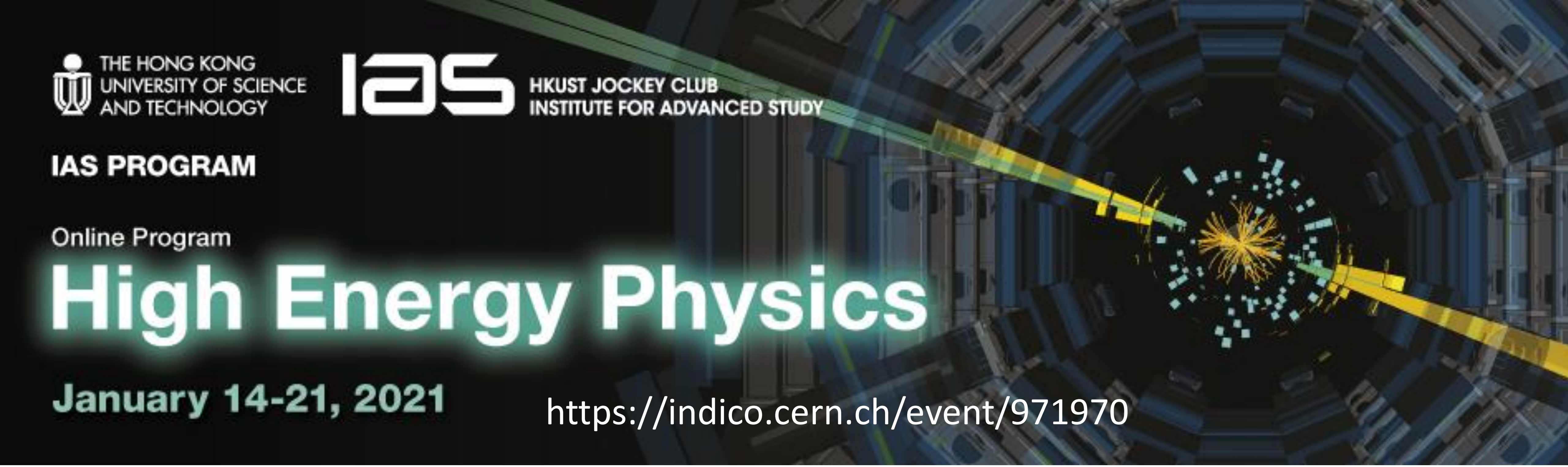
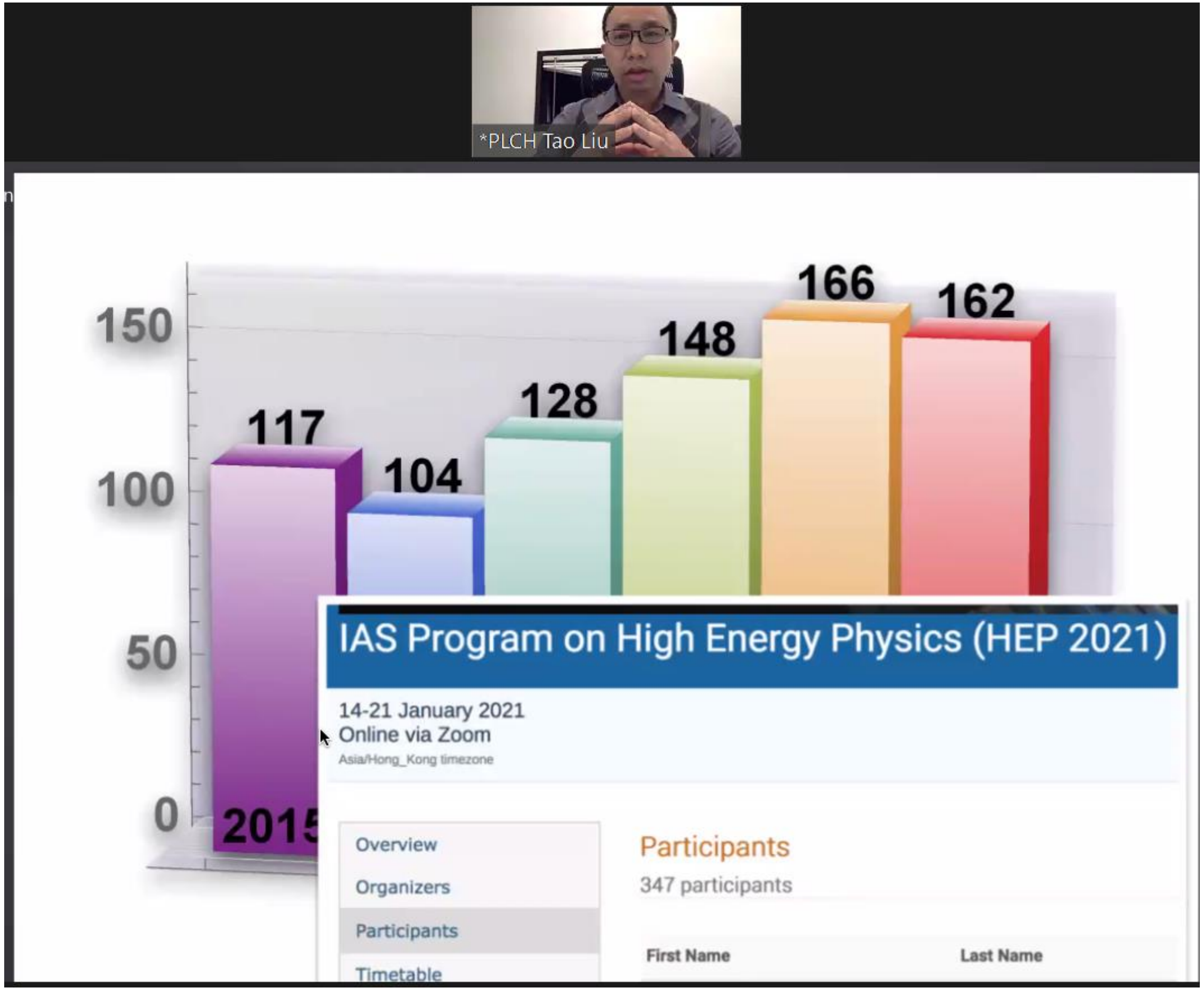


https://indico.cern.ch/event/971970

a few impressions from HKUST IAS 2021 HEP conference

Frank Zimmermann, 22 January 2021



big increase in the number of participants from 162 (2020) to 347 (2021)

-

the boost from virtual meetings

T. Liu

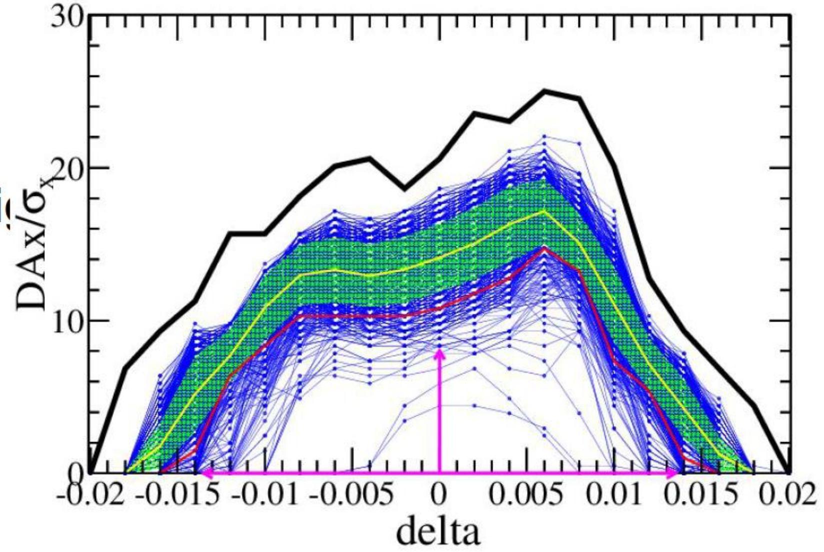
CEPC CDR Lattice DA with Errors

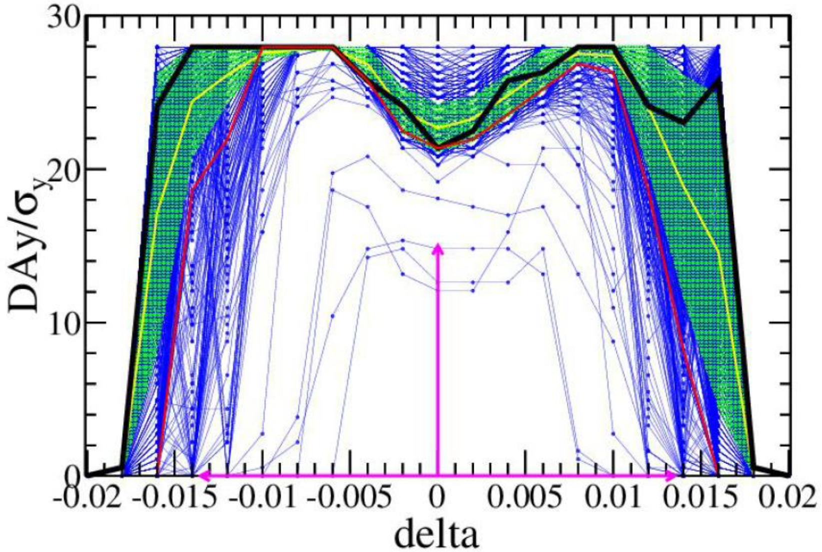
Achieved DA (with errors)@ Higgs: 10σx/21σy/0.00 (on momentum), 2σx/9σy/0.0135 (off momentum)

Design DA goal (with errors)@Higgs: 8σx/15σy/0.00 (on momentum), 1σx/1σy/0.0135 (off momentum)

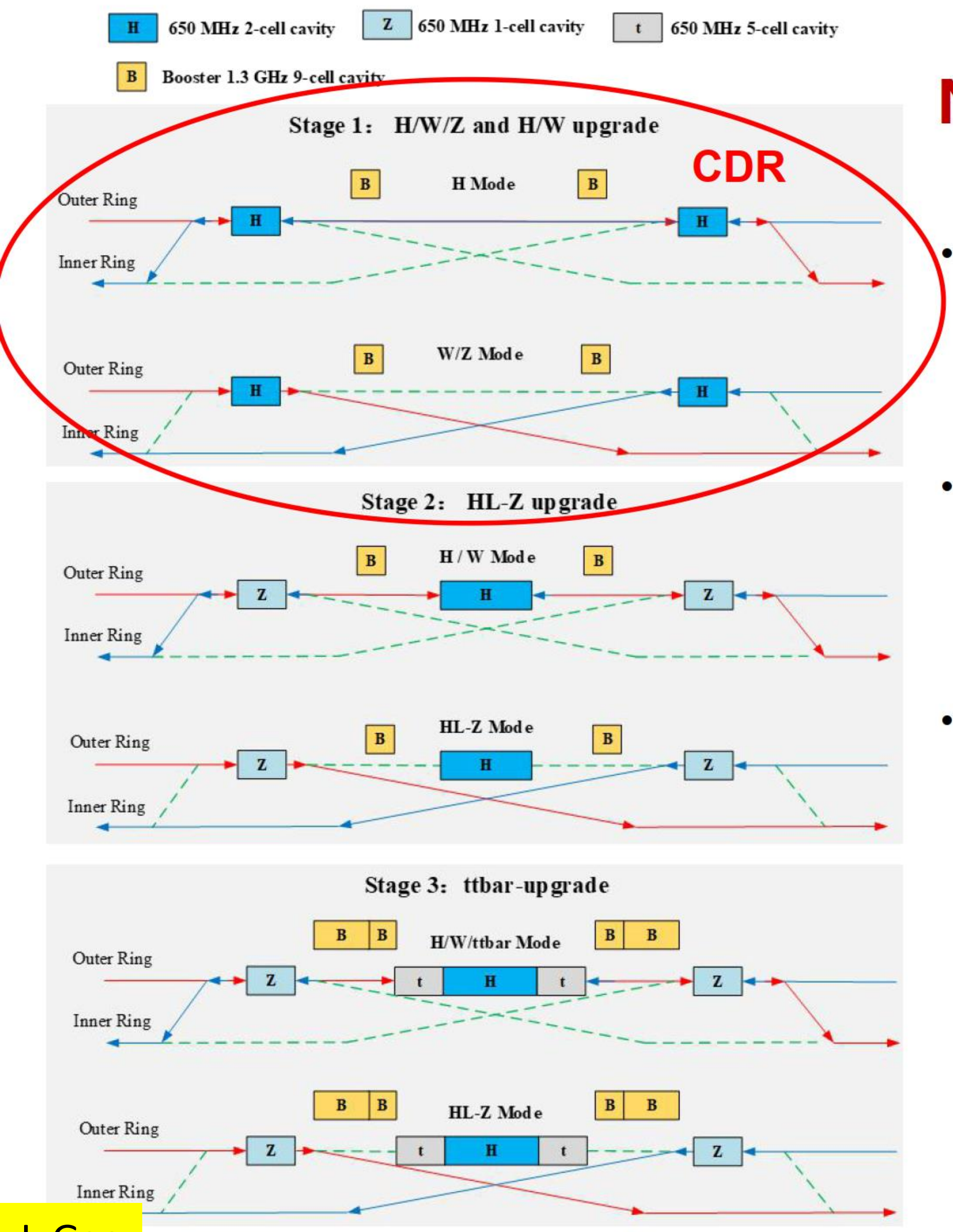
Component	Δx (mm)	Δy (mm)	$\Delta\theta_z$ (mrad)	Field error
Dipole	0.10	0.10	0.1	0.01%
Arc Quadrupole	0.10	0.10	0.1	0.02%
IR Quadrupole	0.05	0.05	0.05	
Sextupole	0.10	0.10	0.1	

CDR lattice design with errors reached the DA design goal





J. Gao



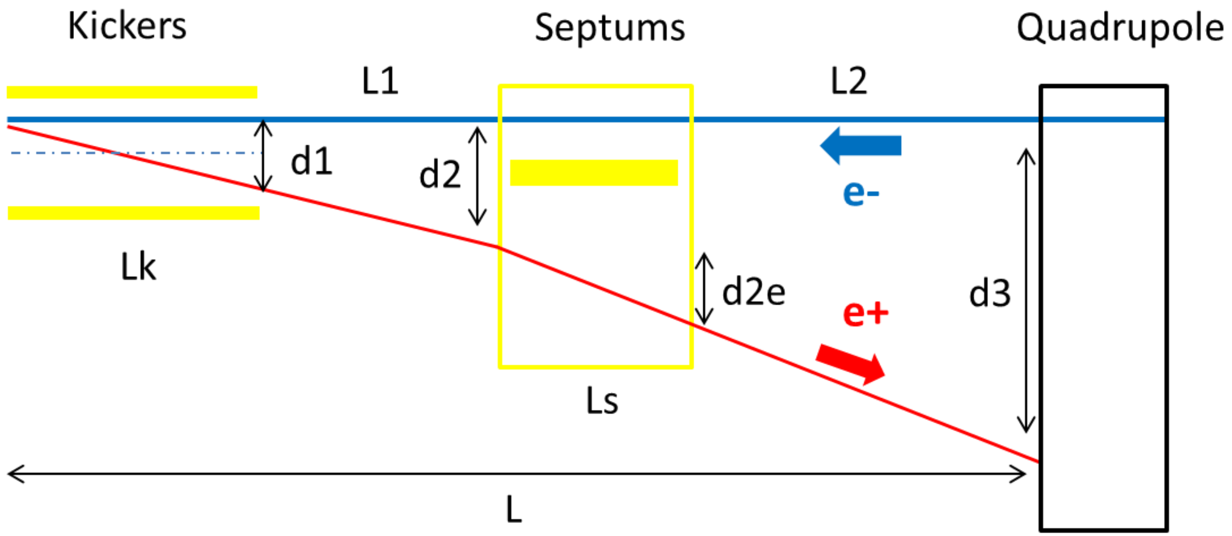
New RF Staging & By-pass Scheme for CEPC

- **Stage 1 (H/W run for 8 years):** Keep CDR RF layout for H(HL-H)/W and 50 MW upgrade. Common cavities for H. Separate cavities for W/Z. Z initial operation for energy calibration and could reach CDR luminosity. **Minimize phase 1 cost and hold Higgs priority**.
- **Stage 2 (HL-Z upgrade)**: Move Higgs cavities to center and add high current Z cavities. **By-pass low current H cavities**. International sharing (modules and RF sources): Collider + 130 MV 650 MHz high current cryomodules.
- **Stage 3 (ttbar upgrade):** add ttbar Collider and Booster cavities. International sharing (modules and RF sources): Collider + 7 GV 650 MHz 5-cell cavity. Booster + 6 GV 1.3 GHz 9-cell cavity. Both low current, high gradient and high Q, Nb_3Sn etc. 4.2 K?

Unleash full potential of CEPC with flexible operation. **Seamless mode switching** with unrestricted performance at each energy until AC power limit. **Stepwise cost, technology and international involvement with low risk.**

J. Gao

Alternative separation scheme at RF region



With kicker instead of electro-static separator to reduce the impedance (Proposed by Jinhui Chen)

	Kicker	Septum	
Integrated strength BL [T*m]	0.1624	1.4	
Strength B [Guass]	203	1000	Field for up to 182.5GeV. Septum is weak to suppress emittance growth.
Effective length Leff [m]	8	14	
Half width of good field region Hgf/Vgf [mm]	10.1/3.8 @ 5E-4	18.9/3.8 @ 5E-4	Kicker: 18σx+3mm+d1/2, 18σy+3mm Septum: 18σx+3mm+d2e/2, 18σy+3mm
Half width of beam stay clear Hbsc/Vbsc [mm]	9.6/3.6	9.2/3.6	18σx+3mm, 18σy+3mm
Septum width width [mm]	-	5	

Y. Wang

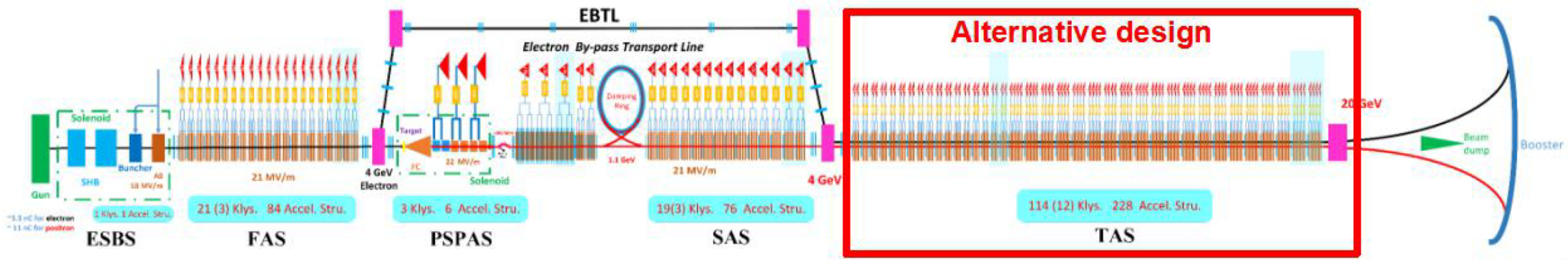
CEPC SRF Parameter with By Pass Schemes

	BEPCII 500 MHz 4.2 K	BEPC3 500 MHz 4.2 K	CEPC CDR H 30 MW 3E34	CEPC CDR Z 16.5 MW 32E34	CEPC 1-cell H 30 MW 3E34	CEPC TDR Z 30 MW 100E34	CEPC TDR H 30 MW 3E34	CEPC TDR W 30 MW 10E34	CEPC Ultimate Z 50 MW 167E34
Beam current (mA)	400 (600)	900	2 x 17.4	460	2 x 17.4	**838**	2 x 17.4	2 x 87.7	1400
Cell number	1	1	2		1	1	2/1	2/1	1
Cavity number / ring	1	2	2 x 120	60	2 x 120	60	2x(90+60)	2x(90+60)	60
Eacc (MV/m)	6 (1.5 MV)	10 (2.5 MV)	**19.7**	3.6	**40**	**9.4**	**19.7**	4.2	9.4
Q_0 @ 4.2 K / 2 K	1E9	1E9	**1.5E10**	1.5E10	**3E10**	**1.5E10**	**1.5E10**	1.5E10	1.5E10
Total wall loss (kW)			6.1	0.1	6.1	0.35	6.1	0.27	0.35
Input power (kW)	110	150	250	275	250	**500**	250/125	250/125	**835**
Cavity# / klystron	1	1 SSA	2		2/1	1	2/1	2/1	1
Klystron power (kW)	250	150 SSA	800	800	800	800	800	800	1200
Total KLY number	2	4	120		60+120	120	90+120	90+120	120
HOM damper	Absorber	Absorber	Hook+ Absorber		Hook+ Absorber	Absorber	Hook+ Absorber	Hook+ Absorber	Absorber
HOM power (kW)	8*	20	0.6	1.9	0.23	2.4	0.46 / 0.23	**1.5** / 0.75	**4**

* Bunch length 15 mm, cavity cell HOM loss factor 0.1 V/pC, tapers 0.06 V/pC, absorbers 0.26 V/pC.

J. Gao

CEPC 20-GeV Linac Injector Alternative Scheme



- **Parameters**

S-band Accelerating structure

Parameter	Symbol	Unit	Baseline	Alternative
e^- /e^+ beam energy	E_{e-}/E_{e+}	GeV	10	20
Repetition rate	f_{rep}	Hz	100	100
Bunches/pulse			1	1
e^- /e^+ bunch population	Ne-/Ne+	nC	>1.5 (3)	>1.5 (3)
Energy spread (e^- /e^+)	σ_E		$<2\times10^{-3}$	$<2\times10^{-3}$
Emittance (e^- /e^+)	ε_r	nm	40	20

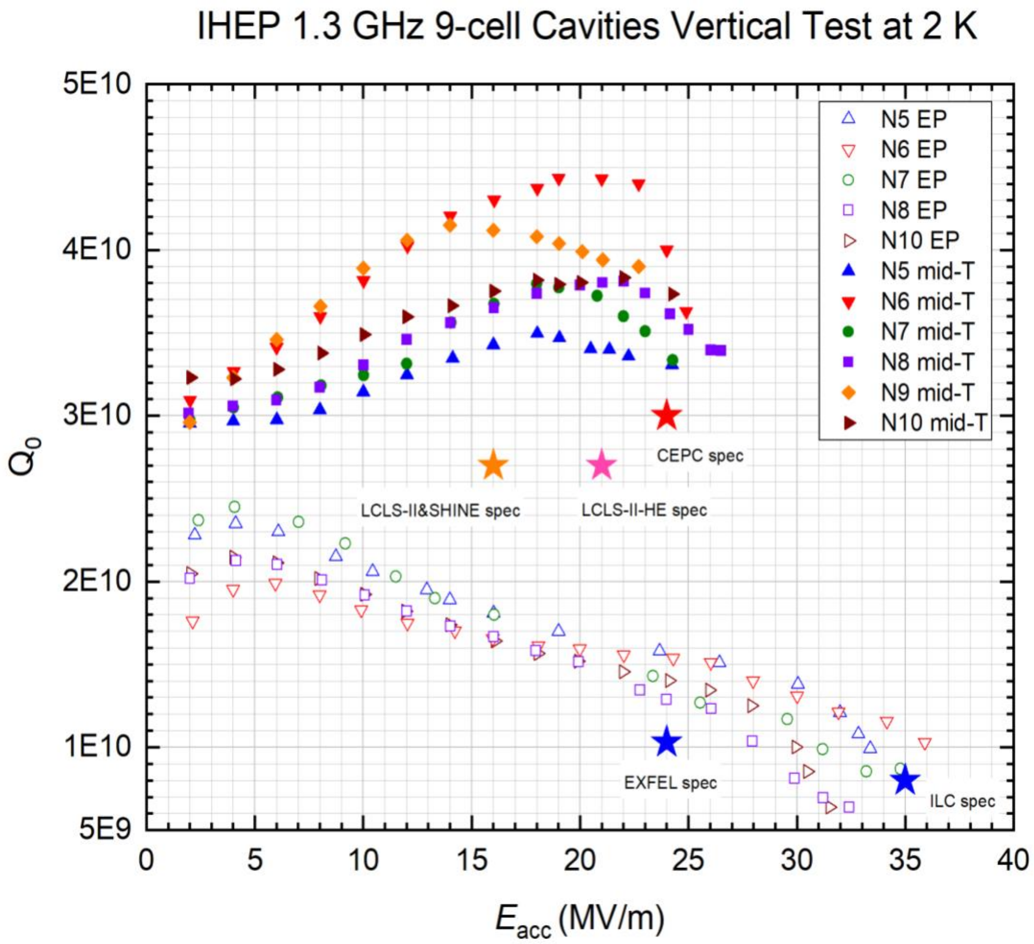
C-band Accelerating structure

C-band: 4GeV → 20GeV

Parameter	Unit	S-band	C-band
Frequency	MHz	2860	5720
Length	m	3.1	1.8
Cavity mode		2π/3	3π/4
Aperture diameter	mm	20~24	11.8~16
Gradient	MV/m	21	**45**

J. Gao

1.3 GHz 9-cell Cavity



- Five EP 9-cells > 30 MV/m, max 36 MV/m, reach ILC spec.
- Six Mid-T Furnace Bake 9-cells: 3.4~4.5E10@16~22 MV/m, beyond CEPC and SHINE spec.

https://arxiv.org/abs/2012.04817v1
https://indico.desy.de/event/27572/contributions/94299/

meeting or exceeding SC cavity specs for all projects

J. Zhai

CEPC SRF R&D

CEPC SRF System TDR Status and Plan

TDR Phase 1: 2019-2020 (Components Prototyping)

- ✓ SRF system TDR design and optimization (RF staging and bypass scheme proposed)
- ✓ High Q, high gradient cavity, high power components and other key technology R&D (close to CEPC spec)
- ✓ 650 MHz high Q short cryomodule prototyping (assembly in Dec 2020)
- ✓ PAPS SRF facility construction (equipment installation)

TDR Phase 2: 2021-2022 (Cryomodule Prototyping)

- ☐ SRF system TDR design re-baseline and optimization
- ☐ 650 MHz high Q short cryomodule operation and improvement (to meet CEPC spec)
- ☐ 1.3 GHz high Q full cryomodule prototyping (to meet CEPC spec)
- ☐ 650 MHz high current cryomodule design (some tech verification in BEPC3)
- ☐ PAPS SRF facility commissioning, operation and upgrade
- ☐ Industrialization in synergy with other SRF projects in China

Post-TDR: 2023-2025 (Mass-Production Preparation)

- 650 MHz full cryomodule prototyping, engineering design, mass-production technology preparation

J. Gao

CEPC 650MHz High Efficiency Klystron Development

Facility: CEPC high power and high efficincy test facility (lab) is located in IHEP

Established "High efficiency klystron collaboration consortium", including IHEP & IE(Institute of Electronic) of CAS, and Kunshan Guoli Science and Tech.

- 2016 – 2018： Design conventional & high efficiency klystron
- 2017 – 2018： Fabricate conventional klystron & test
- 2018 - 2019 ： Fabricate 1st high efficiency klystron & test
- 2020 - 2021 ： Fabricate 2nd high efficiency klystron & test
- 2021 - 2022 ： Fabricate 3rd high efficiency klystron & test

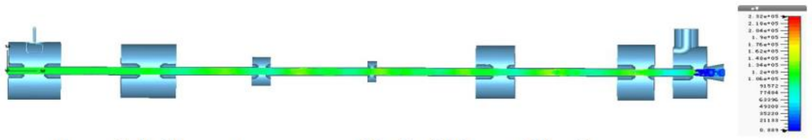
Parameters	Conventional efficiency	**High efficiency**
Centre frequency (MHz)	650+/-0.5	**650+/-0.5**
Output power (kW)	800	**800**
Beam voltage (kV)	80	-
Beam current (A)	16	-
Efficiency (%)	~ 65	**> 80**



1st Klystron of 62% efficiency

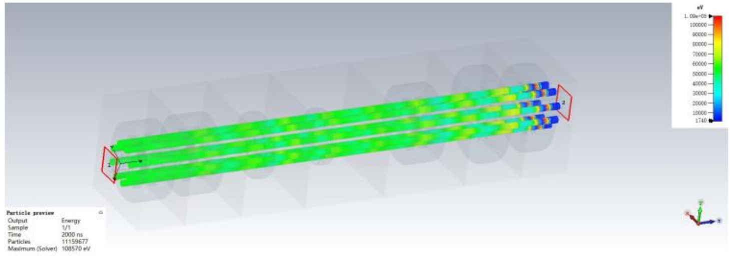
On March 10， 2020， the first CEPC650Mhz klystron output power has reached pulsed power of 800kW (400kW CW due to test load limitation), efficiency 62% and band width>+-0.5Mhz.

800kW Load



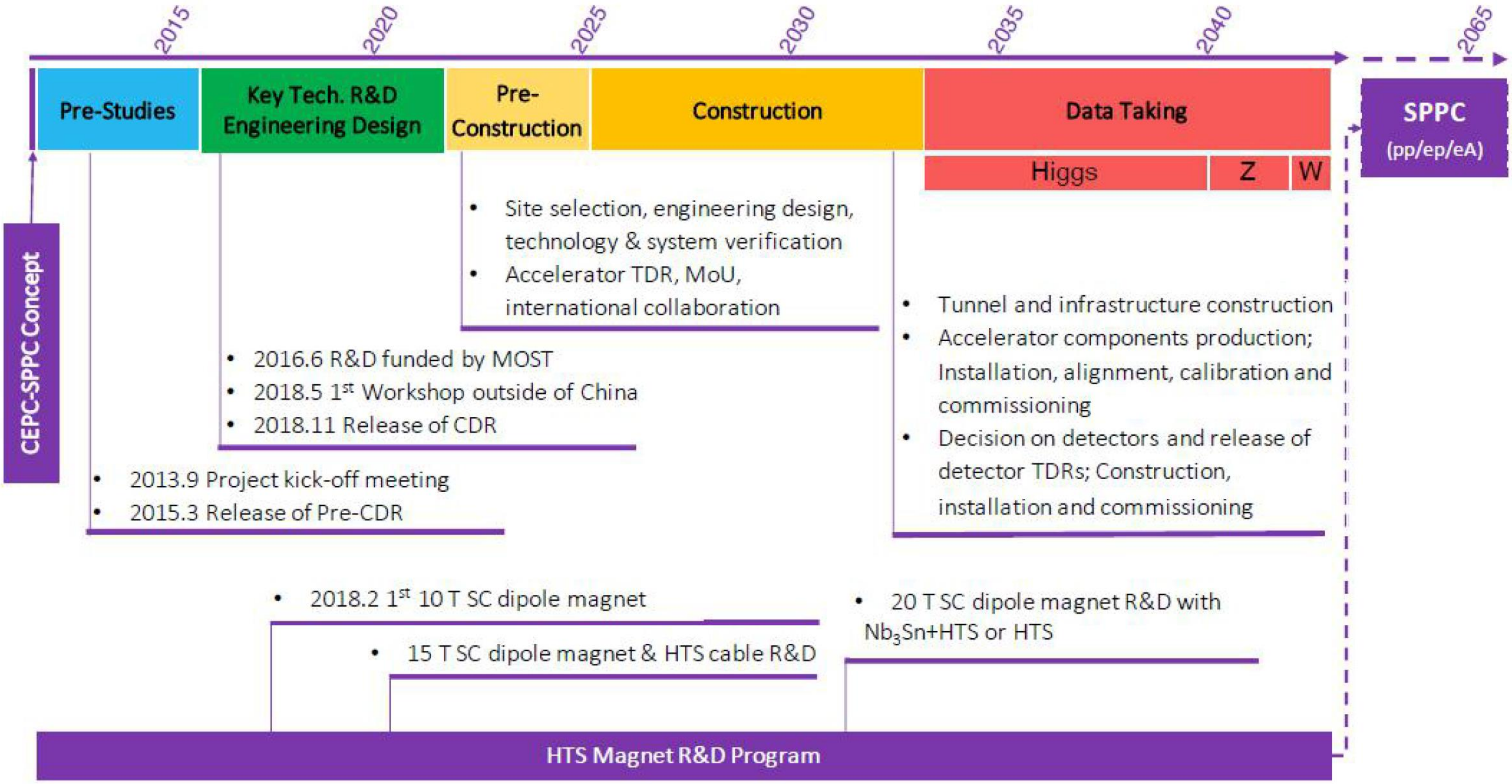
2nd Klystron of 77% efficiency

3nd Klystron of 80% efficiency



J. Gao

CEPC Project Timeline



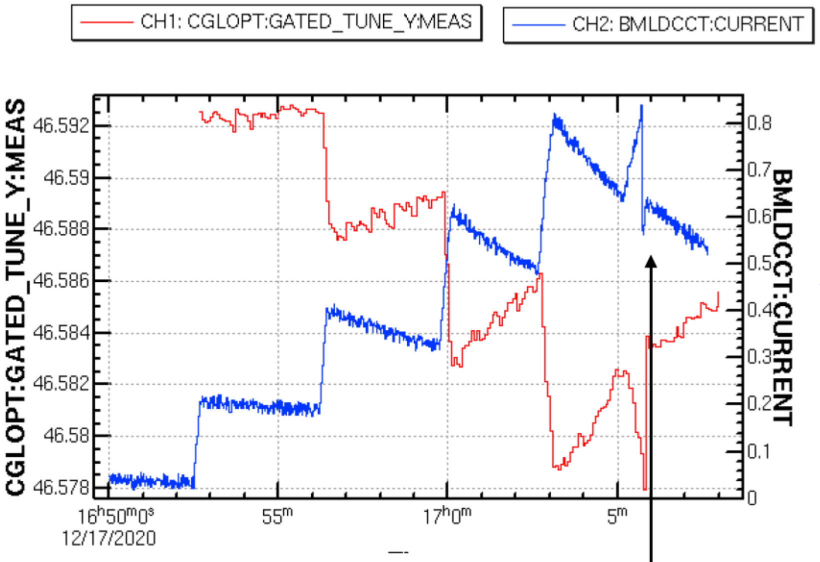
J. Gao

Comparison between Machine Parameters

	KEKB : June 17, 2009		SuperKEKB : June 21, 2020		SuperKEKB : July 1, 2020		SuperKEKB : final design		Unit
Ring	LER	HER	LER	HER	LER	HER	LER	HER	
Emittance	18	24	4.0	4.6	4.0	4.6	3.2	4.6	nm
Beam Current	1637	1188	712	607	536	530	3600	2600	mA
Number of bunches	1585		978		978		2500		
Bunch current	1.03	0.750	0.728	0.621	0.548	0.542	1.44	1.04	mA
Horizontal size σ_x^*	147	170	17.9	16.6	15.5	16.6	10.1	10.7	μm
Vertical cap sigma Σ_y^*	1.33		0.403		0.317		0.079		μm
Vertical size σ_y^*	0.940		0.285		0.224		0.048	0.062	μm
Betatron tunes ν_x / ν_y	45.506 / 43.561	44.511 / 41.585	44.523 / 46.581	45.531 / 43.577	44.525 / 46.581	45.531 / 43.574	44.53 / 46.57	45.53 / 43.57	
β_x^* / β_y^*	1200 / 5.9	1200 / 5.9	80 / 1.0	60 / 1.0	60 / 0.8	60 / 0.8	32 / 0.27	25 / 0.30	mm
Piwinski angle	0	0	10.7	12.7	12.3	12.7	19.3	19.0	
Beam-Beam parameter ξ_y	0.129	0.090	0.0389	0.0261	0.0345	0.0199	0.0881	0.0807	
Specific luminosity	1.71×10^{31}		5.43×10^{31}		6.90×10^{31}		2.14×10^{32}		$cm^{-2}s^{-1}/mA^2$
Luminosity	2.11×10^{34}		2.40×10^{34}		2.00×10^{34}		8×10^{35}		$cm^{-2}s^{-1}$
Remarks	Crab crossing		Crab waist (80 %, 40 %)		Crab waist (80 %, 40 %)		-		

Y. Ohnishi

Single Bunch Tune Shift and TMCI in LER (2020c)

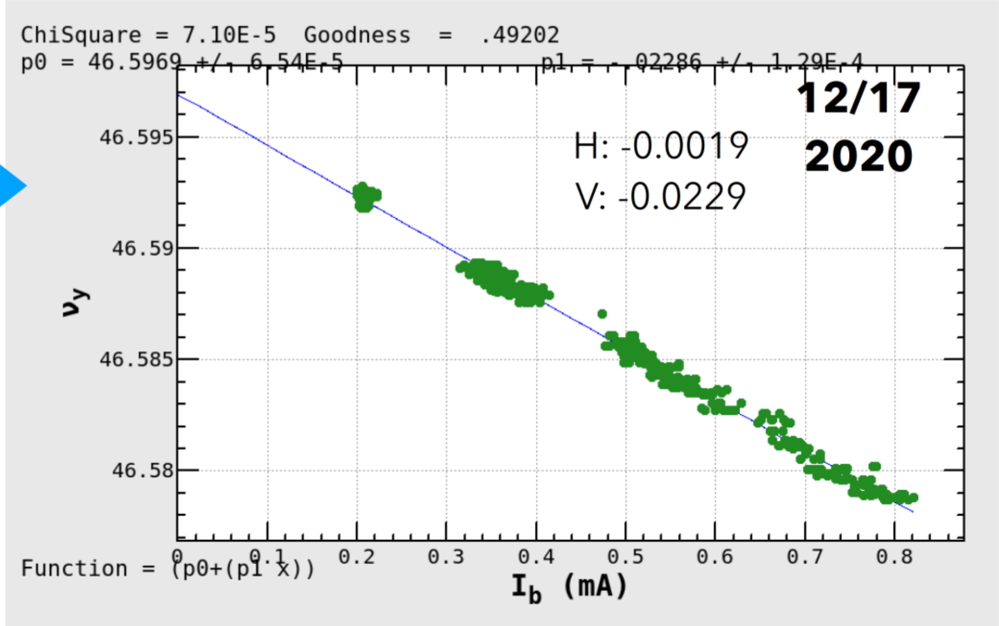


vert. tune

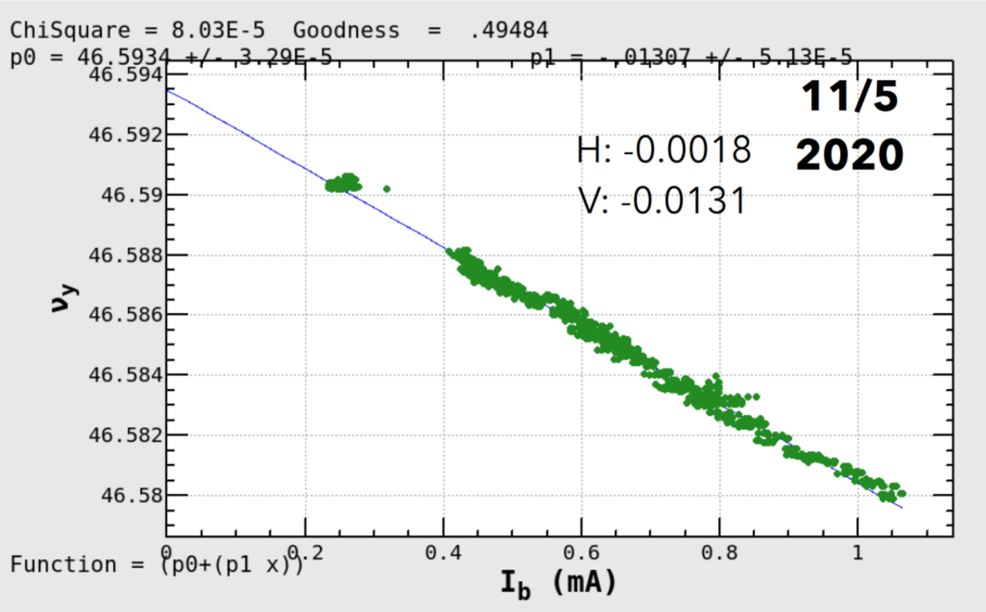
single bunch current

Tune shift is same as synchrotron tune

$\nu_s = -0.0235$



Beam current can not be stored larger than 0.8 mA/bunch.



2020	11/5	12/17
D02V1 (mm)	1.52 / 1.2 (1.36)	1.68 / 1.2 (1.44)
D03V1 (mm)	2.0 / 1.98 (1.99)	0.68 / 1.38 (1.03)
D06V1 (mm)	3.2 / 3.2 (3.2)	2.7 / 1.2 (1.95)
D06V2 (mm)	2.2 / 1.9 (2.05)	2.28 / 1.85 (2.07)

← carbon head

Y. Ohnishi

Colliders: Probability to be built

~1/ Cost^2

1/LHC = 100%
1/ (2 x LHC)= 25%

Global Strategy ?

- **Highest priority: Higgs coupling to 1%**
  - FCC-ee and CEPC should proceed in parallel until one is approved:
    - Competition can enhance the chance for both
    - Higgs factory is too important to miss
  - Try to get one of the two: ILC or CLIC
    - The world can accommodate one linear and one circular collider at the same time: push-pull option is not a good choice
    - Linear technology can not be ignored since higher energy (~10 TeV) lepton colliders may be needed, if new physics is discovered
- **Major R&D effort for pp collider:**
  - Aiming for (iron-based) HTC magnet(~ 10-15 yrs): FCC-hh/SPPC
  - Low energy FCC-hh(40 TeV) lacks the technology impact to the society: not a good option
- **Major R&D effort for $\mu^+\mu^-$ and wake-field acceleration for a higher energy lepton collider**
  - Solutions for muon production and cooling ?
  - A hybrid of the plasma and traditional accelerator may be a choice to overcome difficulties: CEPC injector, future higher energy ILC & CLIC

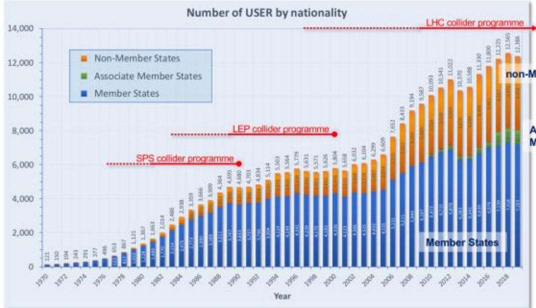
Presentation 9

HEP Panel Discussion

FUTURE COLLIDERS

WIN – WIN – WIN !

Rich program of Classic physics explorations, after which we are guaranteed to dramatically transform our understanding	Experimental & Engineering challenges to excite a new generation.	Spin-off benefits to: – excitement of society – magic of E=mc² – education & training – technology, materials – international cooperation in 21st century



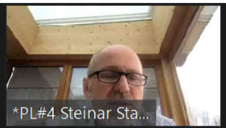
Recording

While every frontier may make breakthroughs/discoveries, **high-energy collider** programs are indispensable to uncover the nature at shortest distances.

Personally, I would like to see ...

1. LHC/SuperKEKB/BEPC-II continue to deliver
2. EIC will be in mission on time
3. ILC is of a priority of the field & will be moving forward
4. CEPC/SPPC & FCC_{ee}/FCC_{hh} will be further developed
5. Muon collider/detector R&D will be fully engaged in the US

We physicists must present convincing physics/technology cases to the funding agencies and the governments.



Recording

Background: Linear Colliders

(1) Multiple roadmaps (new collider proposals) have been drawn for HEP of next decades.
It will be important to generate a world-wide strategy to synergize the ongoing and future endeavors, strengthen mutual co-ordinations/collaborations, and eventually benefit all parties.

- *We discuss and present performances, costs and power – on paper - for all options (also in this meeting)*
- *We do not consider (enough) real timescales, real costs including personnel and operation, available resources when this exercise is made and existing commitments are folded in*
- *International collaboration we all support, but almost in all cases it means "support my project"*

(2) Impressing achievements have been made in astrophysical/cosmological/GWs observations and detections in last decade. The progress expected to be made in the coming decades along these directions may have important impacts for the future development of HEP in terms of scientific targets, strategies, etc.

- *Correct, but with our long timescales for future accelerators and no clear energy scale for BSM, this is good ? The planning of future colliders (in particular beyond a Higgs factory) will benefit*
- *I also consider lower energy accelerator based (or not) searches (Light DM, dark sector, quantum devices/effects) important at this stage*