Special Beam Physics Seminar

Highlights of the 2007 Particle Accelerator Conference

Andrew Hutton, Yuhong Zhang, and Rong-Li Geng

July 19, 2007

3:30 p.m.

CEBAF Center, Room F113

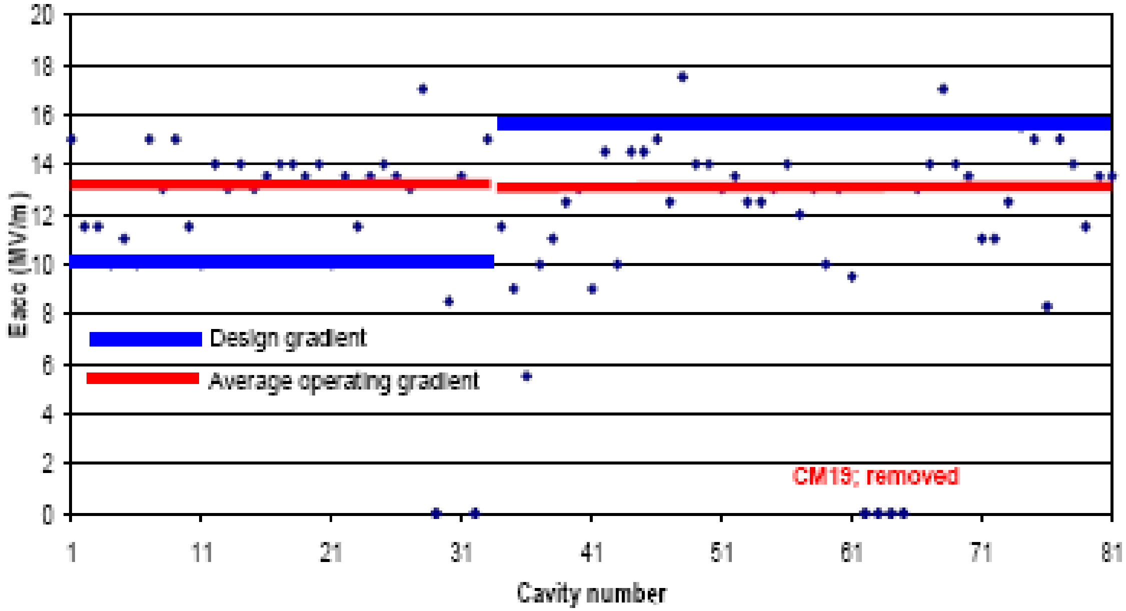
Rong-Li Geng
SRF Institute

SRF Highlights at PAC2007

- SNS – Achievements and Lessons Learned
- ILC R & D – High Gradient Frontier
- ERL & FEL – High Q and High Current Frontier
- New cavity facilities
- Multipacting simulation
- Crab cravity

SNS Formal Operation Began Oct. 2006

- Linac output energy highest demonstration 1010 MeV, nominal 890 MeV
- 77 cavities installed: 75 in operation, 2 offline; one high-beta module removed from tunnel for repair.
- Design 2.1K operation, but most run so far at 4.5K
- Foremost challenge: Beamloss 1 Watt/m
- Heavy field emission heats end groups and limits operation gradient



Lessons learned about FE in SNS Cavities

- Field emission affects neighbor cavities and causes heating. These effects limit availability when rep rate is increased to 60 Hz
- FE on-set gradient 10 MV/m +/- 3 MV/m
- FE a major contributor to cyogenic loss
- Individual cavity amplitude/phase control useful in FE mitigation

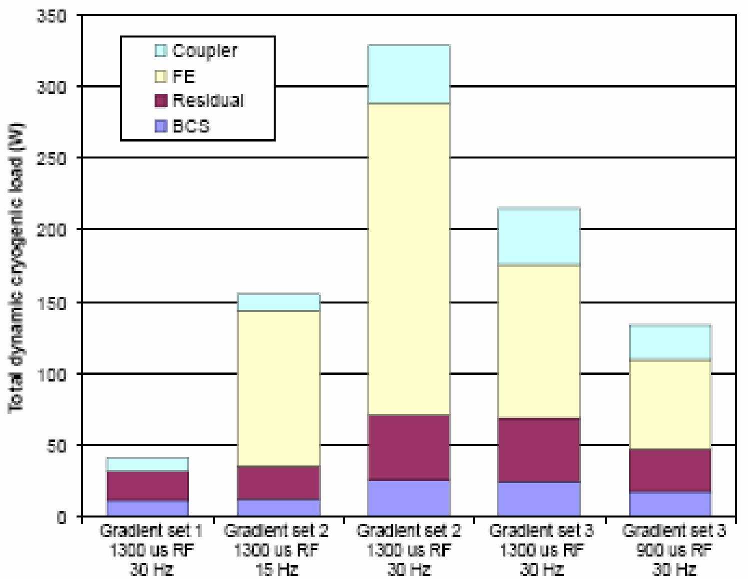


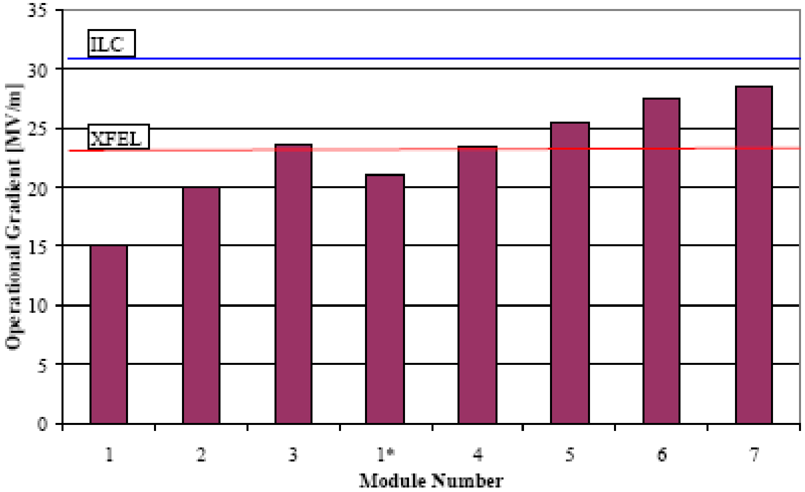
Figure 9. Classification of cryogenic loads from RF.

Future plan:
- HOM filter re-work
- Acquire spare cavity & module
- …

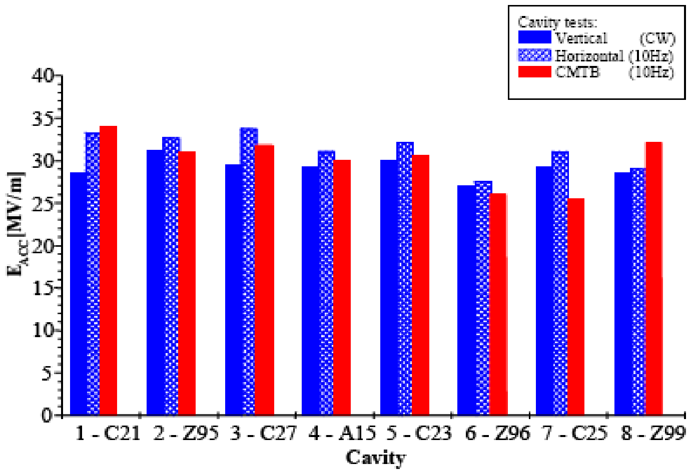
ILC High-Gradient Cavity R & D

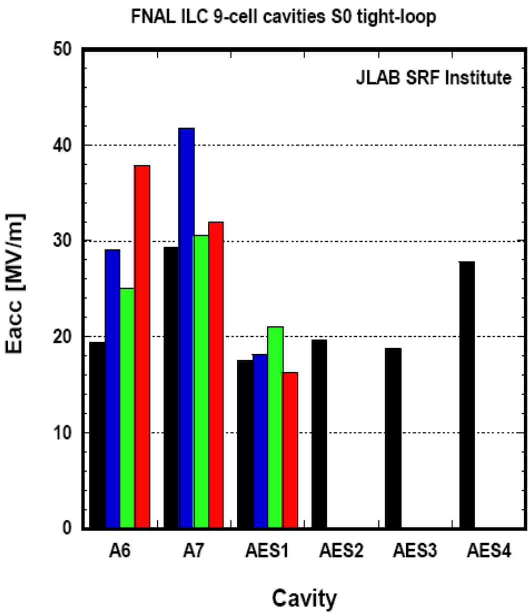
Realizing gradient goal is cruicial

35 MV/m vertical test acceptance; 31.5 MV/m module operation



Not there yet!





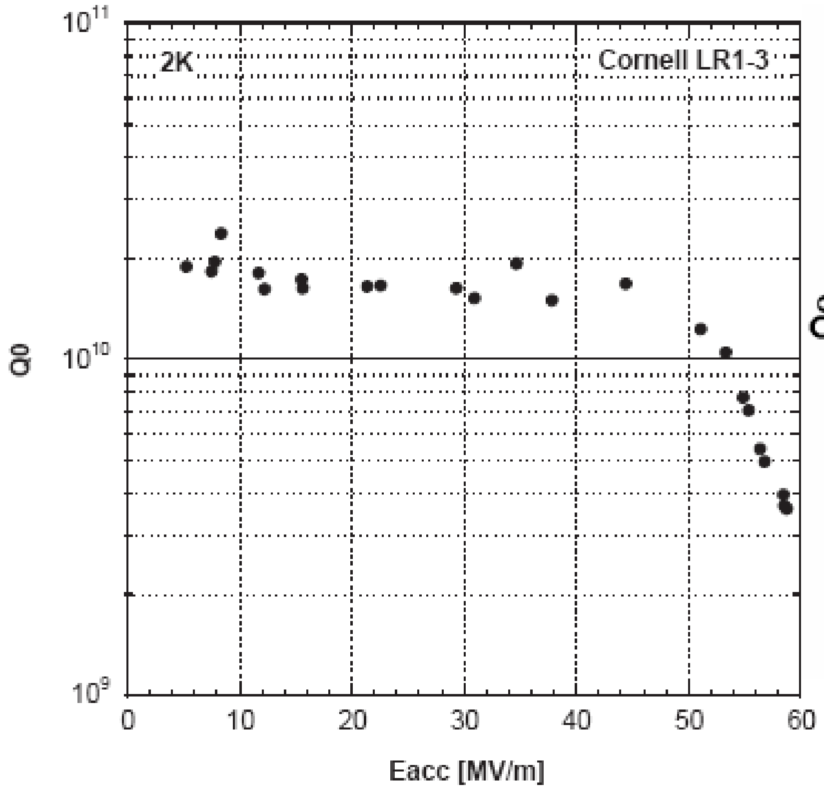
ILC 9-cell

New Results on 1-Cell New Shape Cavities

Cornell

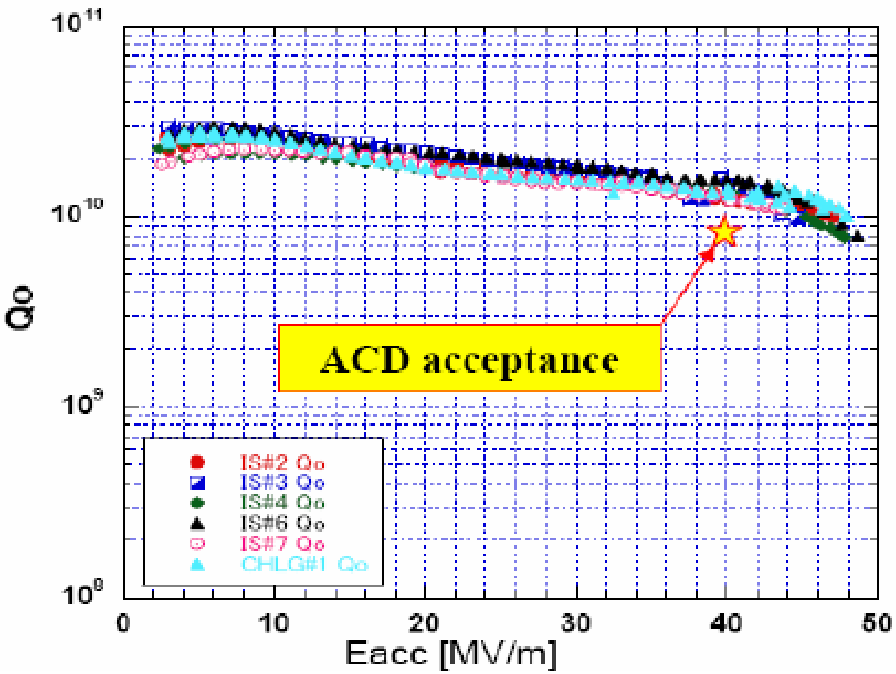
Gradient 59 MV/m in re-entrant cavity

Record Hpk 2065 Oe



KEK

More low-loss cavities reach > 45 MV/m



New Results on Large-Grain Niobium Cavities

EP gives better gradient – also better Q0

Table 1: Summary of the RF test results

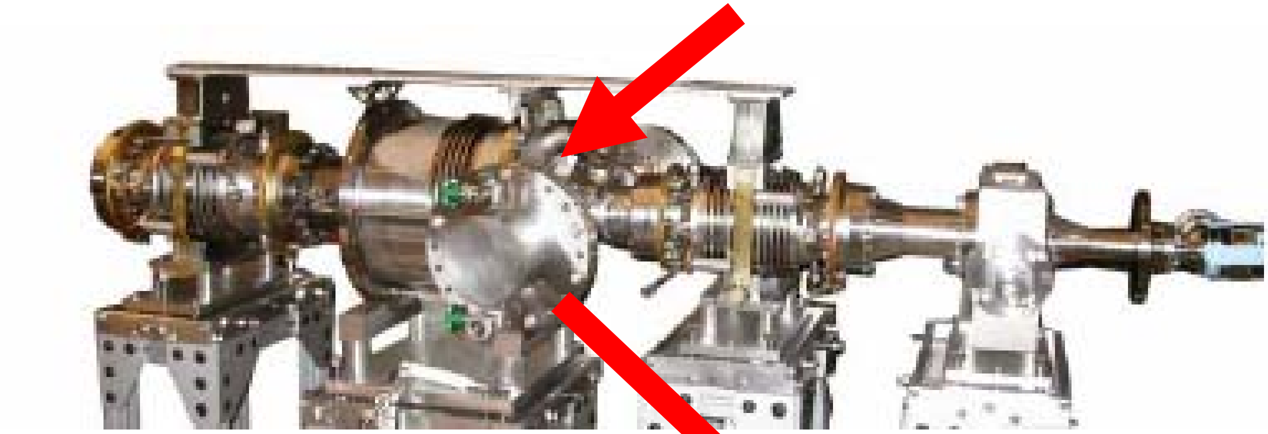
Material of the company	No./Type	Treatment	Eacc, MV/m	Qo at Eacc=23.5	Limitation
Heraeus/large grain	1AC3/single cell	190µm **EP**, 800°C 2h, 120°C 48h, HPR	41.2	3.2E+10	Quench at equator
		52µm **BCP,** 133°C 48h	28.5	1.2E+10	Quench
Heraeus/large grain	1AC4/single cell	190µm **EP**, 800°C 2h, 120°C 48h, HPR	38,5	2.3E+10	Quench at equator
		41µm **BCP,** 135°C 48h,	28,2	1.2 E+10	Quench at equator
Heraeus/large grain (spinning)	1AC5/single cell	190 µm **EP**, 800°C 2h, 135°C 48h, HPR	29.7	2.0E+10	Quench, not equator
		85µm **BCP**, 127°C 110h	30.3	2.1E+10	
Heraeus/large grain	1AC7/single cell	220µm **BCP**, 800°C 2h, HPR, no baking	25.2	1.5E+10	Quench
		100µm**EP**, 120°C 48h, HPR	25.3	3.0E+10	
Heraeus/large grain	AC112/nine cell	**100 µm BCP**, 800°C, **20 µm BCP**, HPR	30,5	2.0E+10	Field Emission FE
Heraeus/large grain	AC113/nine cell	**100 µm BCP**, 800°C, **20 µm BCP**, HPR	27,4	2.0E+10	Quench at equator
Heraeus/large grain	AC114/nine cell	**100 µm BCP**, 800°C, **20 µm BCP**, HPR	28.7	2.1E+10	Quench probably FE induced

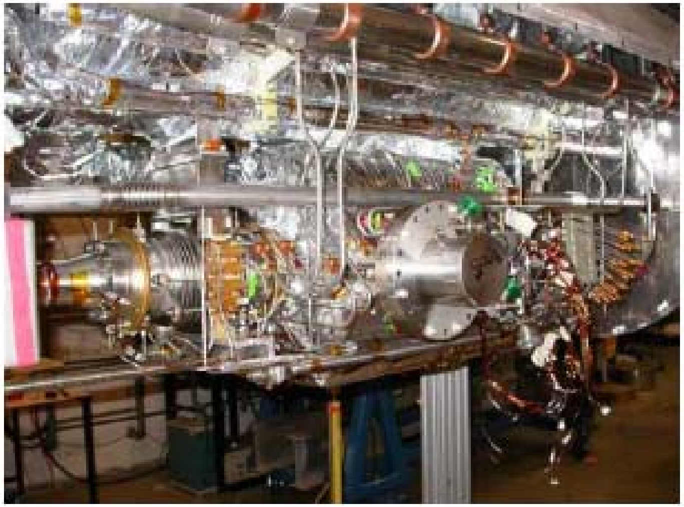
Large-grain 9-cell results: 27-30 MV/m, BCP etching only
DESY next step is EP 9-cell large-gram cavities

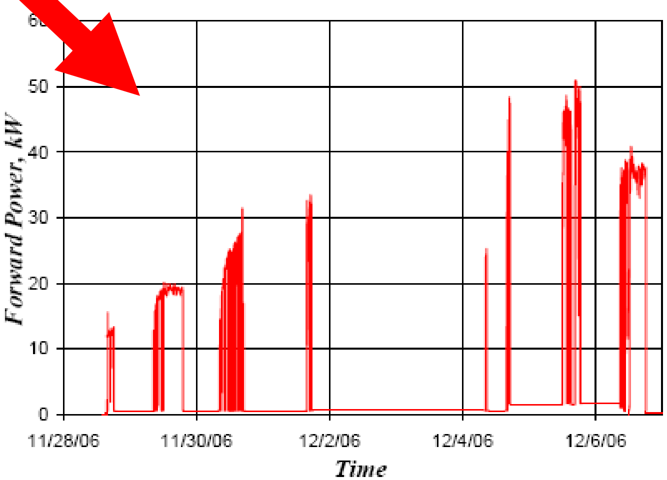
Cornell ERL Injector Prototype Going Well

1300 MHz input couplers tested to 50 kW, CW

1-cavity module first test July 2007



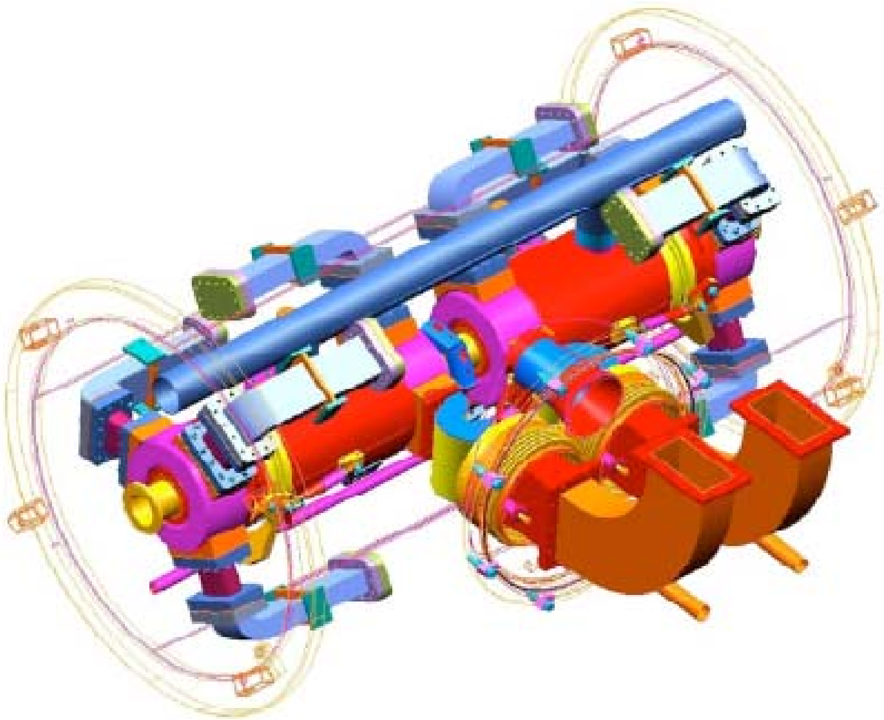




ANL Proposes ERL Upgrade of APS

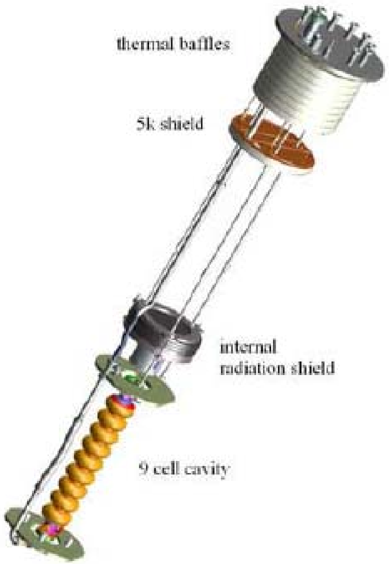
Operation gradient 20 MV/m
2K cryogenic loss 16 kW assuming Q – 1E10, 45 MW AC power for helium plant

JLAB High-Current Cryomodule

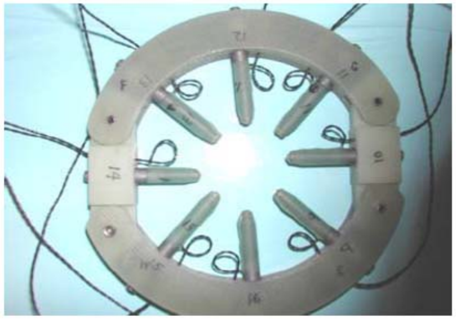


New SRF Facilities

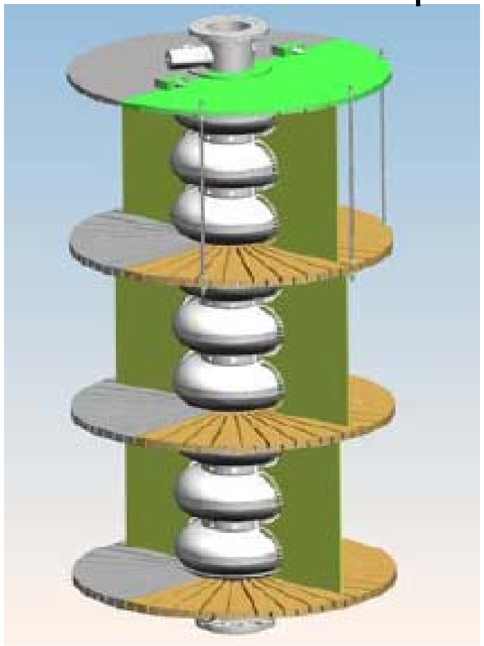
Fermi Lab cavity vertical test system



FNAL fast thermometry



LANL 9-cell T-map

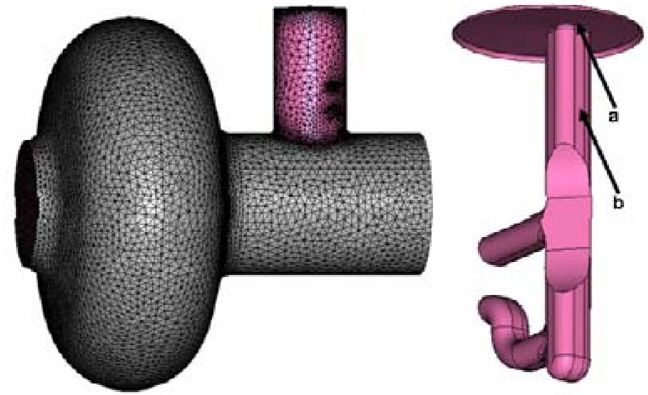


KEK STF SC system

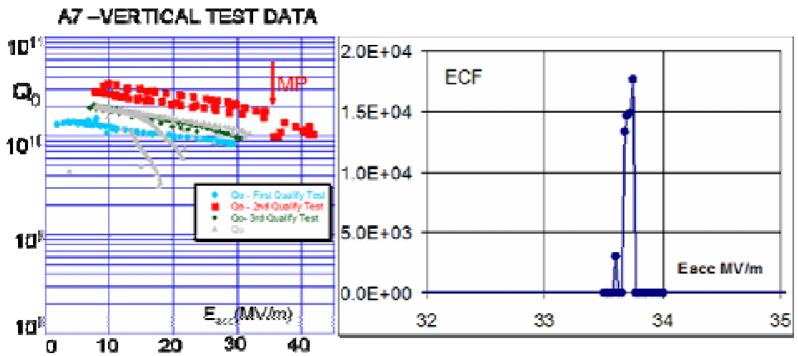
New 3D Multi-pacting Simulations

FNAL
STAAR Inc

HOM coupler in TESLA cavity



MP at Eacc 33-34 MV/m
Impact energy 480 eV



SLAC

SNS beta=0.81 cavity HOM coupler

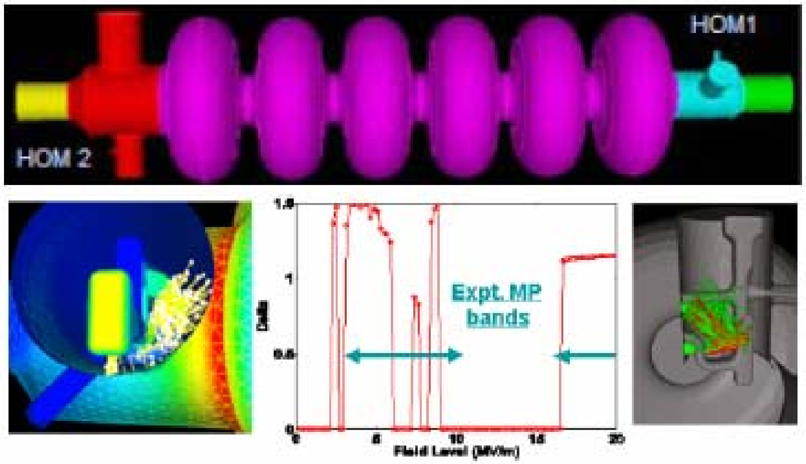
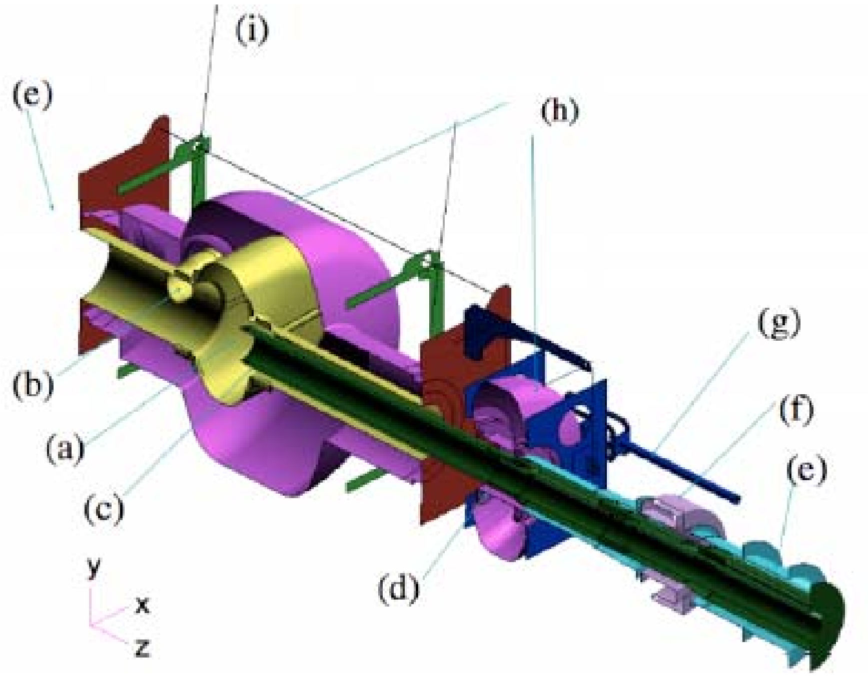


Figure 6: Multipacting in the SNS HOM coupler.

- Both SLAC result and FNAL result show MP in various HOM couplers
- Reasonably good agreement with exp.
- Codes are useful to elucidate exp.
- MP free design is ultimate goal

Crab Cavity Beam Tested at KEKB

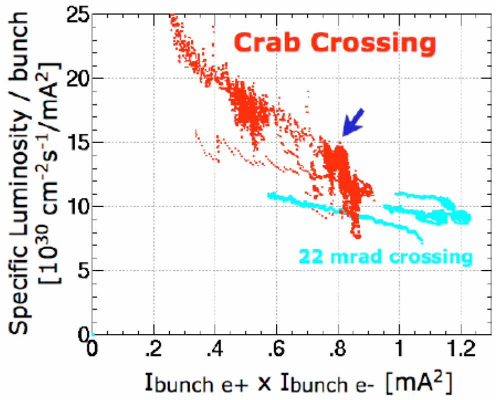
Lowest transverse mode produces horizontal kick



Accelerating mode goes out through coaxial coupler

Reached 1.8 MV kick voltage
Q0 > 1E9

Two cavities installed



Yuhong Zhang

CASA

Outline

- Electron-Ion Collider: statues and R&D (Ptitsyn)
- KEK Crab cavity development and commissioning (Oide)
- Crab waist scheme (Raimondi)
- Electron-cloud experiment and simulation (Fischer, Furman)
- Beam-beam compensation (Shiltsev)
- RHIC (Fedotov) and LHC (Zimmermann) upgrade

Acknowledgements

I would like to thank the following PAC 2007 speakers/authors for providing their slides and papers for preparing this review

- K. Oide (KEK)
- P. Raimondi (LNF-DA)
- Miguel Furman (LBL)
- Vladimir Shiltsev (Fermilab)
- Frank Zimmermann (CERN)
- Alexei Fedotov, Vadim Ptitsyn, Wolfram Fischer (BNL)

Disclaimer:

The following slides contain data, figures, pictures, slides, etc. from all the above authors, none of them is work of the speaker of this review talk.

From HERA to future electron-ion colliders

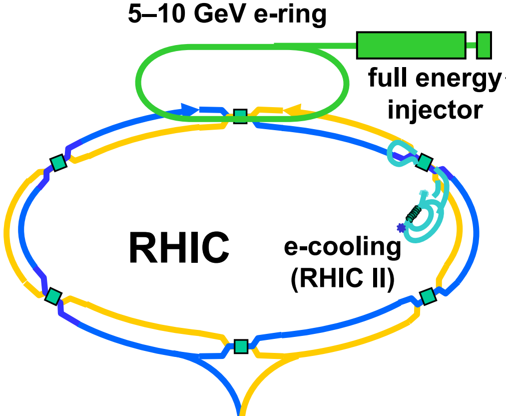
Vadim Ptitsyn
Collider-Accelerator Department
BNL

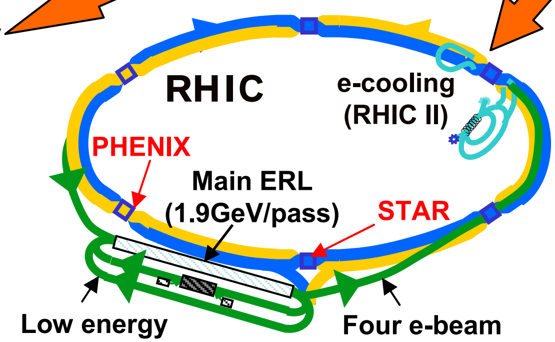
From HERA to Future electron-ion Colliders (Ptitsyn)

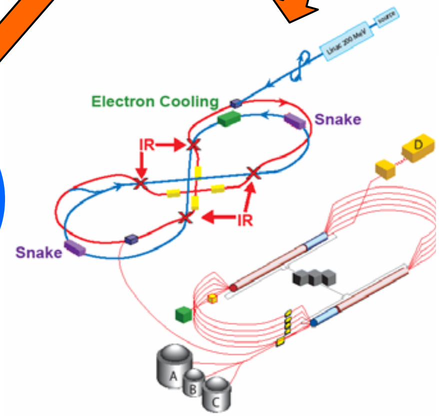
- Vadim Ptitsyn (BNL) gave an invited review talk
- Covered HERA (very success, but will end of its operation this year) and three new designs: ELIC, eRHIC (ring-ring & linac-ring), LHeC
- Discussed common and individual R&D programs
- Features:
  - strong beam focusing at IP, quick beam separation
  - large beam-beam parameters
  - Matching beam sizes at IP and matching beam frequencies
  - Electron cooling
  - Crab cavity (20-25 MV) for ELIC (30 *mrad*) and LHeC (2 *mrad*)
  - High current polarized e-gun (260 mA) and multi-pass ERL (up to 10 GeV) for eRHIC linac-ring design

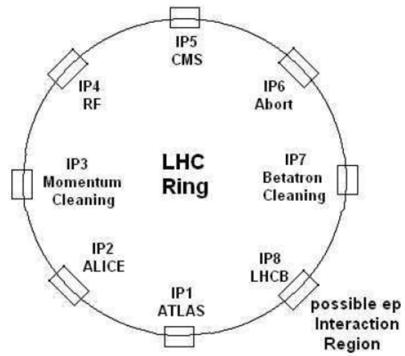
From HERA to Future electron-ion Colliders (Ptitsyn)

	HERA		eRHIC ring-ring		eRHIC ERL-ring		ELIC		LHeC	
	p	e	p	e	p	e	p	e	p	e
Energy, GeV	920	27.5	250	10	250	10	225	9	7000	70
Bunch freq., MHz	10.4		14.1		14.1		1500		40	
Bunch intensity, 10^{11}	0.72	0.29	1	2.3	2	1.2	0.04	0.075	1.7	0.14
Beam current, A	0.1	0.04	0.21	0.48	0.42	0.26	1	1.8	0.54	0.07
Rms emitt.,x/y, nm	5.1/5.1	20/3.4	9.5/9.5	53/9.5	3.8	1.0	5.1/0.2	5.1/0.2	0.5/0.5	7.6/3.8
b*, x/y, cm	245/18	63/26	108/27	19/27	26	100	0.5/0.5	0.5/0.5	180/50	13/7
Beam size at IP, x/y, mm	112/30		100/50		32/32		5/1		31/16	
Max b-b parameter/IP	0.0012	0.037	0.015	0.08	0.015	2.3	0.0064	0.086	0.0008	0.05
Bunch length, cm	19	1	20	1.2	20	1	0.5	0.5	7.6	0.7
Polarization, %	0	45	70	80	70	>80	>70	80	0	0
Peak Lum., 10^{33} $cm^{-2}s^{-1}$	0.04		0.47		2.6		75		1.1	









Compensation of the Crossing Angle with Crab Cavities at KEKB

First time in the world!

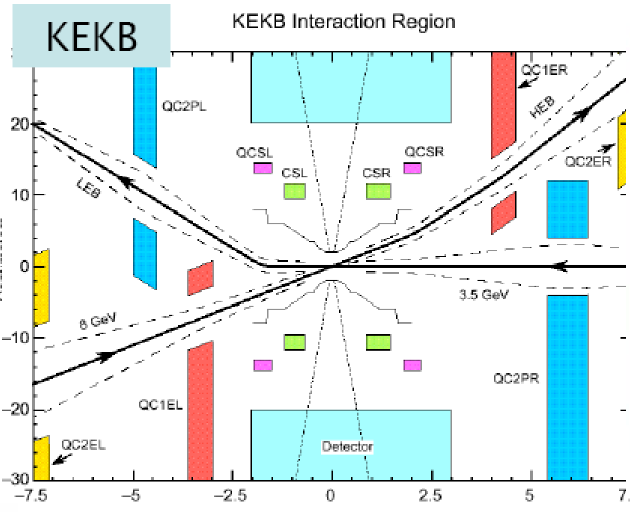
T. Abe, K. Akai, M. Akemoto, A. Akiyama, M. Arinaga, K. Ebihara, K. Egawa, A. Enomoto, J. Flanagan, S. Fukuda, H. Fukuma, Y. Funakoshi, K. Furukawa, T. Furuya, K. Hara, T. Higo, S. Hiramatsu, H. Hisamatsu, H. Honma, T. Honma, K. Hosoyama, T. Ieiri, N. Iida, H. Ikeda, M. Ikeda, S. Inagaki, S. Isagawa, H. Ishii, A. Kabe, E. Kadokura, T. Kageyama, K. Kakihara, E. Kako, S. Kamada, T. Kamitani, K. Kanazawa, H. Katagiri, S. Kato, T. Kawamoto, S. Kazakov, M. Kikuchi, E. Kikutani, K. Kitagawa, H. Koiso, Y. Kojima, I. Komada, T. Kubo, K. Kudo, N. Kudo, K. Marutsuka, M. Masuzawa, S. Matsumoto, T. Matsumoto, S. Michizono, K. Mikawa, T. Mimashi, S. Mitsunobu, K. Mori, A. Morita, Y. Morita, H. Nakai, H. Nakajima, T. T. Nakamura, H. Nakanishi, K. Nakanishi, K. Nakao, S. Ninomiya, Y. Ogawa, K. Ohmi, S. Ohsawa, Y. Ohsawa, Y. Ohnishi, N. Ohuchi, K. Oide, M. Ono, T. Ozaki, K. Saito, H. Sakai, Y. Sakamoto, M. Sato, M. Satoh, K. Shibata, T. Shidara, M. Shirai, A. Shirakawa, T. Sueno, M. Suetake, Y. Suetsugu, R. Sugahara, T. Sugimura, T. Suwada, O. Tajima, S. Takano, S. Takasaki, T. Takenaka, Y. Takeuchi, M. Tawada, M. Tejima, M. Tobiyama, N. Tokuda, S. Uehara, S. Uno, Y. Yamamoto, Y. Yano, K. Yokoyama, Ma. Yoshida, Mi. Yoshida, S. Yoshimoto, K. Yoshino,
KEK, Oho, Tsukuba, Ibaraki 305-0801, Japan
E. Perevedentsev, D. N. Shatilov, BINP, Novosibirsk, Russia

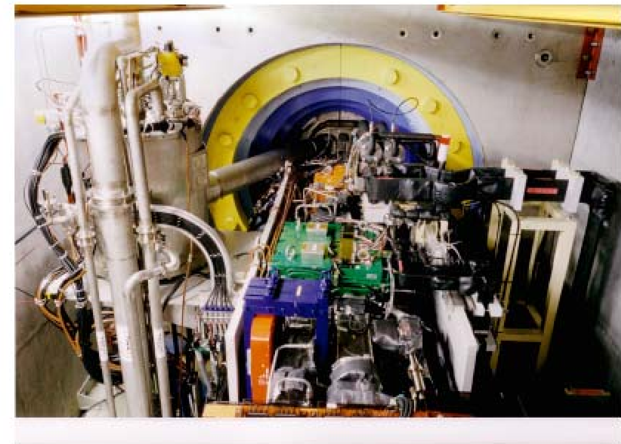
PAC07, 25 June 2007, MOZAKI01
Speaker: K. Oide

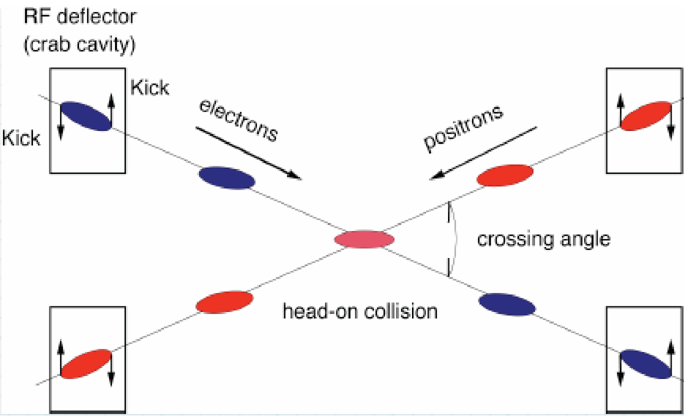
KEK Crab Cavity (Oide)

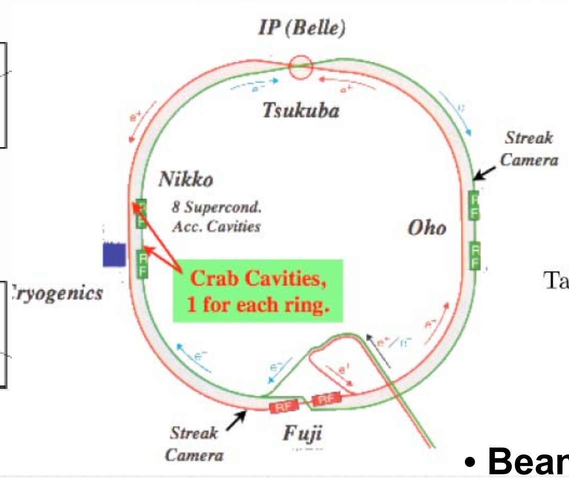
KEKB has 22 mrad horizontal crossing angle at the IP:

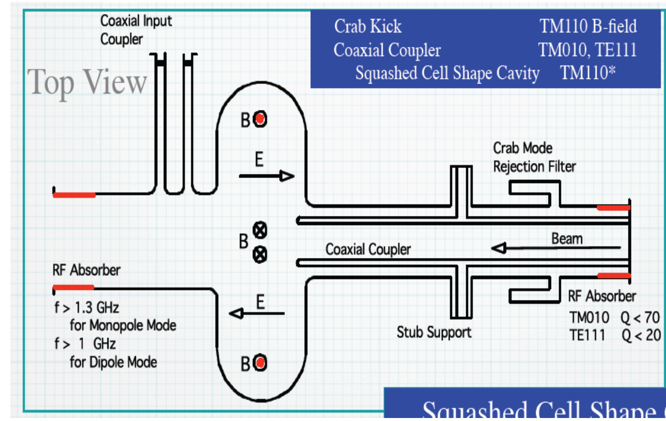
- Easier beam separation
- Simpler design around the IP.
- Less number of components.
- Less synchrotron radiation.
- Less luminosity-dependent background.
- Space for compensation solenoid, etc.









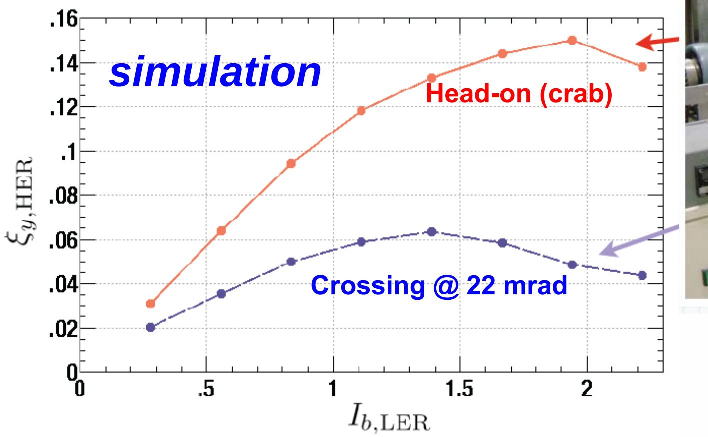


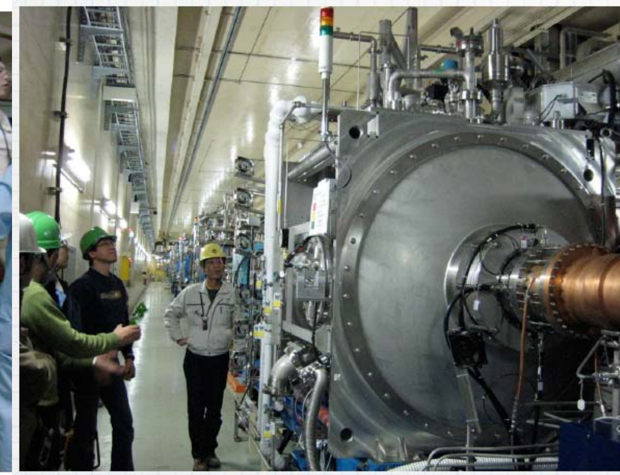
- One crab cavity per ring
- Saves the cost of the cavity and cryogenic
- Avoids synchrotron radiation hitting cavity

- Beam tilts all around the ring
- Z-dependent horizontal closed orbit
- Tilt at the IP

KEK Crab Cavity (Oide)

Crab crossing can boost the beam-beam parameter higher than 0.15! (K. Ohmi)





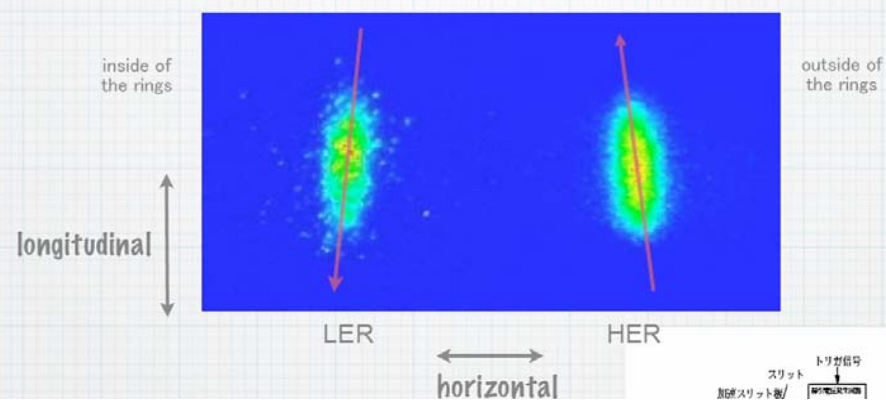
Squashed cell cavity @ TM110 B field

A number of checks have confirmed the effective head-on collisions

- streak camera
- crab-phase scan
- sign change and scan of crab voltage
- horizontal beam-beam kick
- vertical crabbing

Beams has indeed tilted!

- Observation with Streak Cameras (H. Ikeda et al, FRPMN035)



KEK Crab Cavity (Oide)

Specific Luminosity

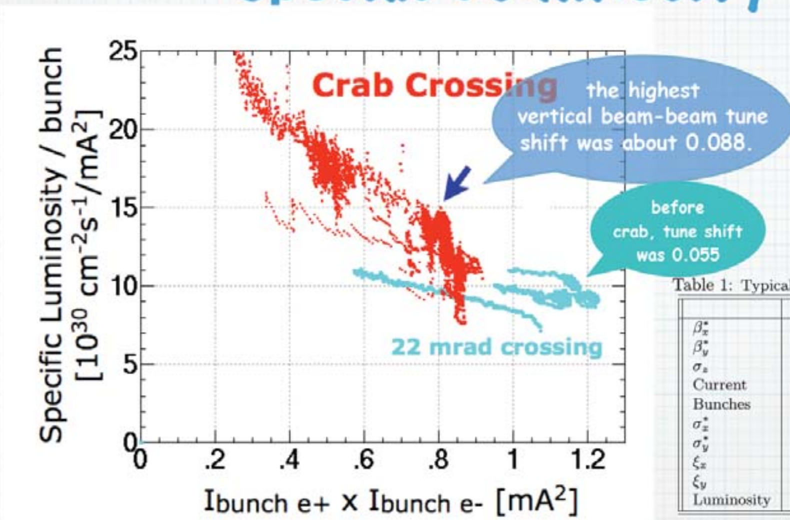


Table 1: Typical parameters for the crab crossing.

	LER	HER	
β_x^*	80	84	cm
β_y^*	0.59	0.65	cm
σ_z	~ 8	~ 6	mm
Current	60.9	33.3	mA
Bunches	50		
σ_x^*	120	140	μm
σ_y^*	1.3	1.3	μm
ξ_x	0.115	0.111	
ξ_y	0.108	0.088	
Luminosity	5.9		$10^{32} cm^{-2} s^{-1}$

- A number of measurements indicate effective head-on collision.
- The vertical tune shift became higher than 0.088. Before crab, it was 0.055.
- The specific luminosity / bunch was improved by about 15% more than the geometric gain.
- Need more time to achieve the goal (X2 specific luminosity).

KEK had built a very nice *world-first* crab cavity, but hadn't reached the predicted luminosity goal. They are checking issues:

- **Too many tuning knobs?**
- **Vertical emittance small enough?**
- **Synchrotron-betatron resonance?**

More Issues

- The LER solenoid was turned off to make the optics closer to the model, but no clear effect was seen on collisioin.
- A negative momentum compaction lattice was tried to mitigate the synchrotron-betatron resonances, but a microwave single-bunch instability was seen in the LER for Ib > 0.6 mA, so it was given up.
- The dynamic emittance blowup due to beam-beam effect, and its dilution to the vertical, is not a problem if the x-y coupling at the IP is corrected.

What concerns us (ELIC)?

- **Luminosity loss 99% without crab cavity**
- **Needs one KEK-type cavity for e-beam**
- **Needs 16 KEK-type cavities or multi-cell cavities for p-beam**
- **One cavity is enough for one ELIC ring?**
- **Effects of Synch-betatron resonance?**
- **Phace stability tolerance?**

SuperB design progress and Dafne Upgrade

P. Raimondi
for the LNF-DA Team

PAC, June 25, 2007

Crab Waist Scheme (Raimondi)

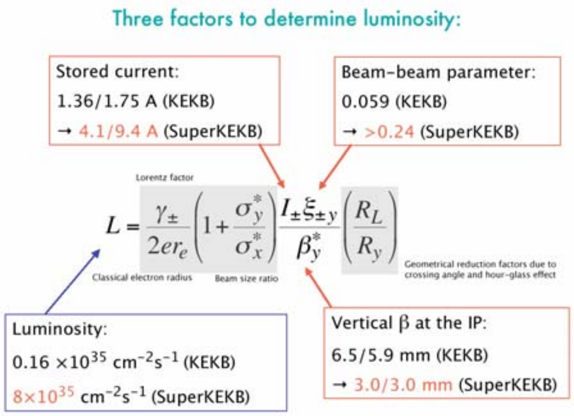
- B-factories: already ~10^{34} $s^{-1}cm^{-2}$.
- SuperKeKB: two orders of magnitude increase in luminosity

Parameters :

- Higher currents
- Smaller damping time
- Shorter bunches
- Crab collision
- Higher Disruption
- Higher power

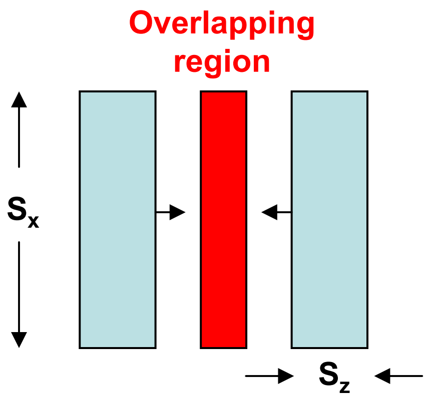
SuperKeKB Proposal is based on these concepts

- Linear extrapolation
- Parameters too aggressive
- Too high cost
- Fundamental limits

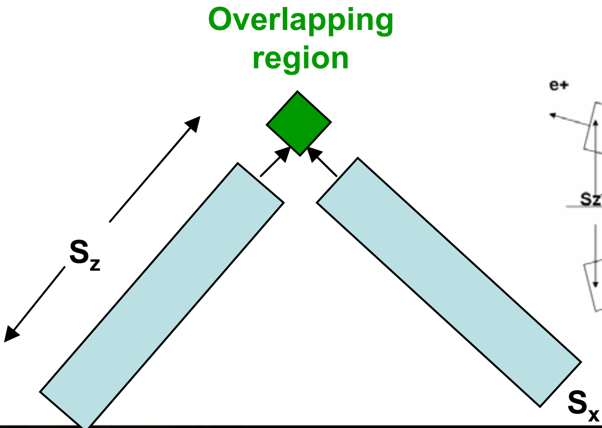


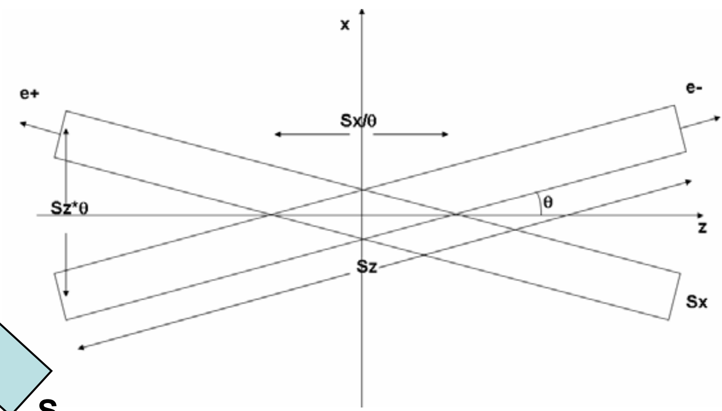
Very similar to the ELIC design!

1) **Standard short bunche schem**, for decreasing hourglass effect and beam disruption



2) **Crossing angle scheme**, Longer bunch and smaller σ_x with large crossing angle, x and z are **swapped at IP**





Crab Waist Scheme (Raimondi)

Crab Waist Advantages

1. Large Piwinski's angle

$\Phi = tg(\theta)\sigma_z/\sigma_x$

- a) Geometric luminosity gain
- b) Very low horizontal tune shift

2. Vertical beta comparable with overlap area

$\beta_y \quad \sigma_x/\theta$

- a) Geometric luminosity gain
- b) Lower vertical tune shift
- c) Vertical tune shift decreases with oscillation amplitude
- d) Suppression of vertical synch-betatron resonances

3. Crabbed waist transformation

$y = xy'/(2\theta)$

- a) Geometric luminosity gain
- b) Suppressing X-Y betatron & synch-betatron resonances

Crab Waist Scheme

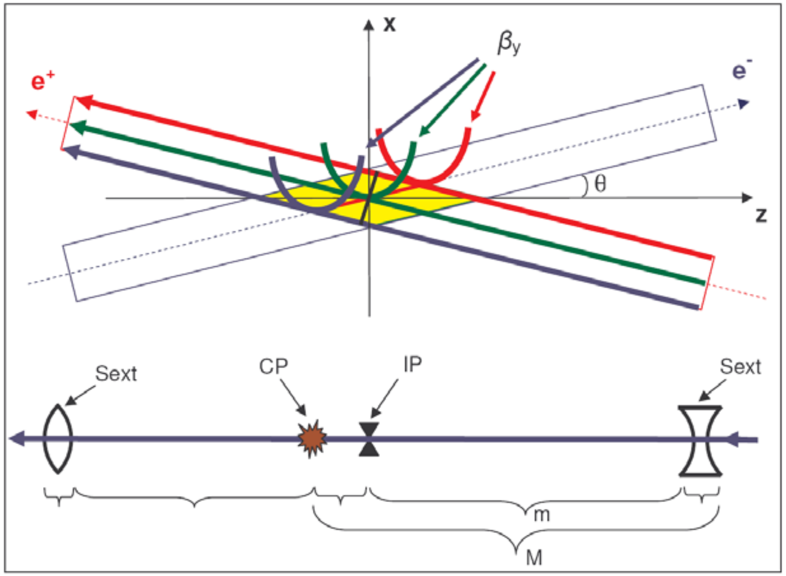
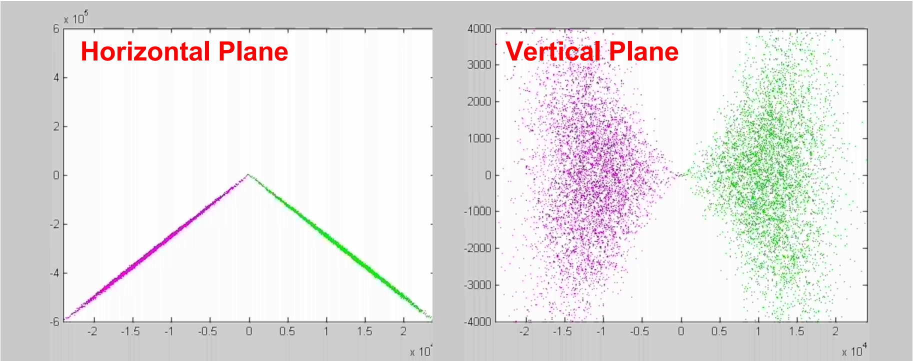


FIG.7: Collision in a "Crabbed Waist" scheme.

Collisions with uncompressed beams angle = 2*25mrad
Relative Emitt. growth per collision: $1.5*10^{-3}$ $\varepsilon_{yout}/\varepsilon_{yin}=1.0015$



What concerns us (ELIC) ?

- **Could this scheme be applied to ELIC?**
- **If so, no crab cavity is needed for ELIC**
- **Then what is the implication?**

ABSOLUTE MEASUREMENTS OF ELECTRON CLOUD DENSITY

M. Covo, R. Cohen, A. Friedman, A. Molvik (LLNL), D. Baca, F, Bieniosek, B. Logam, P. Seidl, J. Vay (LBNL), J. Vujic (UCB)

PAC07 – TUXAB01
Albuquerque, NM, June 26, 2007

Electron cloud experiments, and cures in RHIC

Wolfram Fischer
M. Blaskiewicz, H.-C. Hseuh, H. Huang, U. Iriso, V. Ptitsyn, T. Roser, P. Thieberger, D. Trbojevic, J. Wei, S.Y. Zhang

BROOKHAVEN NATIONAL LABORATORY

PAC'07 – Albuquerque, New Mexico
26 June 2007

SELF-CONSISTENT 3D MODELING OF ELECTRON CLOUD DYNAMICS AND BEAM RESPONSE

Miguel A. Furman
Lawrence Berkeley National Laboratory

PAC07 – TUXAB03
Albuquerque, NM, June 26, 2007

Electron Cloud in RHIC (Fischer)

E-cloud Observations in RHIC

- Dynamic pressure rise
- Tune shift
- Electrons
- Instabilities
  - Beam instabilities
  - Pressure instabilities
- Emittance growth

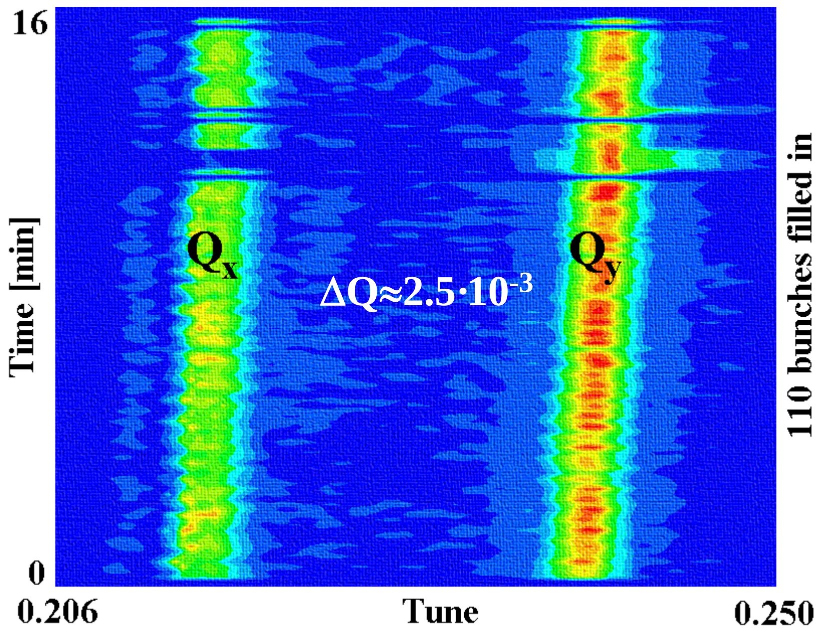
E-cloud curses in RHIC

- In-situ baking
- NEG coating
- Bunch patterns
- Solenoids
- Anti-grazing rings
- Pre-pumping in cold regions
- Scrubbing

Open Problems

- Instabilities during transition crossing
- Emittance growth

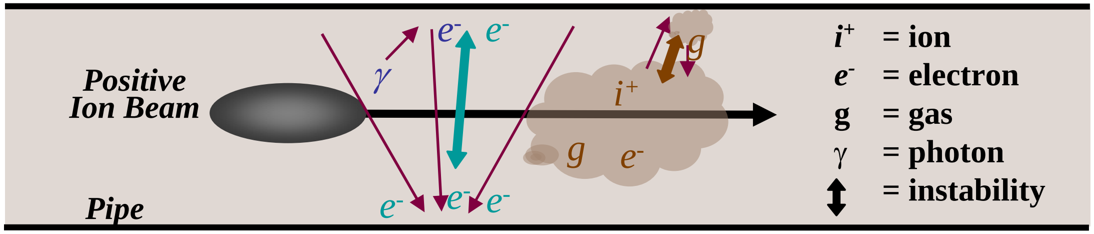
$33 \cdot 10^{11}$ p+ total, $0.3 \cdot 10^{11}$ p+/bunch, 110 bunches, 108 ns spacing (2002)



(1) From measured tune shift, the e-cloud density is estimated to be 0.2 – 2.0 $nC \cdot m^{-1}$

(2) E-cloud density can be reproduced in simulation with slightly higher charge and 110 bunches (CSEC by M. Blaskiewicz)

Electron Cloud Simulations (Furman)



Code WARP-POSINST

WARP → 3D self-consistent PIC code for beam transport
POSINST → 2D e-cloud build-up code with detailed secondary electron emission models

- Beam transport through arbitrary lattice (E & M)
- Arbitrary chamber shape (perfect conductor BC's)
- Space-charge effects
- Gas ionization
- Gas desorption off the walls and gas transport
- Charge-exchange reactions
- Primary and secondary electron emission sources
- Tracking of electrons

Self-consistency (SC):

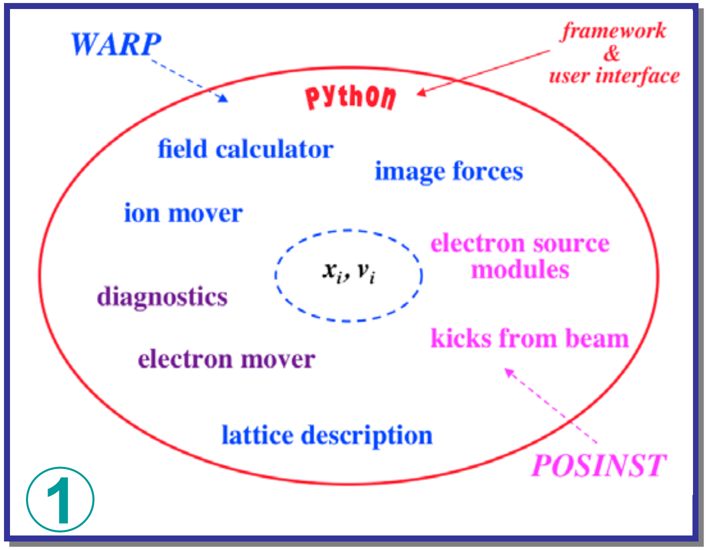
- Basic SC: beam-e-cloud mutual effects
- Full SC: residual gas ionization, beam losses and scraping, charge exchange, gas desorption,…

Primary electron sources:

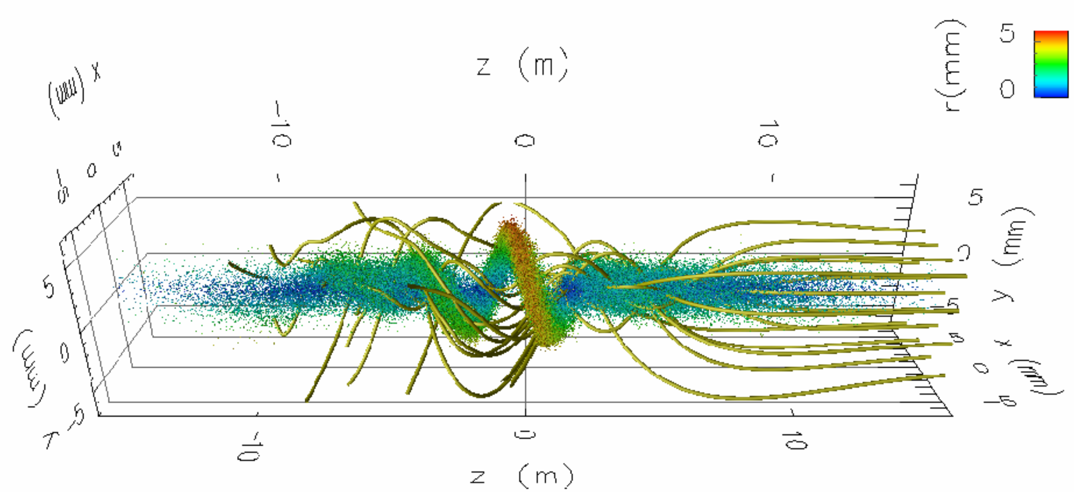
1 Ionization of
  background gas
  desorbed gas
2 Ion induced emission from
  expelled ions hitting vacuum wall
  beam halo scraping
3 photo-emission from synch-rad.

Secondary electron sources:

electron-wall collisions



Electron Cloud Simulations (Furman)



Run movie

Summary

- **WARP/POSINST code suite developed for HIF e-cloud studies**
  - **Parallel 3D AMR-PIC code for any given accelerator lattice follows beam self-consistently with gas/electron generation and evolution,**
- **Detailed validation at the HCX facility**
  - **highly instrumented section dedicated to e-cloud studies**
- **Successful code-to-code benchmarking**
- **Being applied to HEP accelerators**
  - **LHC, ILC damping ring, FNAL main injector, SPS, …**
- **Recent Lorentz-boosted frame algorithm:**
  - **cost of self-consistent calculation is greatly reduced thanks to relativistic contraction/dilation bridging space/time scales disparities,**
  - **1000x speedup demonstrated on proof-of-principle case,**
  - **will apply to LHC, Fermilab MI, ILC**
  - **some practical issues remain to be clarified, but very promising**

New algorithm

Experimental Demonstration of *Beam-Beam Compensation* by **Tevatron Electron Lenses** and Prospects for LHC

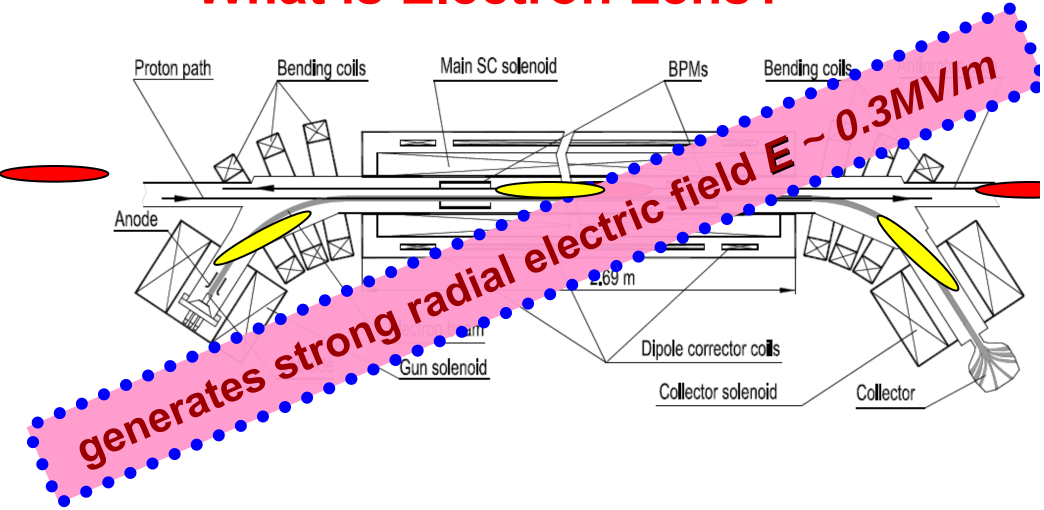
Vladimir Shiltsev
for FNAL Beam-Beam Compensation Team

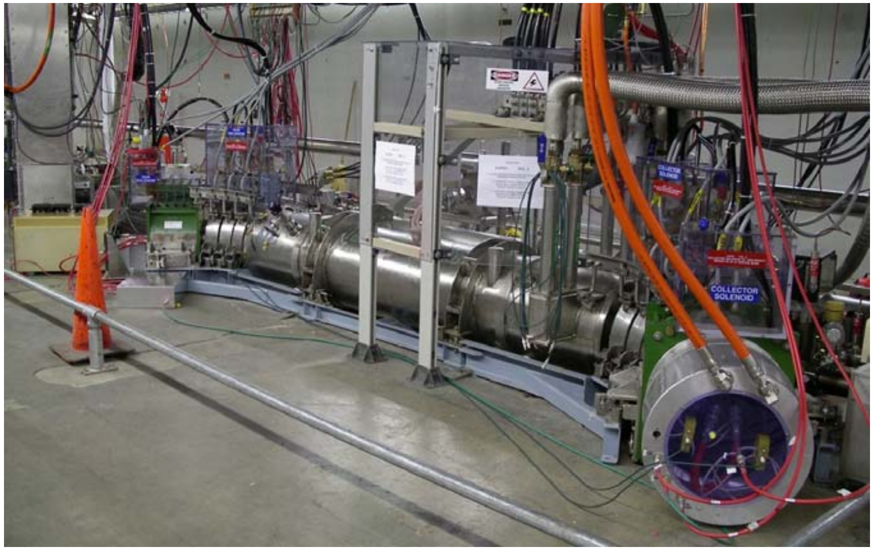
Yu.Alexahin, R.Hively, V.Kamerdzhiev, M.Kufer, G.Kuznetsov, H.Pfeffer, G.Saewert, V.Scarpine, V.Shiltsev N.Solyak, D.Wildman, D.Wolff, X.L.Zhang,

IEEE PAC 2007, June 26, 2007

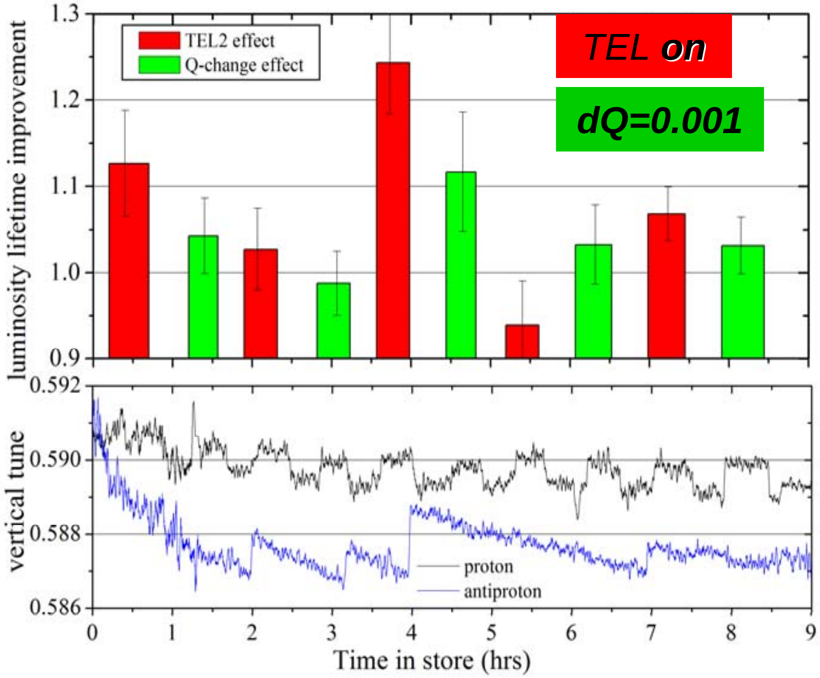
Beam-beam Compensation (Shiltsev)

What is Electron Lens?





12% Increase of Luminosity Lifetime



What concerns us (ELIC)?

Beam-beam Compensation

LARP Mini-Workshop on Beam-Beam Compensation 2007

Welcome to the LARP Mini-Workshop on Beam-Beam Compensation 2007

July 2 - 4, 2007
Stanford Linear Accelerator Center
Menlo Park, California

Research Office Building, SLAC

The US LHC Accelerator Research Program (LARP) hosts a mini-workshop on beam-beam compensation at SLAC. The workshop will review the experience with beam-beam compensation tests, both long-range and head-on, in existing machines (DCI, SPS, Tevatron, DAFNE, KEKB, RHIC), and outline milestones for the implementation of beam-beam compensation schemes in the LHC. It is also intended to be a platform for young scientists to present their work. The workshop is by invitation only.

Program

LARP Mini-Workshop on Beam-Beam Compensation 2007

Monday, 2 July 2007			
Morning I - Machines performances, Chair: A. Chao, SLAC			
8:45	15 min	J. Dorfan, SLAC	Welcome
9:00	35+10 min	F. Zimmermann, CERN	LHC expected beam-beam performance for nominal and upgrade parameters
9:45	35+10 min	K. Ohmi, KEK	B-Factories beam-beam performance
Morning II - Machines performances, Chair: A. Chao, SLAC			
10:45	35+10 min	A. Valishev, FNAL	Tevatron beam-beam phenomena and counter-measures
11:30	35+10 min	W. Fischer/C. Montag, BNL	RHIC beam-beam performance/New working point
Afternoon I - General simulations, Chair: F. Zimmermann, CERN			
1:30	20+10 min	A. Kabel, SLAC	What can be predicted with beam-beam simulations in hadron machines
2:00	20+10 min	A. Valishev, FNAL	Simulations that explain and predict beam-beam effects in the Tevatron
2:30	20+10 min	J. Qiang, LBNL	Beam-beam simulations for RHIC and LHC
Afternoon II - New operating modes, theory, unexplained observations, Chair: F. Zimmermann, CERN			
3:15	20+10 min	K. Ohmi, KEK	Experience with crab cavity operation in KEKB
3:45	20+10 min	Y. Alexahin, FNAL	Theory and reality of coherent effects in Tevatron, RHIC, and LHC
4:15	20+10 min	Y. Cai, SLAC	Unexplained phenomena in lepton machines
Tuesday, 3 July 2007			
Morning I - Long-range beam-beam compensation, Chair: V. Shiltsev, FNAL			
8:45	20+10 min	V. Kamerdzhiev, FNAL	Beam-beam compensation with TEL
9:15	20+10 min	U. Dorda, CERN	LHC with long-range compensation
9:45	20+10 min	C. Milardi, LNF-INFN	Long-range compensation in DAΦNE
Morning II - Long-range beam-beam compensation, Chair: V. Shiltsev, FNAL			
10:30	20+10 min	F. Zimmermann, CERN	Open issues from the SPS long-range experiments
11:00	20+10 min	N. Abreu, BNL	RHIC long-range experiments with a DC wire
11:30	20+10 min	H.J. Kim/T. Sen, FNAL	Simulation of RHIC experiments

RHIC Upgrade (Fedotov)

RHIC plans towards higher luminosity

Alexei Fedotov

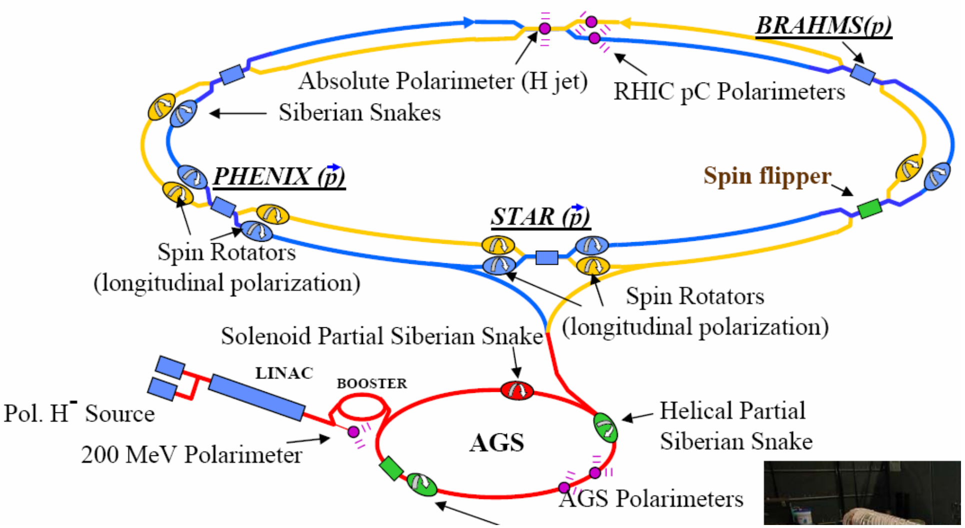
for Collider-Accelerator Department team, BNL

June 26, 2007

Upgrade Roadmap

1. Electron Beam Ion Source (EBIS)
2. Stochastic cooling
3. Electron cooling for RHIC-II
4. Low-energy RHIC operation
5. eRHIC

Polarized Hadron collider



RHIC II – major luminosity upgrade

Parameter	unit	Enhanced design	RHIC II
Au-Au operation			
Energy	GeV/n	100	100
No of bunches	...	111	111
Bunch intensity	10^9	1.0	1.0
Average $\mathcal{L}$	$10^{26}cm^{-2}s^{-1}$	8	70
p↑- p↑ operation			
Energy	GeV	250	250
No of bunches	...	111	111
Bunch intensity	10^{11}	2.0	2.0
Average $\mathcal{L}$	$10^{30}cm^{-2}s^{-1}$	150	400
Polarization $\mathcal{P}$	%	70	70

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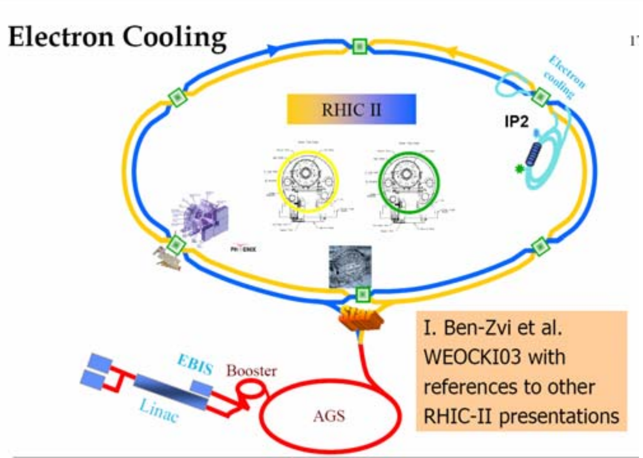
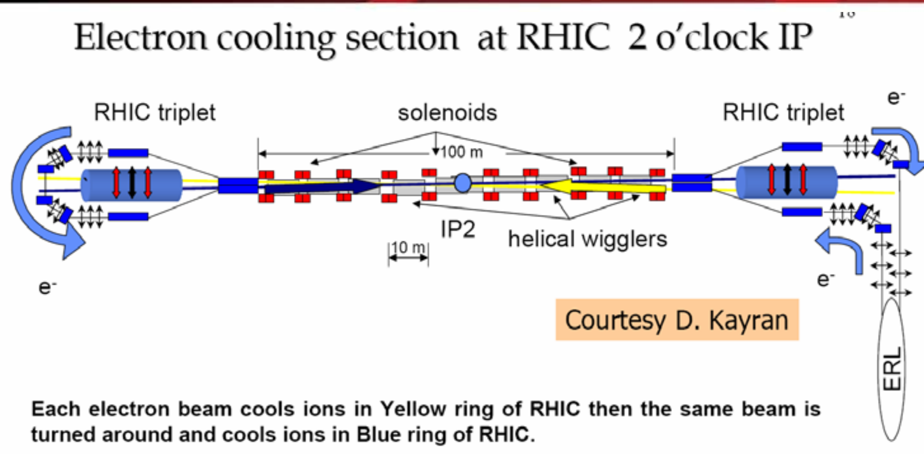
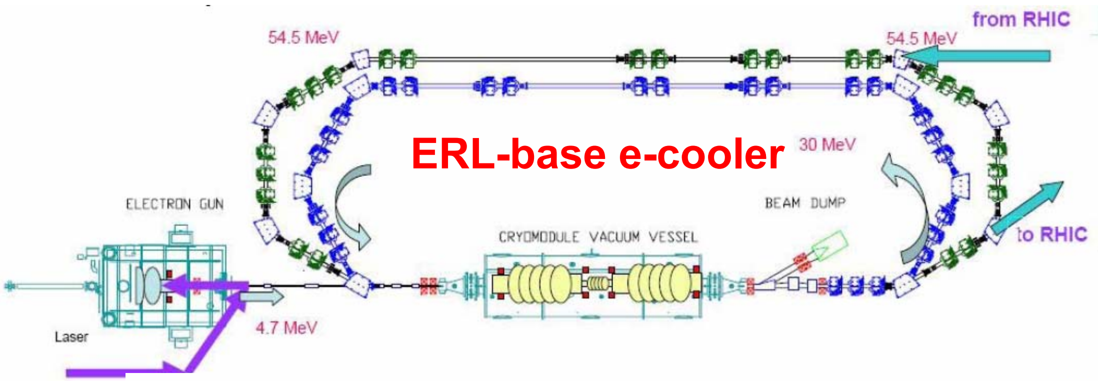
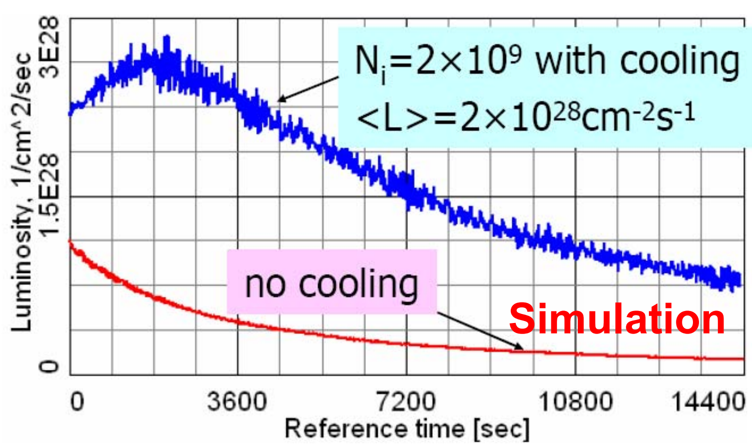
and e

RHIC Upgrade (Fedotov)





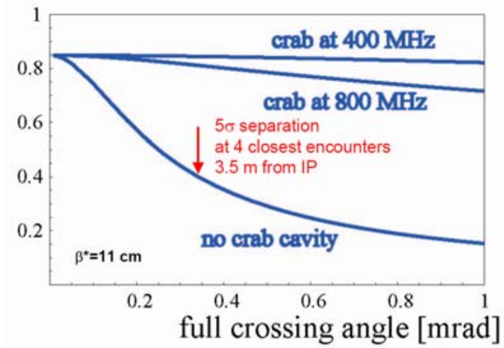




1. Provides cooling of various ion species at 100 GeV/nucleon.
2. Delivers luminosity required by RHIC-II upgrade.
3. Maintains short bunch length which is important for detectors.
4. Provides pre-cooling of protons (above transition energy) to required transverse and longitudinal emittances.
5. Provides cooling of various ion species at other collisions energies in the range of 25-100 GeV/nucleon.

LHC Upgrade (Zimmermann)

ES scheme needs crab cavities

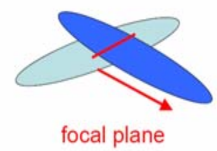


crab waist scheme

Hamiltonian $H_I = -\frac{1}{4} p_y^2 \left(\frac{2x}{\theta_c} \right)$

minimizes β at $s = -x/\theta_c$

initiated and led by LNF in the frame of FP7; first beam tests at DAFNE later in 2007



implementation:
add sextupoles at right phase distance from IP

parameter	symbol	Early Separation	Large Piwinski Angle
transverse emittance	ε [μm]	3.75	3.75
protons per bunch	N_b [10^{11}]	1.7	4.9
bunch spacing	Δt [ns]	25	50
beam current	I [A]	0.86	1.22
longitudinal profile		Gauss	Flat
rms bunch length	σ_z [cm]	7.55	11.8
beta* at IP1&5	β* [m]	0.08	0.25
full crossing angle	θ_c [μrad]	0	381
Piwinski parameter	$\phi = \theta_c \sigma_z / (2^* \sigma_x^*)$	0	2.0
hourglass reduction		0.86	0.99
peak luminosity	L [10^{34} cm^{-2}s^{-1}]	15.5	10.7
peak events per crossing		294	403
initial lumi lifetime	τ_L [h]	2.2	4.5
effective luminosity ($T_{turnaround}$=10 h)	L_{eff} [10^{34} cm^{-2}s^{-1}]	2.4	2.5
	$T_{run,opt}$ [h]	6.6	9.5
effective luminosity ($T_{turnaround}$=5 h)	L_{eff} [10^{34} cm^{-2}s^{-1}]	3.6	3.5
	$T_{run,opt}$ [h]	4.6	6.7
e-c heat SEY=1.4(1.3)	P [W/m]	1.04 (0.59)	0.36 (0.1)
SR heat load 4.6-20 K	P_{SR} [W/m]	0.25	0.36
image current heat	P_{IC} [W/m]	0.33	0.78
gas-s. 100 h (10 h) τ_b	P_{gas} [W/m]	0.06 (0.56)	0.09 (0.9)
extent luminous region	σ_l [cm]	3.7	5.3
comment		D0 + crab (+ Q0)	wire comp.

early separation (ES)
large Piwinski angle (LPA)

two new upgrade scenarios

compromises between heat load and # pile up events

ES scenario assessment

merits:
negligible long-range collisions,
no geometric luminosity loss,
no increase in beam current beyond ultimate,
could be adapted to crab waist collisions (LNF/FP7)

challenges:
D0 dipole deep inside detector (~3 m from IP),
optional Q0 doublet inside detector (~13 m from IP),
strong large-aperture quadrupoles (Nb_3Sn)
crab cavity for hadron beams (emittance growth),
or shorter bunches (requires much more RF)
4 parasitic collisions at 4-5σ separation,
off-momentum β beating 50% at $\delta = 3\times10^{-4}$ compromising collimation efficiency,
low beam and luminosity lifetime ~β*

LPA scenario assessment

merits:
no elements in detector, no crab cavities,
lower chromaticity,
less demand on IR quadrupoles
(NbTi expected to be possible),
could be adapted to crab waist collisions (LNF/FP7)

challenges:
operation with large Piwinski parameter unproven for hadron beams (except for CERN ISR),
high bunch charge,
beam production and acceleration through SPS,
larger beam current,
wire compensation (almost etablished),
off-momentum β beating ~30% at $\delta = 3\times10^{-4}$

Keep both options open until operation experience gained

Other interesting stuff

- **Electron cooling simulations (BNL, TechX)**
- **Electron gun development for eRHIC (BNL)**
- **Beam dynamics software development (LBL, TechX)**
- **Genetic algorithm based gun design optimization (several places)**
- **Beam-beam simulations (BNL, Fermilab)**