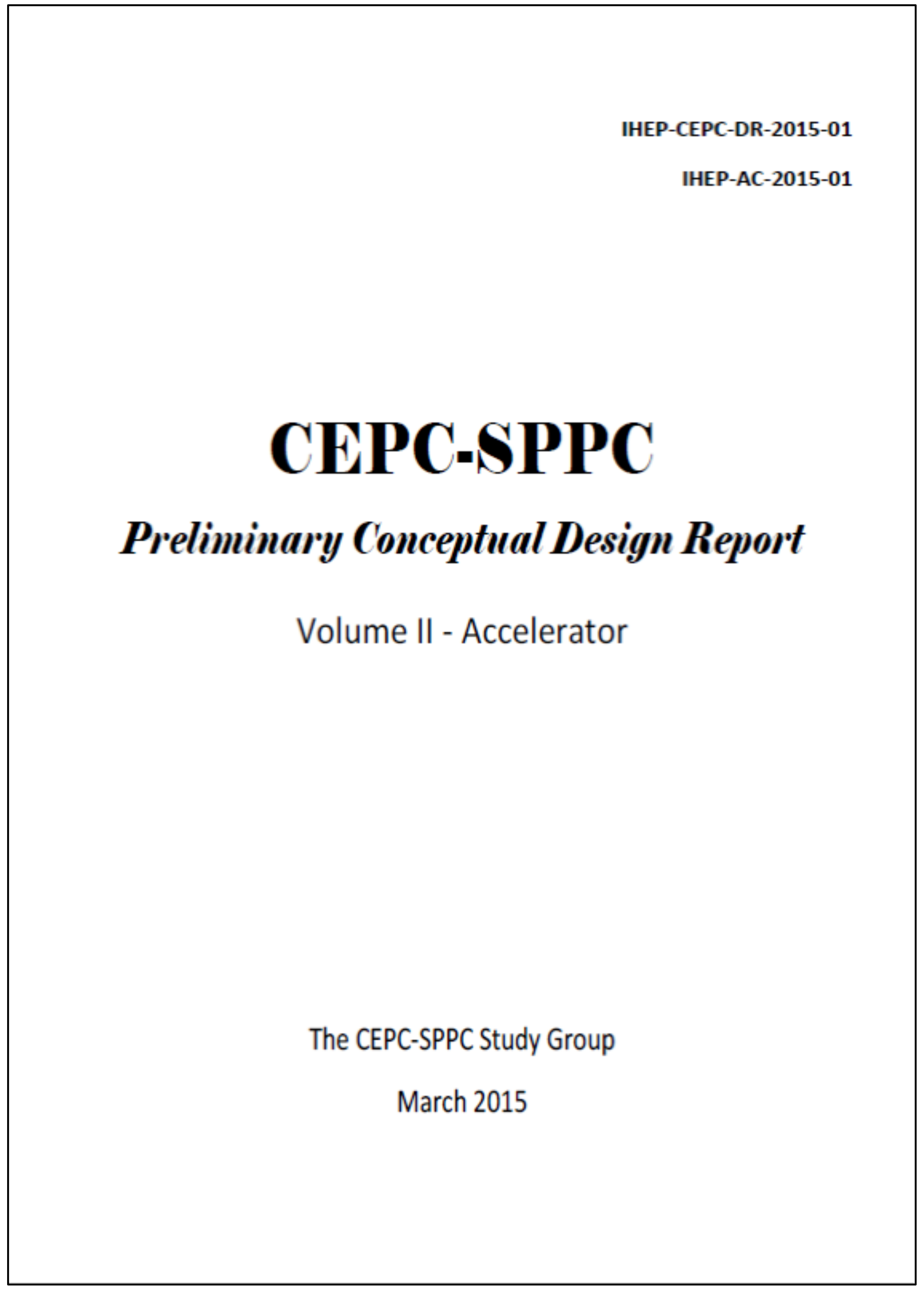
Parameter	Design Goal
Particles	e+, e-
Center of mass energy	2*120 GeV
Luminosity (peak)	>2*10^34/cm^2s
No. of IPs	2

CEPC Design – Z-pole Parameters

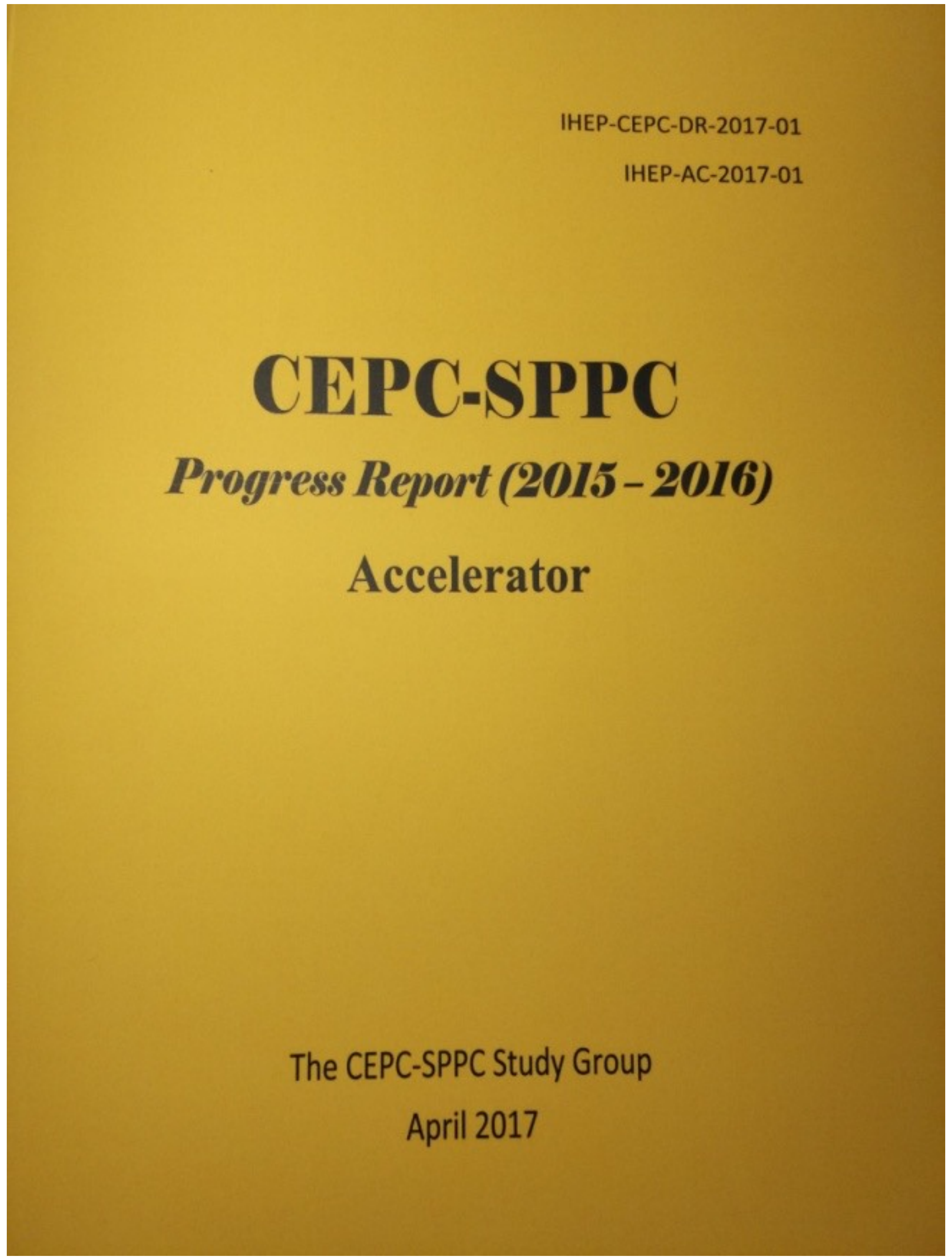
Parameter	Design Goal
Particles	e+, e-
Center of mass energy	2*45.5 GeV
Integrated luminosity (peak)	>10^34/cm^2s
No. of IPs	2
Polarization	to be considered in the second round of design

CEPC-SppC from Pre-CDR towards CDR

http://cepc.ihep.ac.cn

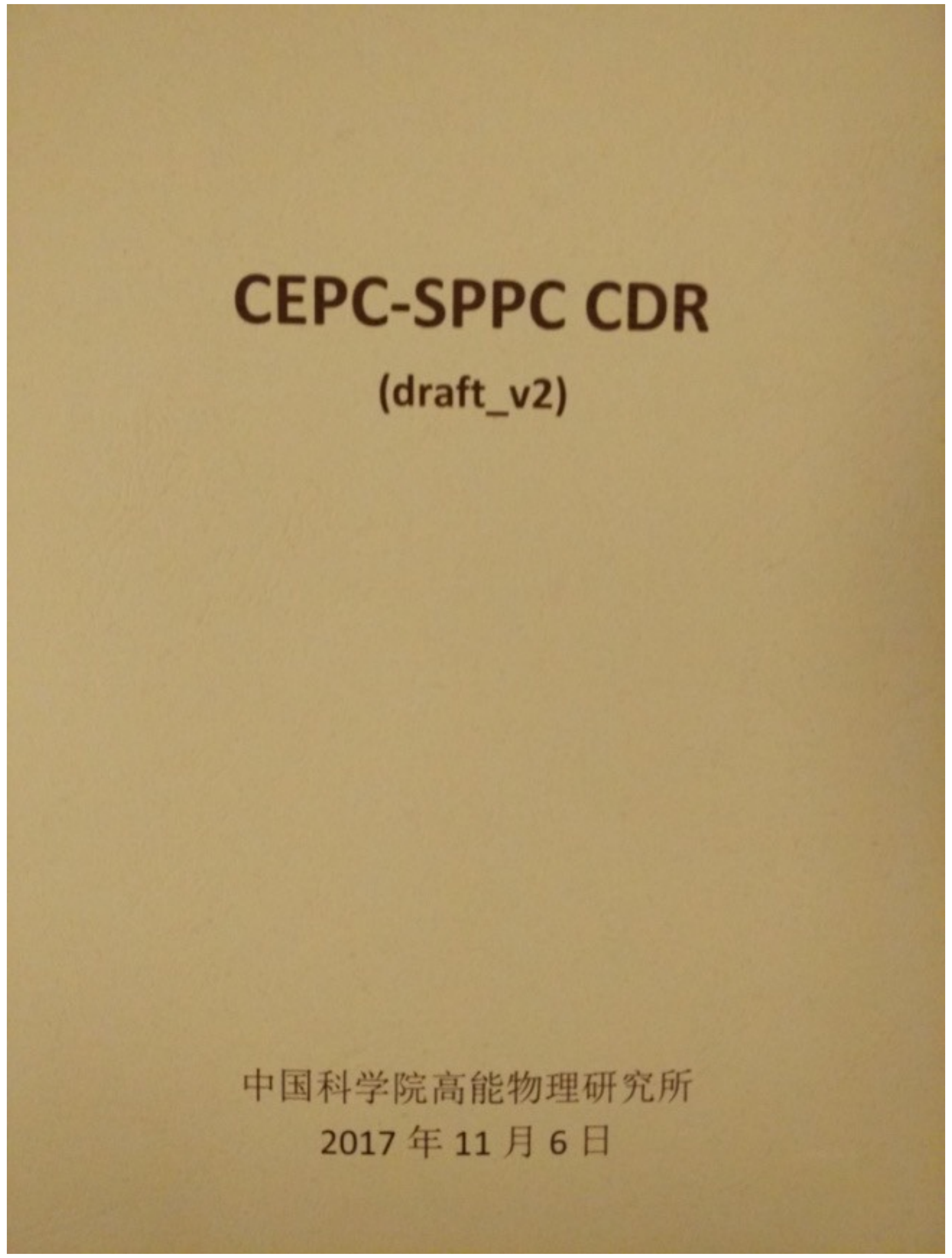


March 2015



April 2017

CEPCSppC baseline and alternative decision processe recorded



Nov 2017

CEPC-SppC CDR Preliminary Draft during CEPC-SppC Mini review

CEPC-SppC CDR will be printed before May 2018

CEPC-SPPC Timeline (preliminary and ideal)

CEPC

1st Milestone: Pre-CDR (by the end of 2014) ;**2nd Milestone:** R&D funding from MOST (in Mid 2016);
3rd Milestone: CEPC CDR Status Report (by the end of 2016); **4th Milestone:** CEPC CDR Report (by the end of 2017);**5th Milestone:** CEPC TDR Report and Proto R&D (by the end of 2020);**6th Milestone:** CEPC construction start (2022);

SPPC

J. Gao IHEP, Beijing

CEPC Status/Timeline

- Sept. 2012: CEPC-SppC was proposed by Chinese scientists
- Mar. 2015: CEPC-SppC Pre-CDR was printed
- Apr. 2017: CEPC-SppC Progress Report was printed
- Before Jun. 2018: CEPC CDR will be printed
- 2018: CEPC entered R&D phase towards TDR to be completed by 2022

Challenges and Key R&D items

- Accelerator design
  - Beam physics: dynamic aperture, momentum acceptance, electron cloud, single ring scheme, …
  - Power consumption, cost effectiveness
- Key technology development
  - High Q_0 SRF cavities and high efficiency thermal power removing SRF accelerating unit
  - High efficiency RF power sources(Klystron, solid state, …)
  - High power Cryogenic system
  - Beam monitor and diagnostics
  - Silicon detectors
  - Magnets, vacuum pipes, …
  - High field SC magnets(for SPPC)

"no show-stoppers"

CEPC Site Selections

Bejing

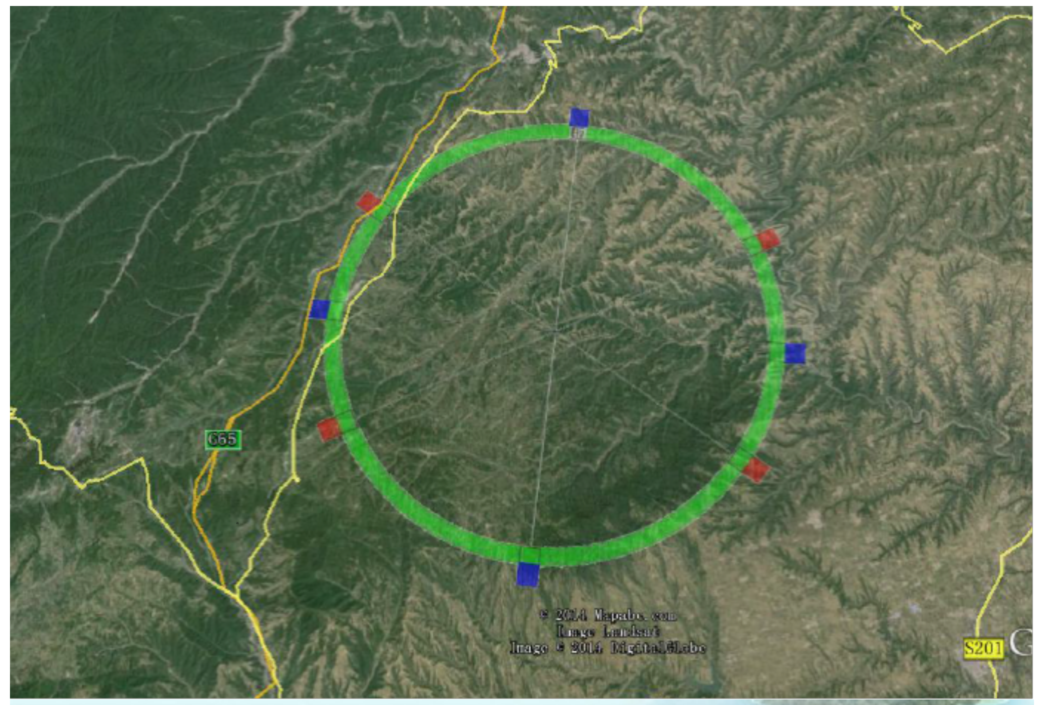
Baoding
(xiong an)

Tianjin

4

1

2



3

1) Qin huang dao, Heihe （Completed in 2014）

2) Huanging, Shanxi （Completed in 2017）

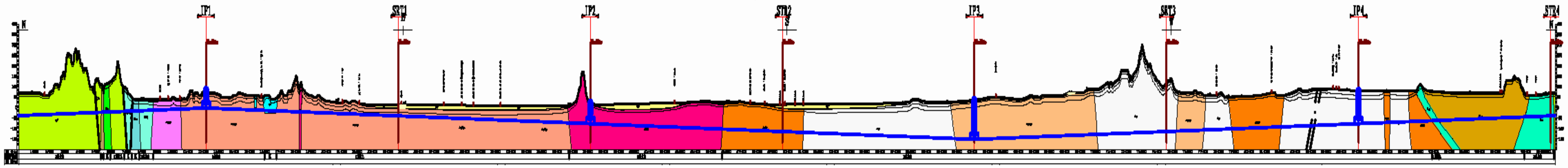
3)Shen shan, Guangdong (Completed in 2016)

4) Baoding (Xiong an), Hebei (Started in August 2017, near Beijing

5) Zhejiang (under contact)

6) Jiangsu (under contact)

Longitudinal profile of tunnel （at Funing site, 1）



CEPC Parameters

	Higgs	*W*	*Z*（*3T*）	*Z*（*2T*）
Number of IPs	2			
Beam energy (GeV)	120	80	45.5	
Circumference (km)	100			
Synchrotron radiation loss/turn (GeV)	1.73	0.34	0.036	
Crossing angle at IP (mrad)	16.5×2			
Piwinski angle	2.58	7.0	23.8	
Number of particles/bunch N_e (10^{10})	15.0	12.0	8.0	
Bunch number (bunch spacing)	242 (0.68μs)	1524 (0.21μs)	12000 (25ns+10%gap)	
Beam current (mA)	17.4	87.9	461.0	
Synchrotron radiation power /beam (MW)	30	30	16.5	
Bending radius (km)	10.7			
Momentum compact (10^{-5})	1.11			
β function at IP β_x^* / β_y^* (m)	0.36/0.0015	0.36/0.0015	0.2/0.0015	0.2/0.001
Emittance $\varepsilon_x/\varepsilon_y$ (nm)	1.21/0.0031	0.54/0.0016	0.18/0.004	0.18/0.0016
Beam size at IP σ_x/σ_y (μm)	20.9/0.068	13.9/0.049	6.0/0.078	6.0/0.04
Beam-beam parameters ξ_x/ξ_y	0.031/0.109	0.013/0.106	0.0041/0.056	0.0041/0.072
RF voltage V_{RF} (GV)	2.17	0.47	0.10	
RF frequency f_{RF} (MHz) (harmonic)	650 (216816)			
Natural bunch length σ_z (mm)	2.72	2.98	2.42	
Bunch length σ_z (mm)	3.26	5.9	8.5	
HOM power/cavity (2 cell) (kw)	0.54	0.75	1.94	
Natural energy spread (%)	0.1	0.066	0.038	
Energy acceptance requirement (%)	1.35	0.4	0.23	
Energy acceptance by RF (%)	2.06	1.47	1.7	
Photon number due to beamstrahlung	0.29	0.35	0.55	
Lifetime _simulation (min)	100			
Lifetime (hour)	0.67	1.4	4.0	2.1
F (hour glass)	0.89	0.94	0.99	
Luminosity/IP *L* ($10^{34}cm^{-2}s^{-1}$)	2.93	10.1	16.6	32.1

Internationalisation has commenced

- International Advisory Committee
- International Workshops

Stephen Hawking, Gordon Kane (arXiv:1804.00682v1)
"Should China build the Great Collider?" 2 Apr. 2018

"The country that makes the greatest advances in discovering the workings of nature itself, via the sciences of particle physics and cosmology, will be permanently remembered in history for glorious achievements."

China New Scientific Policies

January 23, 2018 : The China Reform and Development Committee (led by President J.P. Xi) had the meeting on Jan 23, 2018, and passed the plan of "Chinese Initiated International Large Scientific Plan and Large Scientific Project"

March 28, 2018 : Chinese Government (led by Premier Minister Keqiang Li) made public details of "Chinese Initiated International Large Scientific Plan and Large Scientific Project" :

...till 2020 China will prepare 3~5 projects (hopefully, CEPC is inside)and finally select 1~2 projects to construct...(hopefully, CEPC will be selected)

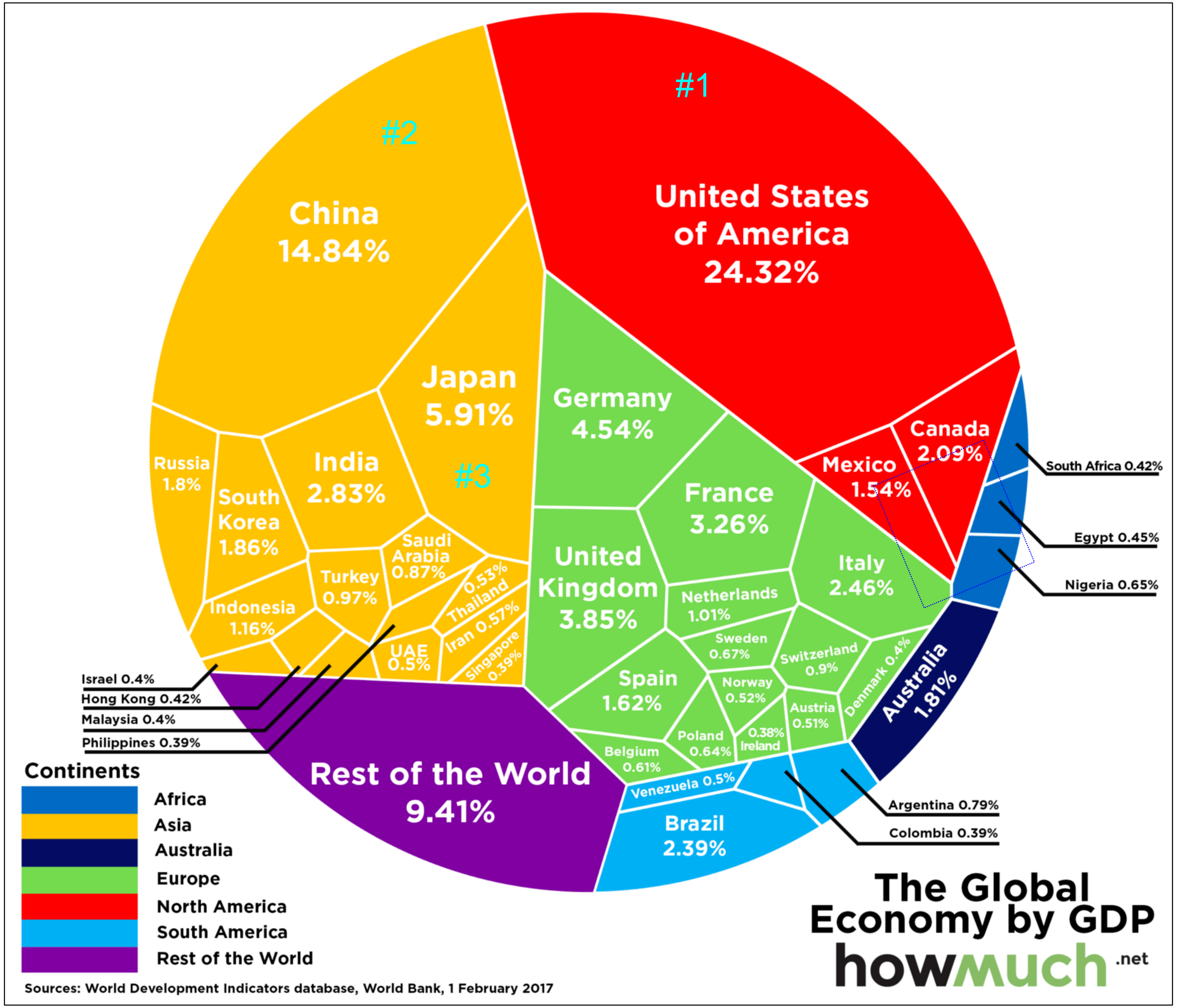
...Actively participate in other country or multinational initiated Large Scientific Projects (hopefully, ILC will have good news from Japan at the end of 2018)

...Actively participate important international scientific organisations' scientific projects and activities...

(translated by J. Gao)

It's the Economy ...

+ Technology/Manpower



World HEP Cannot Afford to "miss the China train"

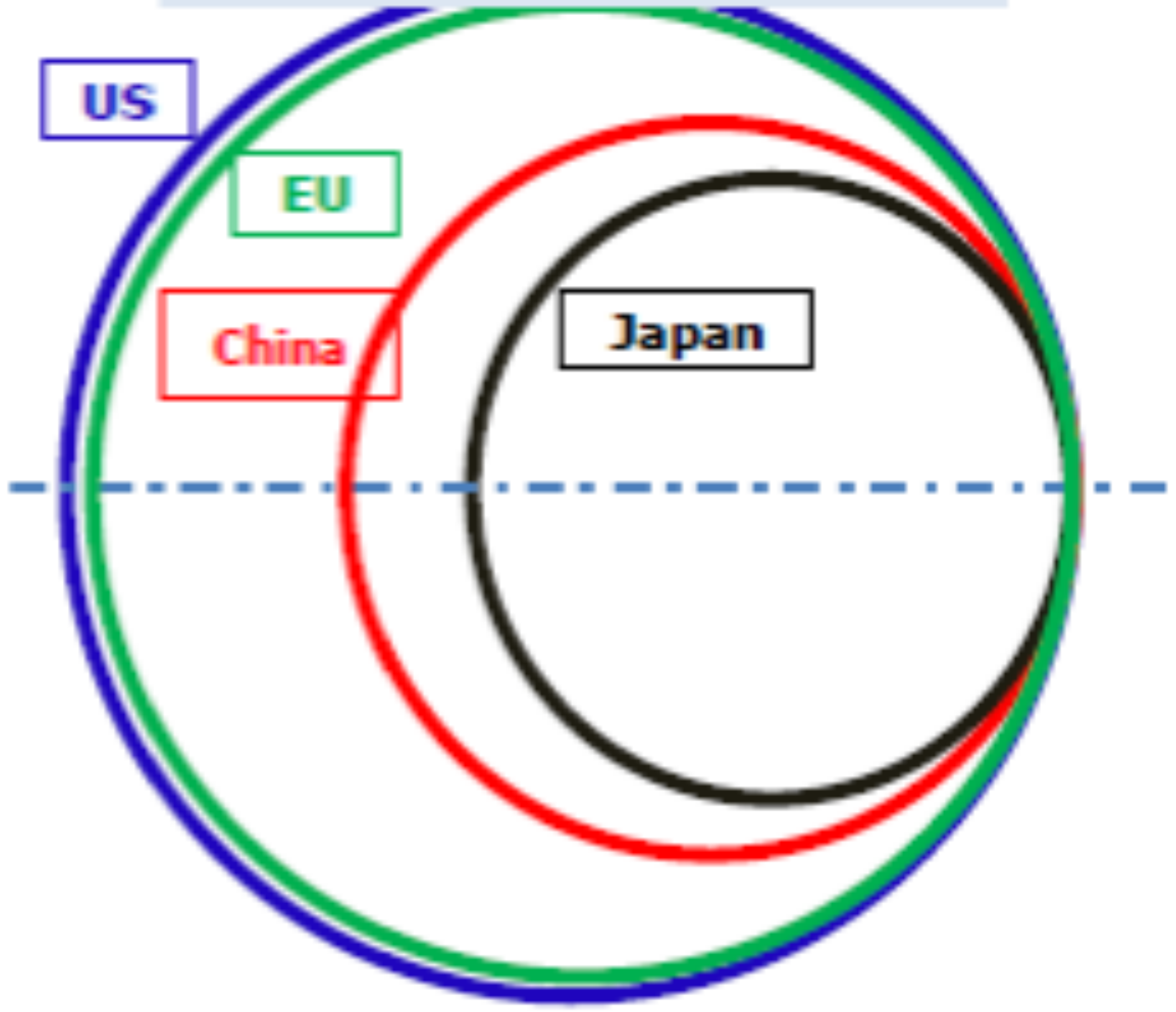
Can We afford ?

BEPC: Cost/4yrs/GDP of China 1984 ≈ 0.0001
SSC: Cost/10yrs/GDP of US 1992 ≈ 0.0001
LEP: Cost/8yrs/GDP of EU 1984 ≈ 0.0002
LHC: Cost/10yrs/GDP of EU 2004 ≈ 0.0003
ILC: Cost/8yrs/GDP of JP 2018 ≈ 0.0002
CEPC: Cost/8yrs/GDP of China 2020 ≈ 0.00005
SppC: Cost/8yrs/GDP of China 2036 ≈ 0.0001

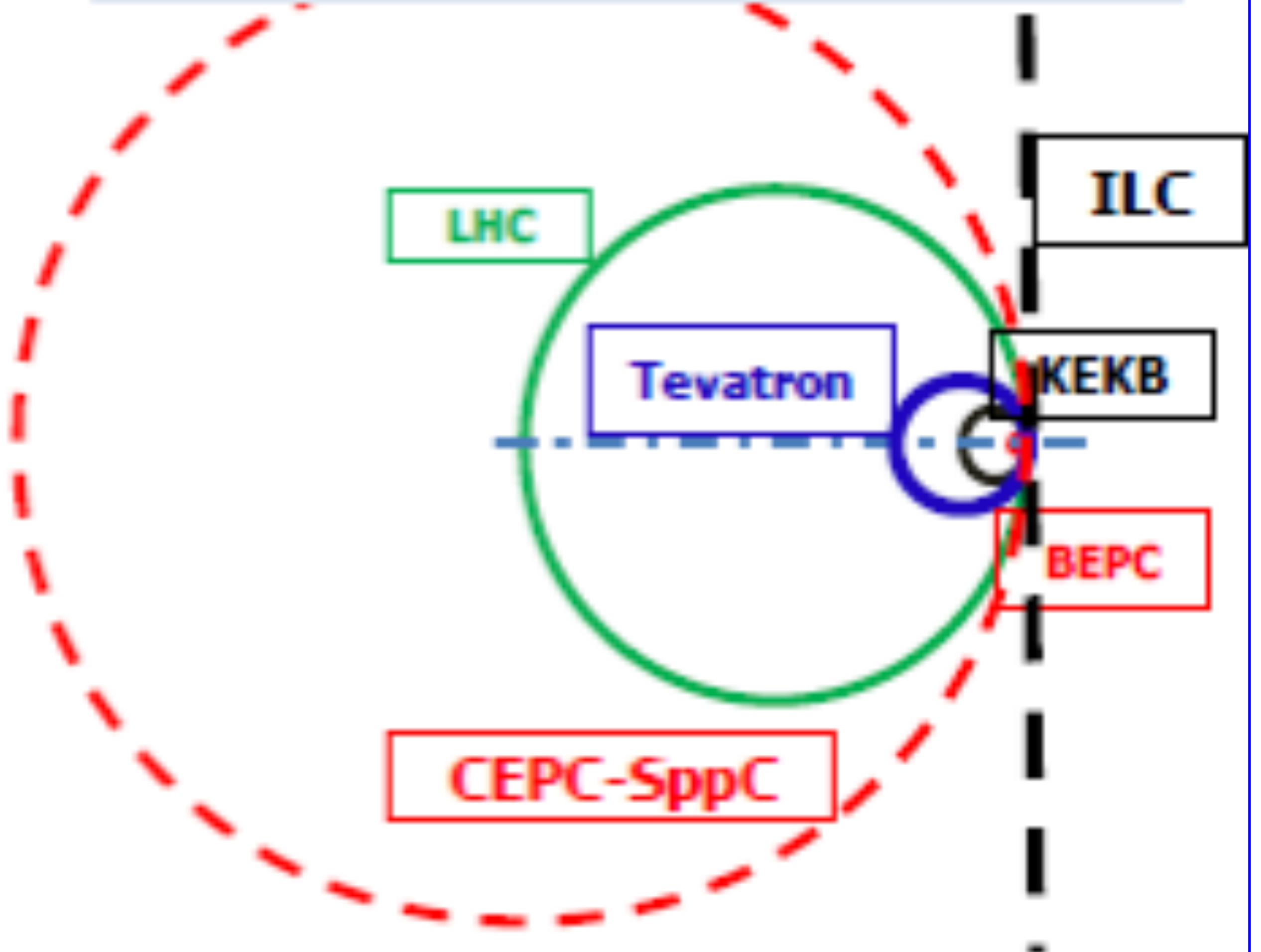
	population	GDP/capita($)	Burden/capita($)	Burden/(GDP/capita)
China	1.3 B	8,000	4	0.0005
US*	0.3 B	57,000	35	0.0006
Japan*	0.12 B	39,000	88	0.0023
EU*	0.5 B	32,000	21	0.0007
Malaysia	0.03 B	9,500	177	0.0186
Mexico	0.12 B	8,000	44	0.0055

* Cost of construction is ~× 2

GDP of countries



Accelerators of countries



Feb. 2016

AsiaHEP/ACFA Statement on ILC + CEPC/SPPC

AsiaHEP and ACFA reassert their strong endorsement of the ILC, which is in a mature state of technical development. The aim of ILC is to explore physics beyond the Standard Model by unprecedented precision measurements of the Higgs boson and top quark, as well as searching for new particles which are difficult to discover at LHC. The Higgs studies at higher energies are especially important for measurement of WW fusion process, to fix the full Higgs decay width, and to measure the Higgs self-coupling. In continuation of decades of world-wide coordination, we encourage redoubled international efforts at this critical time to make the ILC a reality in Japan. The past few years have seen growing interest in a large radius circular collider, first focused as a “Higgs factory", and ultimately for proton-proton collisions at the high energy frontier. We encourage the effort lead by China in this direction, and look forward to the completion of the technical design in a timely manner.

Collider Activities in Asia
Summary

- Asian collider physics is mature, with decades of achievement
- Current activities show a highly capable and technically advanced regional capacity
- Future plans are ambitious and important for the field.
- There is an imperative to consider the needs of the international HEP community, at the same time as important national and laboratory priorities.
- Its a critical time for collider physics.

Acknowledgements/ Apologies

- I acknowledge the contributions by Yasuhiro Okada (KEK), Jie Gao (IHEP), Masanori Yamauchi (KEK), Yifang Wang (IHEP), Shin Michizono (KEK/LCC), George Hou (NTU)

- Apologies for the vast activities in neutrino physics and non-accelerator physics in Asia.

SppC parameters

Parameter	Value	Unit
Main parameters		
Circumference	100	km
Beam energy	37.5	TeV
Lorentz gamma	39979	
Dipole field	12.00	T
Dipole curvature radius	10415.4	m
Arc filling factor	0.780	
Total dipole magnet length	65442.0	m
Arc length	83900	m
Total straight section length	16100	m
Energy gain factor in collider rings	17.86	
Injection energy	2.10	TeV
Number of IPs	2	
Revolution frequency	3.00	kHz
Revolution period	333.3	μs
Physics performance and beam parameters		
Nominal luminosity per IP	1.01E+35	$cm^{-2}s^{-1}$
Beta function at initial collision	0.75	m
Circulating beam current	0.73	A
Nominal beam-beam tune shift limit per	0.0075	
Bunch separation	25	ns
Bunch filling factor	0.756	
Number of bunches	10080	
Bunch population	1.5E+11	
Accumulated particles per beam	1.5E+15	
Normalized rms transverse emittance	2.4	μm
Beam life time due to burn-off	14.2	hour
Turnaround time	3.0	hour
Total cycle time	17.2	hour

Total / inelastic cross section	147	mbarn
Reduction factor in luminosity	0.85	
Full crossing angle	110	μrad
rms bunch length	75.5	mm
rms IP spot size	6.8	μm
Beta at the 1st parasitic encounter	19.5	m
rms spot size at the 1st parasitic encoun	34.5	μm
Stored energy per beam	9.1	GJ
SR power per ring	1.1	MW
SR heat load at arc per aperture	12.8	W/m
Critical photon energy	1.8	keV
Energy loss per turn	1.48	MeV
Damping partition number	1	
Damping partition number	1	
Damping partition number	2	
Transverse emittance damping time	2.35	hour
Longitudinal emittance damping time	1.17	hour