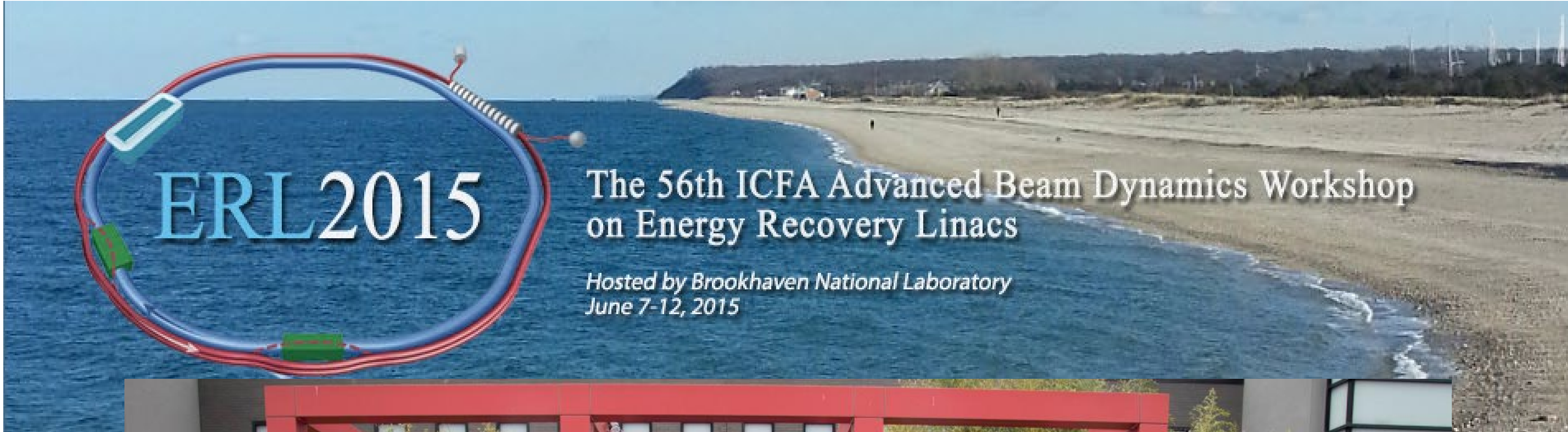
ERL2015 Report

ワークショップ期間：2015/6/7 - 12

ERL検討会 2015/06/25

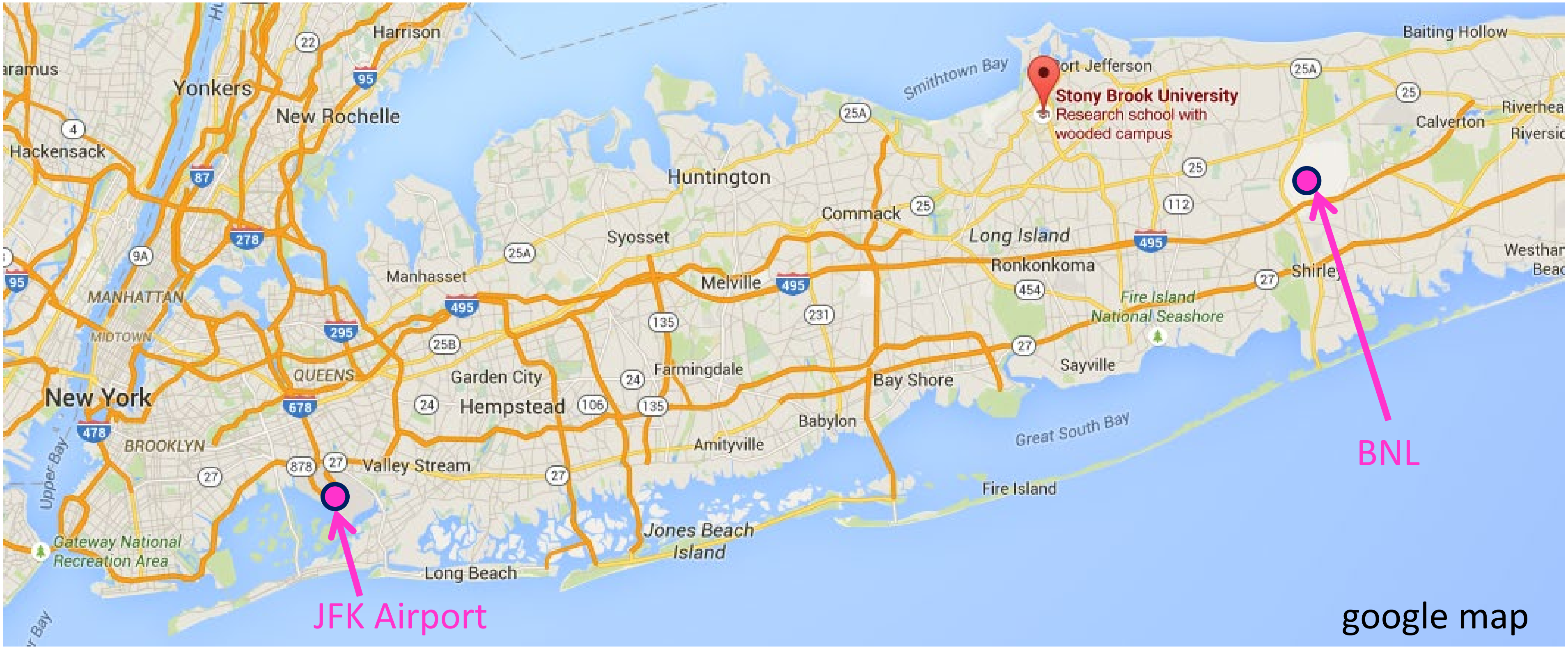
T. Obina


ERL2015
The 56th ICFA Advanced Beam Dynamics Workshop
on Energy Recovery Linacs
Hosted by Brookhaven National Laboratory
June 7-12, 2015


CHARLES B. WANG CENTER
ERL 2015

Location

- ワークショップ会場：Stony Brook University
  - JFK空港から車で１時間強
- 見学：BNL (Brookhaven National Laboratory)
  - ERL, ATF, NSLS2
  - ワークショップの見学とは別に Weixing Cheng氏, James Rose 氏に案内してもらった



参加人数・発表数

Area	人数
USA	72
Europe	26
Asia	16
Total	114

発表種別	数
Talk	72
Poster	12

Working Group / Convener について

- WG1 ERL Injectors: Injector Performance, Electron Guns, Cathodes, Lasers
  - Thorsten Kamps (HZB), Adam Bartnik (Cornell)
- WG2 ERL Beam Dynamics and Optics: Collective Effects, Multi-Pass Effects, Halo Simulations
  - Michael Abo-Bakr (HZB), Vadim Ptitsyn (BNL)
- WG3 ERL Beam Instrumentation, Controls, Beam Losses and Halo Management
  - Takashi Obina (KEK), Colwyn Gulliford (Cornell)
- WG4 ERL and SRF, including SRF System Performance, Field Stability, Synchronization, Special Requirements, HOM Damping
  - Hiroshi Sakai (KEK), Erk Jensen (CERN)
- WG5 ERL Applications
  - Vladimir Litvinenko (Stony Brook), Oliver Bruning (CERN)

Timetable

Plenary + Parallel + Poster

Parallel

Plenary

Parallel

Parallel

ポスター

WG Summary

Sunday - June 7

- 5pm-7pm Check in/ Registration

Monday - June 8

- Registration / Theater lobby
- **Theater**
  - Opening — S. Belomestnykh (BNL/SBU)
  - Welcome — I. Ben-Zvi (BNL)
  - Energy Recovery Linacs : Past, Present and Future — M. Tigner (Cornell University)
  - ERL-based Electron-Ion Colliders — V. Ptitsyn (BNL/SBU)
  - Group photo / Theatre lobby
- Coffee Break (15 min)
- **Theater**
  - The Femto-Science Factory: A Multi-turn ERL Based Light Source — T. Atkinson (HZB)
  - CERN SC RF and ERL Test Facility Plans — D. Pellegrini (CERN)
  - A FFAG-... Cornell Collaboration
  - bERLinPro Overview — J. Knobloch (HZB)
- Lunch on your Own (1 hr 35 min)
- **Theatre**
  - Successful Result of the Commissioning on cERL in KEK — S. Sakanaka (KEK)
  - Cornell Injector Performance — A. Bartnik (Cornell University)
  - 10 Years of ALICE: From Concept to Operational User Facility — P. Williams (ASTeC)
  - Design Work of the ERL-FEL as the High Intense EUV Light Source — N. Nakamura (KEK)
- Coffee Break (15 Min)
- **Theatre**
  - Overview of the State-of-the-Art Laser Techniques for Existing ERLs and the Needs for future High Current Machines — S. Zhang (Jlab)
  - High-Q R&D for SRF Challenge in ERLs — F. Furuta (Cornell University)
  - Microbunching Instabilities in ERLs - A Blessing or a Curse? — A. Meseck (HZB)
  - Status and Commissioning Results of the R&D ERL at BNL — D. Kayran (BNL)

Tuesday - June 9

- **Theater**
  - WG1 Challenges in Guns and Injectors — T. Kamps (HZB) & A. Bartnik (Cornell University)
  - WG2 Beam Dynamics Challenges in ERLs — M. Abo-Bakr (HZB) & V. Ptitsyn (BNL)
  - WG3 ERL Instrumentation and Control — T. Obina (KEK) & C. Gulliford (Cornell University)
  - WG4 SRF challenges in ERLs — H. Sakai (KEK) & E. Jensen (CERN)
  - WG5 Applications — V. Litvinenko (BNL/SBU) & O. Bruning (CERN)
  - Discussion
- Coffee Break (15 min)
- **Lecture Hall 1**
  - Operational Experience of DC Photoemission Gun at the Compact ERL — N. Nishimori (JAEA)
  - Development of a 500 kV DC Gun with Narrow Gap — M.Yamamoto (KEK)
  - A High-Peak and H... Current, Low Emi... Lifetime Electron... ERL Applic... — X. Chang (Fa...
  - The Progress of Funneling Gun for eRHIC Injector — E. Wang (BNL)
- **Lecture Hall 2**
  - eRHIC: an Efficient Multi-Pass ERL based on FFAG Return Arcs — S. Brooks (BNL)
  - Correction Methods for Multi-Pass eRHIC Lattice with Large Chromaticity — C. Liu (BNL)
  - ... ERL Design and Beam-... sues — ...Lab)
  - Beam and Polarization Dynamics in Electron FFAG Lattices — F. Meot (BNL)
- Lunch on your Own (1 hr 35 min)
- **Lecture Hall 1**
  - High Accuracy Adaptive Laser and Electron Beam Shaping — J. M. Maxson (Cornell U.)
  - Solving the Roughness of Alkali Antimonides — J. Smedley (BNL)
  - In-situ XRR Analysis on Multialkali Antimonide Photocathode Grown by Sputtering — Z. Ding (SBU)
  - Characterization of Multi-Alkali antimonide Cathode at Cryogenic Temperature and its Performance in SRF Gun — E. Wang (BNL)
- **Lecture Hall 2**
  - Investigations on Transverse Beam Break Up Using a Recirculated Electron Beam — T. Kuerzeder (TU Darmstadt)
  - HOM-BBU Simulation for KEK ERL Light Source — S. Chen (KEK)
  - Linear Microbunching Gain Estimation Including CSR and LSC Impedances in Recirculation Machines — C-Y. Tsai (Virginia)
  - Study of CSR Impact on Electron Beam in the JLab ERL — C. Hall (Colorado State U.)
- Coffee Break (15 Min)
- **Lecture Hall 1**
  - Commissioning Program for the 704 MHz SRF Gun at BNL — W. Xu (BNL)
  - Commissioning and First RF Results of the 2nd 3.5 Cell SRF for ELBE — A. Arnold (HZDR)
  - First Beam Characterization of SRF Gun II at ELBE with a Cu Photocathode — J. Teichert (HZDR)
  - Discussion
- **Lecture Hall 2**
  - Transverse Emittance Preserving Arc Compressor: Sensitivity to Beam Optics, Charge and Energy — S. Di Mitri (Trieste)
  - Aspects of eRHIC Longitudinal Dynamics — Y. Hao (BNL)
  - Discussion

Wednesday - June 10

- **Lecture Hall 1**
  - Science Cases on ERL as a Synchrotron Light Source — H. Kawata (KEK)
  - ERL as FEL Driver — Y. Jing (BNL)
  - ERL Facility at CERN for Applications — E. Jensen (CERN)
  - An Lepton Energy-recovery-linac Scalable to TeV — V. Litvinenko (SBU/BNL)
- **Lecture Hall 2**
  - Non-destructive Beam Position Monitoring in Two-Beam Section of ERL — T. Obina (KEK)
  - Beam Current Monitoring with ICT and BPM Electronics — I. Pinayev (BNL)
  - Fast Electron Beam and FEL Diagnostics at the ALICE IR-FEL at Daresbury Laboratory — F. Jackson (STFC Daresbury)
  - Current Measurement and Associated Machine Protection in the ERL at BNL — T. Miller (BNL)
  - Discussion
- Coffee Break (15 min)
- **Lecture Hall 1**
  - Current Status of the MESA Project — R. Heine (Institute for Nuclear Physics - Mainz University)
  - Laser Compton Sources Based On Energy Recovery Linacs — R. Hajima (JAEA)
  - Using ERLs fo... electron C... — I. Pinayev
  - ERL as High Intensity Mono-energetic Gamma-Ray Sources — V. Yakimenko (SLAC)
- **Lecture Hall 2**
  - Cornell's ERL Main Linac Cryomodule: Design, Construction and Results — R. Eichhorn (Cornell U.)
  - Operational Experience of CW SRF Injector and Main Linac Cryomodules at the Compact ERL — H. Sakai (KEK)
  - The Development of the High ...ucting Cavity — ...P)
  - Recent Progress in SRF Acceleration Technology at Peking University — S. Huang (Peking U.)
- Lunch on your Own (1 hr 35 min)
- **Lecture Hall 1**
  - Ultra-High Flux of X-ray/THz Source based on Asymmetric Dual Axis Energy Recovery Configuration — I. Konoplev (JAI, Oxford U.)
  - ERL for low energy electron cooling at RHIC (LEReC) — J. Kewisch (BNL)
  - An inverse Compton Scattering Beamline for High-energy, Time-resolved X-ray Scattering Studies of Materials — G. Hoffstaetter (Cornell U.)
  - Particle Physics Experiments with Cornell's FFAG ERL — M. Perelstein (Cornell U.)
- **Lecture Hall 2**
  - SRF Cavities for High Curent ERLs — W. Xu (BNL)
  - Development for Mass Production of Super-conducting Cavity by MHI — K. Kanaoka (Mitsubishi Heavy Industries, Ltd.)
  - Harmonic Resonant Kicker Design for the MEIC Electron Circular Cooler Ring — Y. Huang (IMP)
  - Discussion
- Coffee Break (15 Min)
- **Lecture Hall 1**
  - The Optics of the eRHIC Low Energy FFAG Cell with Realistic Field Maps — N. Tsoupas (BN)
  - Optics Considerations for the Cornell-BNL FFAG-ERL Test Accelerator — C. Mayes (Cornell U.)
  - Discussion
- **Lecture Hall 2**
  - Performance of the Digital LLRF Systems for cERL at KEK — F. Qiu (KEK)
  - Resonance Control for Narrow-Bandwidth, Superconducting Accelerator Applications — J. P. Holzbauer (KEK)
  - Using A 1.3GHz 20kW Solid State Amplifier As RF Power Supply For DC-SRF Photo-injector — F. Wang (Peking U.)
  - Discussion

Thursday - June 11

- **Lecture Hall 1**
  - Satellite Meeting
- **Lecture Hall 2**
  - Diagnostic Test-Beam-Line For The MESA Injector — I. Alexander (Institute for Nuclear Physics - ...z U.)
  - ...g Wire Scanner ...igh Intensity ...rators — ...ornell U.)
  - Detection and Clearing of Trapped Ions in the High Current Cornell Photoinjector — S. Full (Cornell U.)
  - GaAs Photocathode R&D — L. Jones (STFC/Cockcroft)
- Coffee Break (15 min)
- **Theater Lobby**
  - Poster Session
- Lunch on your Own (1 hr 35 min)
- **Theater**
  - WG1 Report Challenges in Guns and Injectors
  - WG2 Report Beam Dynamics Challenges in ERLs
  - Coffee Break (15 min)
  - WG4 Report SRF Challenges in ERLs
  - WG5 Report Applications
  - Close out talks / Adjourn

Friday - June 12

- BNL tour

会場

メイン会場

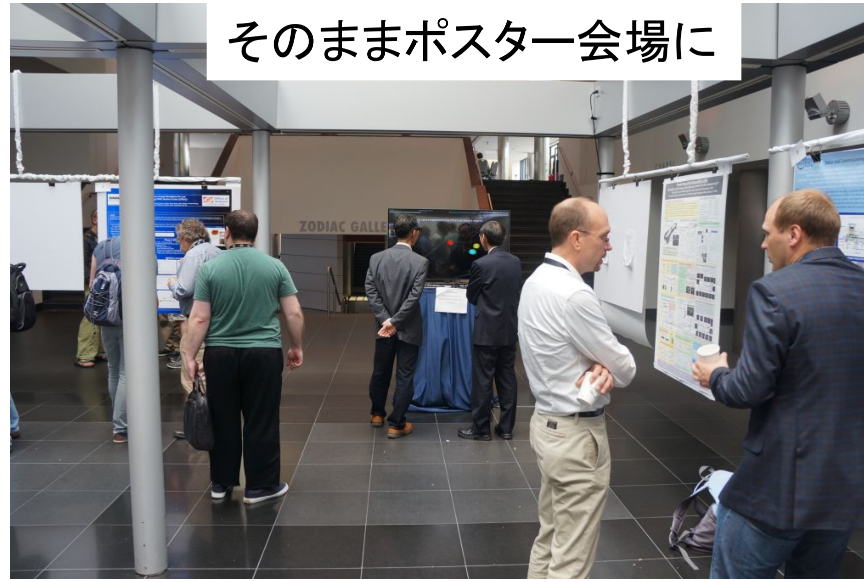
Parallel 1

Parallel 2

ポスター会場など

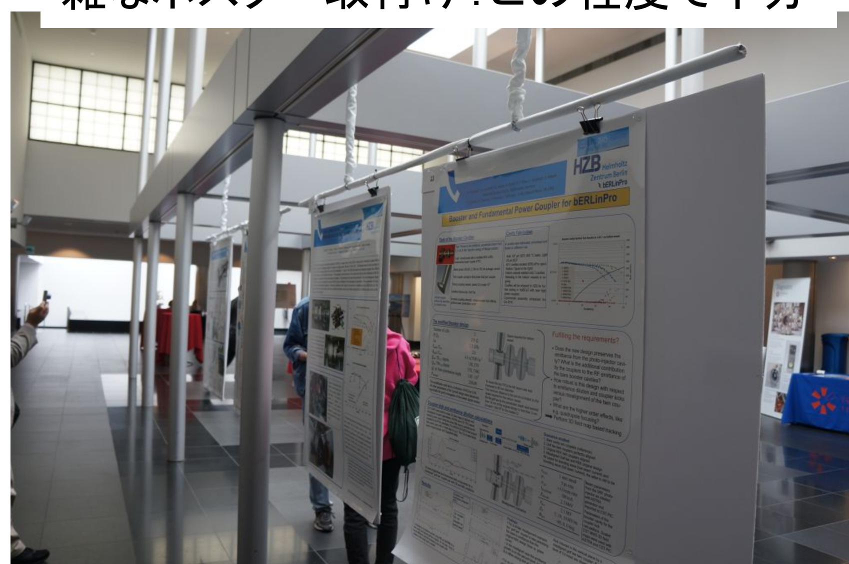
会場前のコーヒーテーブル

そのままポスター会場に



Cornell Cβの 3D Movie を上映中

雑なポスター取付け:この程度で十分



KEK/JAEA からの参加者

発表日時順

- 坂中 Plenary Talk
  - Successful Result of the Commissioning on cERL in KEK
- 中村 Plenary Talk
  - Design work of the ERL-FEL as the high intense EUV light source
- 山本（将）
  - Development of a 500 kV DC Gun with Narrow Gap
- 西森, IPC
  - Operational Experience of DC Photoemission Gun at the compact ERL
- Si Cheng
  - HOM-BBU Simulation for KEK ERL Light Source
- 河田, IOC
  - Science cases on ERL as a synchrotron light source
- 羽島, IOC
  - Laser Compton Sources Based On Energy Recovery Linacs
- 帯名, WG3 Convener
  - Non-destructive Beam Position Monitoring in Two-Beam Section of ERL
- 阪井, WG4 Convener
  - Operational Experience of CW SRF Injector and Main Linac Cryomodules at the Compact ERL
- Feng Qiu
  - Performance of the Digital LLRF Systems for cERL at KEK

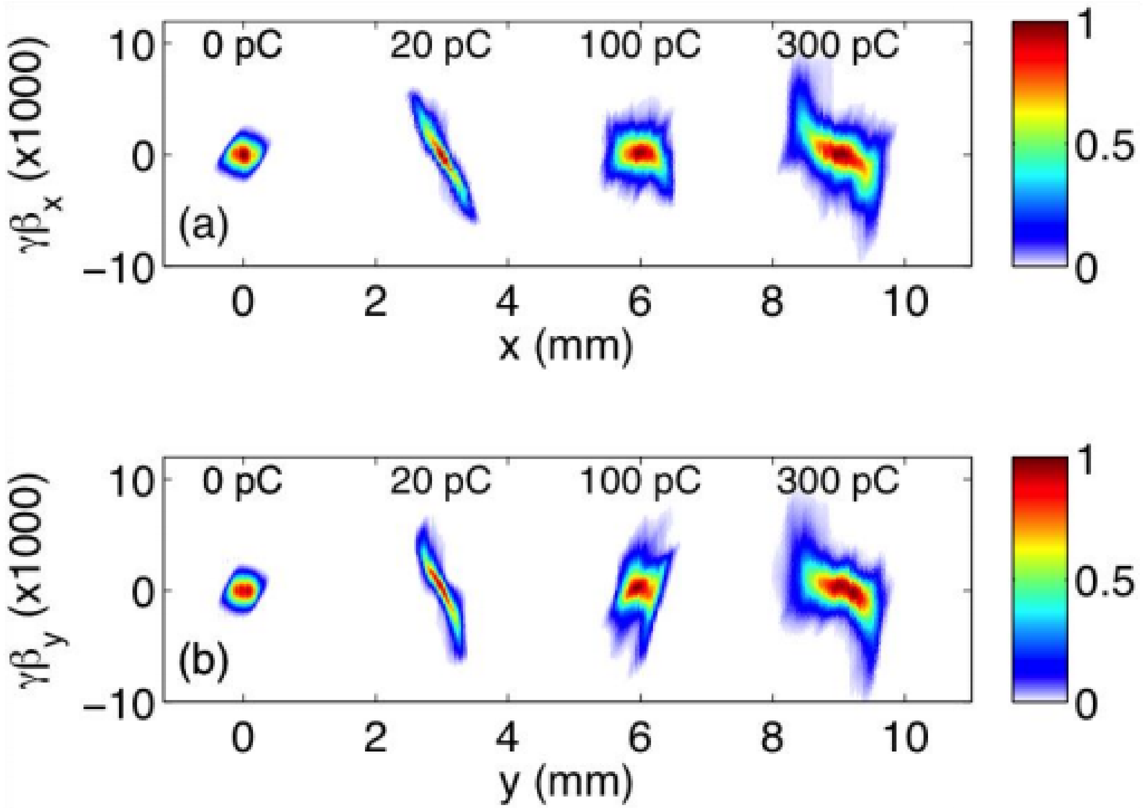
WG1 : Injector (Gun, Laser, Cathode)

- WG1 Summary Talk を参照
- Gun
  - RF / SRF / DC
  - Performance, limitations, operational experience
- カソード開発
  - Black magic or science ?
  - Roughness
  - Operational experience / frustrations
- レーザー開発
  - Power (more or less) solved
  - Need : Stability, synchronization, reliability
  - Shaping

西森さん、山本さんの発表について:
時間の関係で今日は言及しませんが、聴衆の反応はとても良く、今後の開発も非常に期待されていました

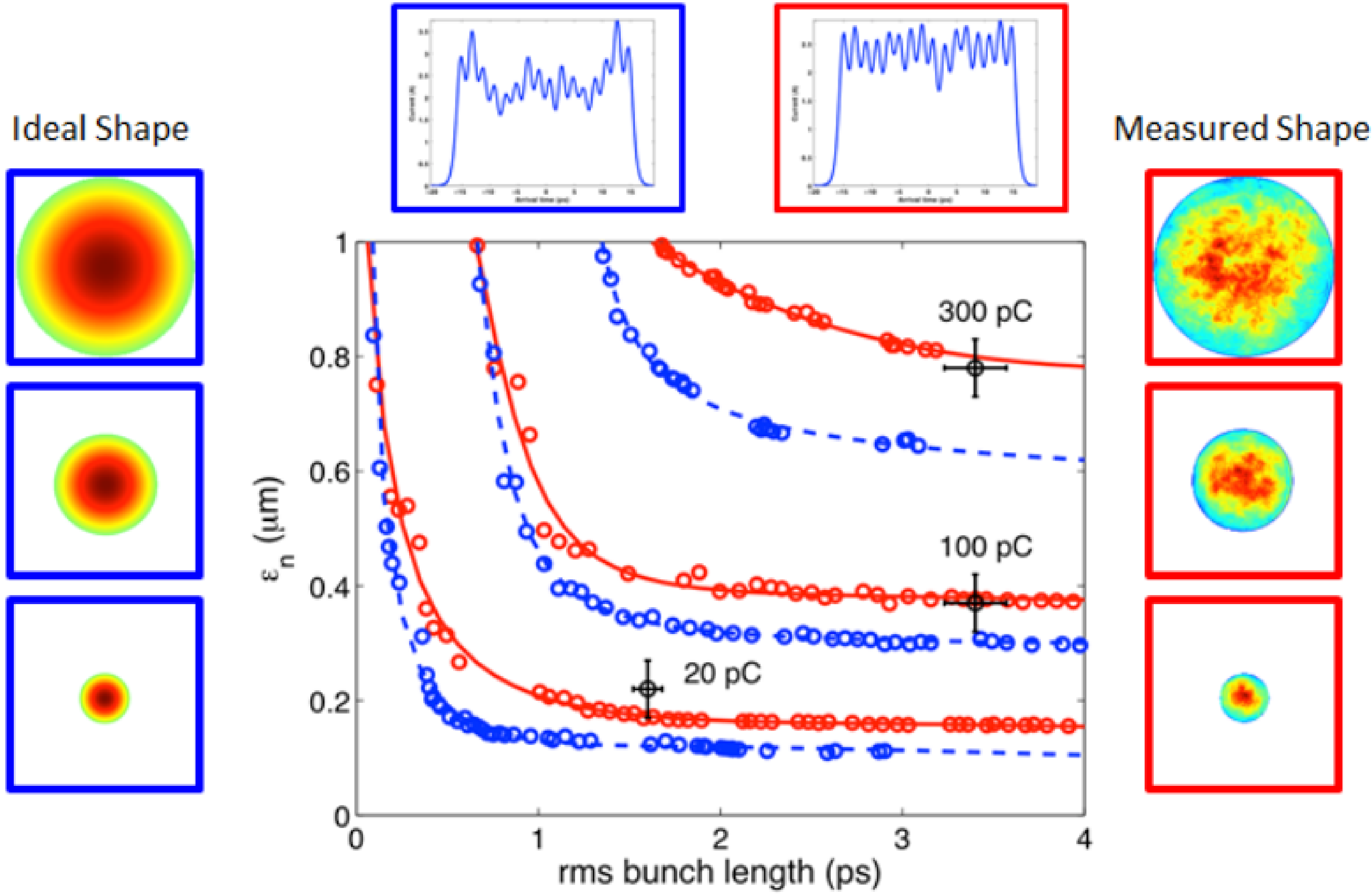
A. Bartnik (Cornell) - DC Gun / Injector
Met specification for LCLS-II FEL Injector

- No emittance asymmetry
- Met LCLS-II spec at all charges
- Same SRF settings for all charges



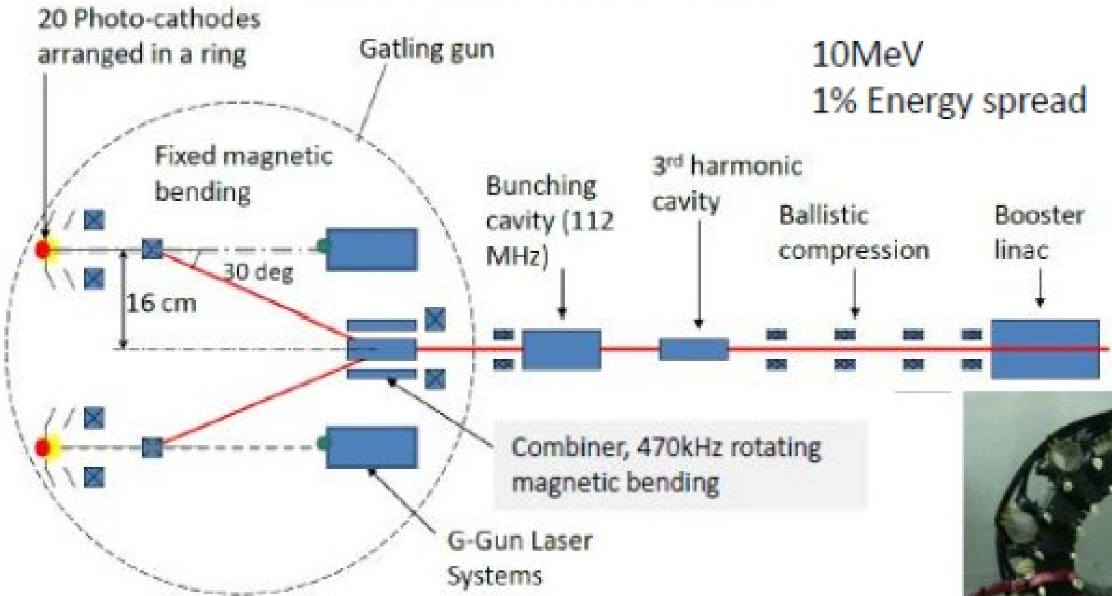
Q (pC)	I_{peak} Target (A)	I_{peak} (A)	ε_n Target (95%, µm)	ε_n (95%, µm)	$\varepsilon_{n,th} / \varepsilon_n$
20	5	5	0.25	**H:** 0.18, **V:** 0.19	**60%**
100	10	11.5	0.40	**H:** 0.32, **V:** 0.30	**80%**
300	30	32	0.60	**H:** 0.62, **V:** 0.60	**70%**

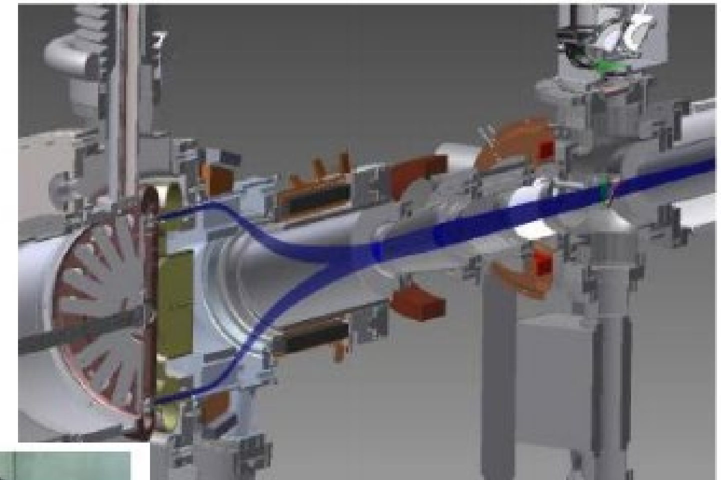
Cornell DC Gun / Injector
Good agreement when using real laser profile

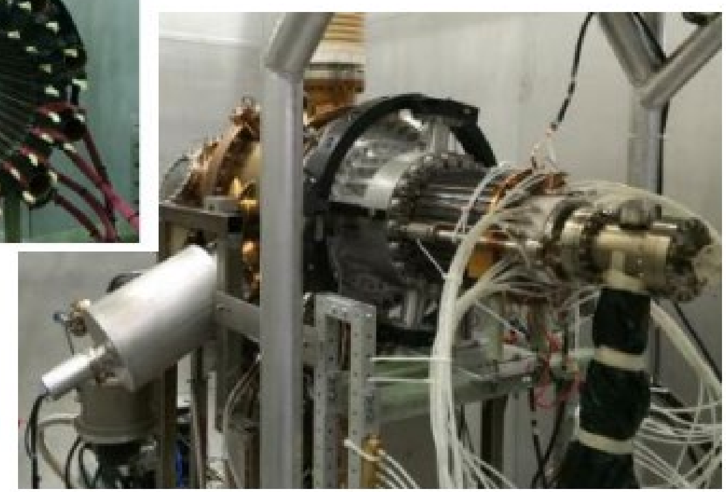


E. Wang (BNL) – Demo for a Funneling DC gun at 50 mA to maximise cathode standing time

Single cathode:470 KHz*5.3nC=2.5mA
After funneling:9.4 MHz*5.3nC=50mA



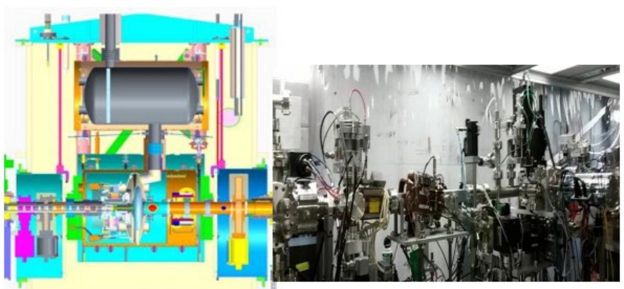




SRF Gun

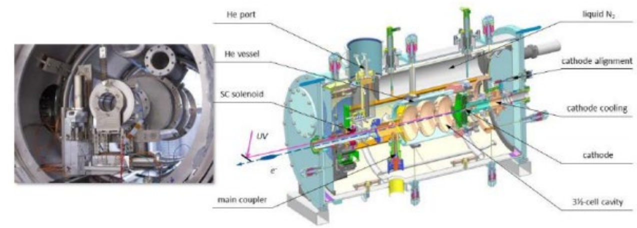
- DC Gun に比べると、まだまだ開発要素が多く残されている
- BNL, HZDR の Activity

W. Xu (BNL) - Commissioning of 704 MHz gun and MP-free cathode stalk design



Building up:
Mid. 2010: vertical cavity test in Jlab, reached 2.9 MV w/o cathode stalk.   2.9 MV/0.082 m = 35 MV/m
Commissioning:
Nov. 2012 to Mar. 2013: Commissioned SRF gun cavity w/o cathode stalk inserted.
→Demonstrated the SRF gun to be able to operate at 2.0 MV CW.
→The amplitude stability is 2.3e-4 rms and the phase stability is 0.035 deg rms.
Aug. to Oct. 2013: Commissioned SRF gun cavity with copper cathode stalk inserted.
→Found operational parameters: 1.85 MV, 180 ms, 1 Hz - limited by multipacting in the stalk.
→Design a new multipacting-free cathode stalk with Ta tip for high QE => high current electron beam.

J. Teichert (HZDR) – Results from beam measurements with SRF gun II at ELBE

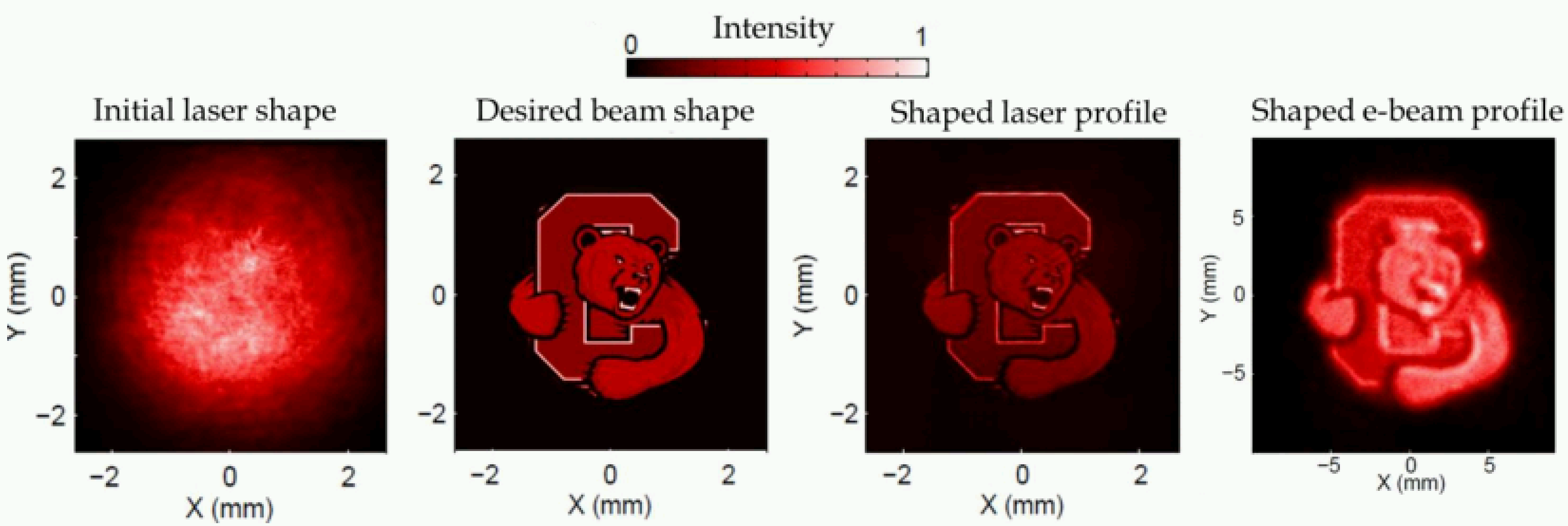


1. SRF Gun II with 7 MV/m acceleration gradient will improve user operation at ELBE
   - Cu cathode measurements show very reproducible and promising results
   - simulation predicts operation up to 500 pC despite the lower gradient
2. The photo cathodes are the bottle neck at present
   high qualitiy & clean photocathodes
   - test of Mg full metal cathodes
   - than Cs2Te photo cathodes
3. A next SRF Gun with high gradient
   - Refurbishment of old SRF gun cavity at DESY within MaT/ARD
   - Cavity design for improved SRF gun cavity and fabrication of new cavities (2017 …)

Drive Laser

J. Maxson (Cornell) - Laser shaping with SLM

- Simple shaping method demonstrated
- High current -> more work needed to surpass thermal damage threshold (e.g., just cool it?)



WG1 のまとめ

Conclusions

- There is a robust choice for an ERL class injector → DC gun
- We need more demo and test experiments to push limits of the SRF gun concept
- Photocathode R&D is now strongly benefitting from material science methods → departing from alchemy
- From the drive laser we expect more results on control of laser parameters in the future.

WG2 : Beam Dynamics / Optics

- Hot Topics
  - FFAGに関する話題が花盛り
  - マイクロバンチング不安定に関する報告
  - BBU に関する議論
  - ビームハローとコリメーションに関するディスカッション

FFAGに関する提案

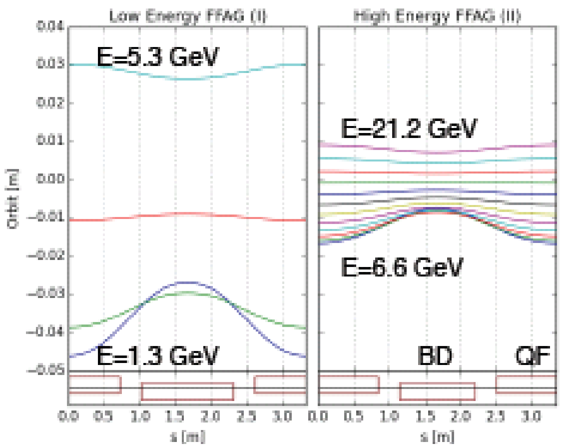
- eRHIC, Cornell で精力的に検討中：Collaboration進行中

FFAG Recirculation (eRHIC):

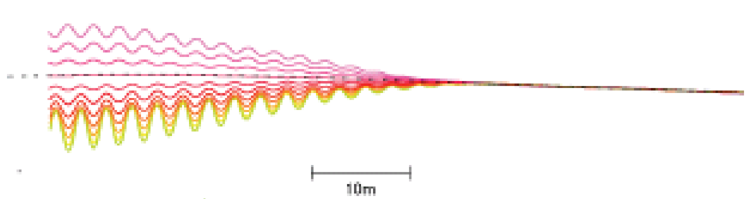
Basic Principle:
Strongly focusing lattice, using quadrupoles, which centers are offset
Should be able to transport beams in wide energy range (factor 4)

Used at:
- Sub-GeV range proton accelerators
- NS-FFAG electron accelerator EMMA

Future applications:
- eRHIC
- Cornel-BNL ERL-FFAG Test Facility
- Other future multiturn recirculators ?



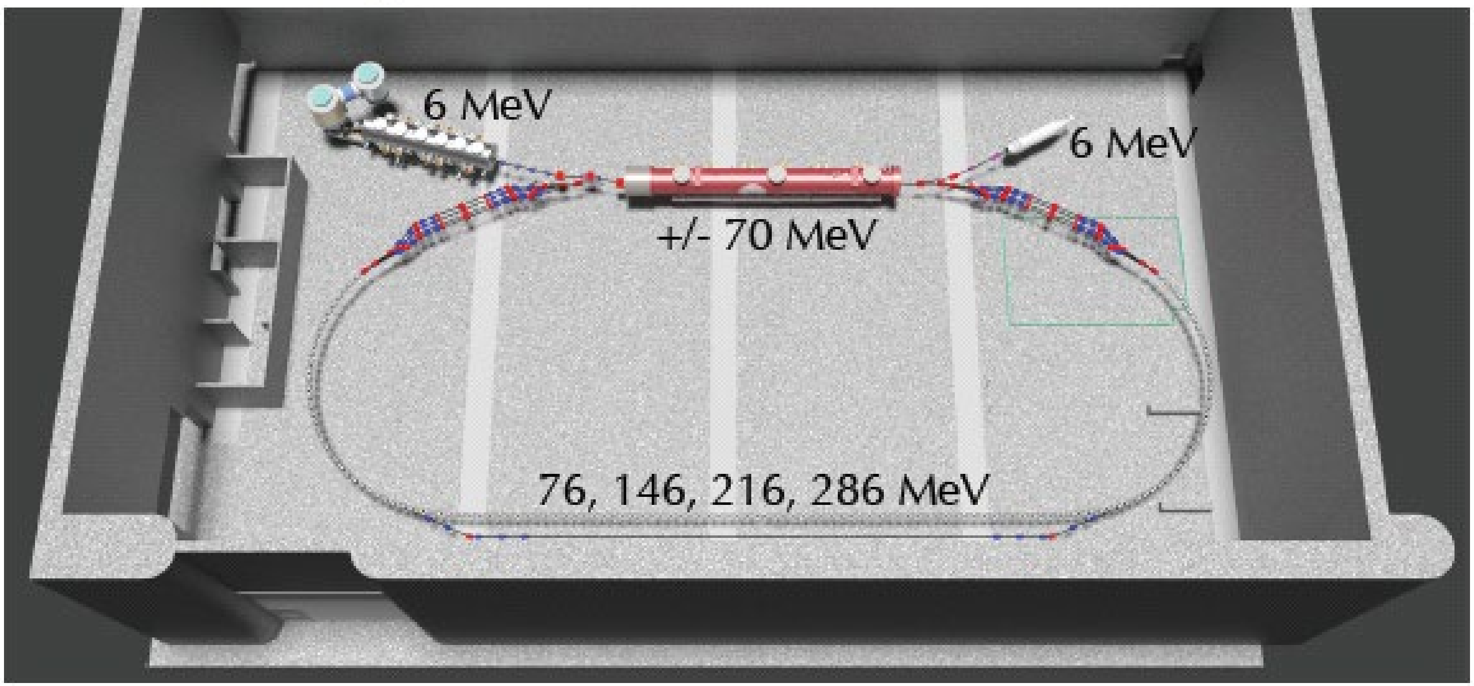
Orbits in eRHIC Transition section



Cornell での計画：2014/12にWhite Paper出した

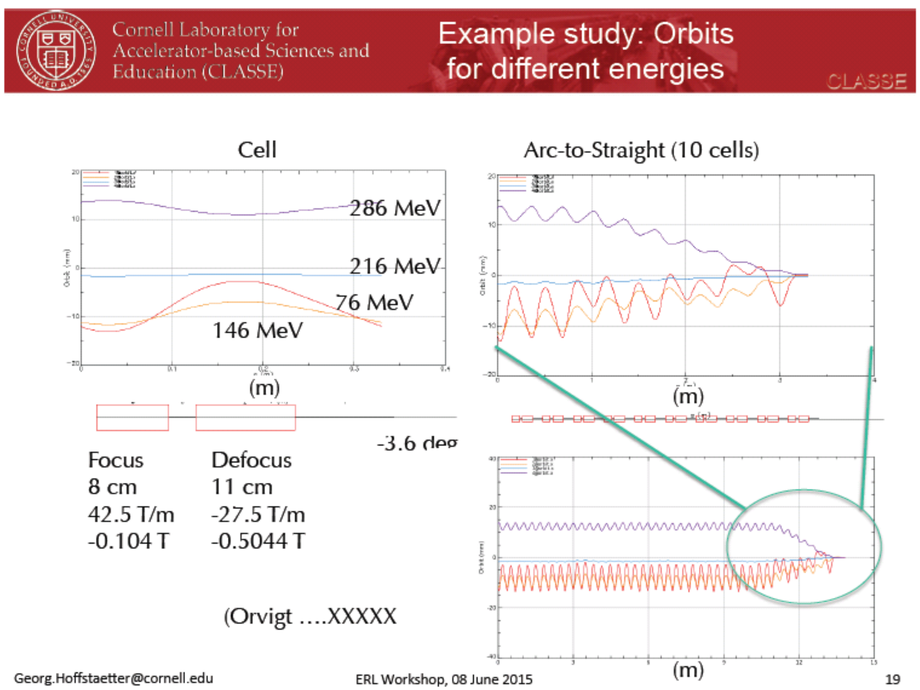
A FFAG-ERL at Cornell, a BNL/Cornell Collaboration,
Georg Hoffstaetter (Cornell University)

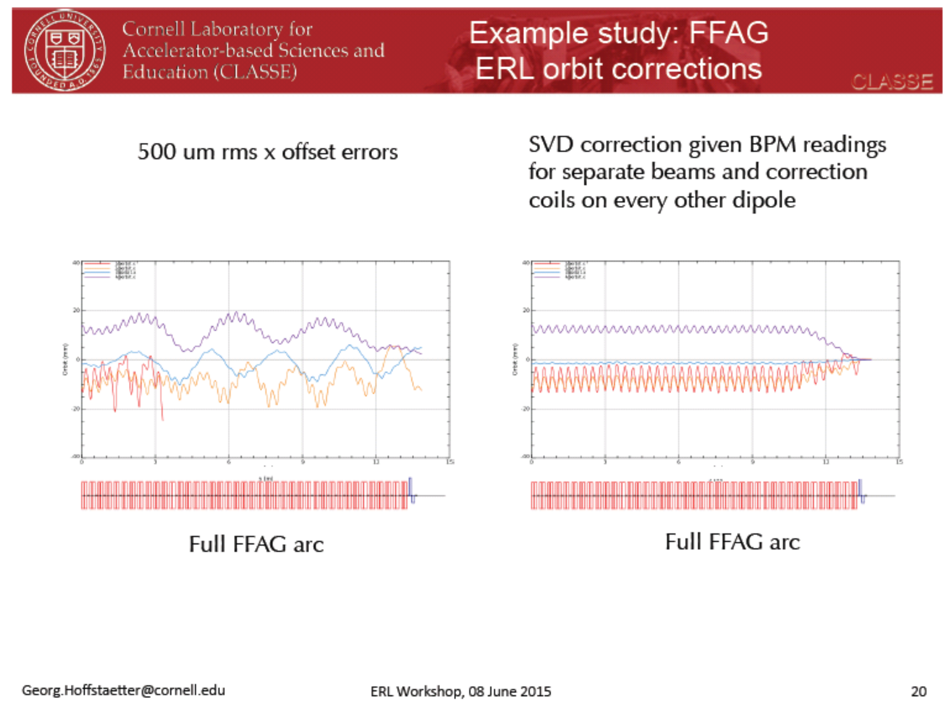
- NS-FFAG arcs, four passes (similar to first eRHIC loop)
- Momentum aperture of x4, as for eRHIC
- Uses Cornell DC gun, injector (ICM), dump, 70MeV SRF CW Linac
- Prototyping of essential components of eRHIC design
- Implementation in stages



Cornellで計画している試験加速器

- spreader 部分のオプティクスや multi-energy に対する起動補正
- 4-Turn で最大286 MeV
- 空洞 16MV/m
- 8-Turn 600 MeV という野望もあるらしい





予定地を整備中


Cornell Laboratory for
Accelerator-based Sciences and
Education (CLASSE)
L0E cleaned out for Cβ ERL
CLASSE

Conell Cβ ERL 年次計画

- どこまで予算の裏付けがあるのかは不明…誰か聞きました？

Cornell Laboratory for Accelerator-based Sciences and Education (CLASSE)

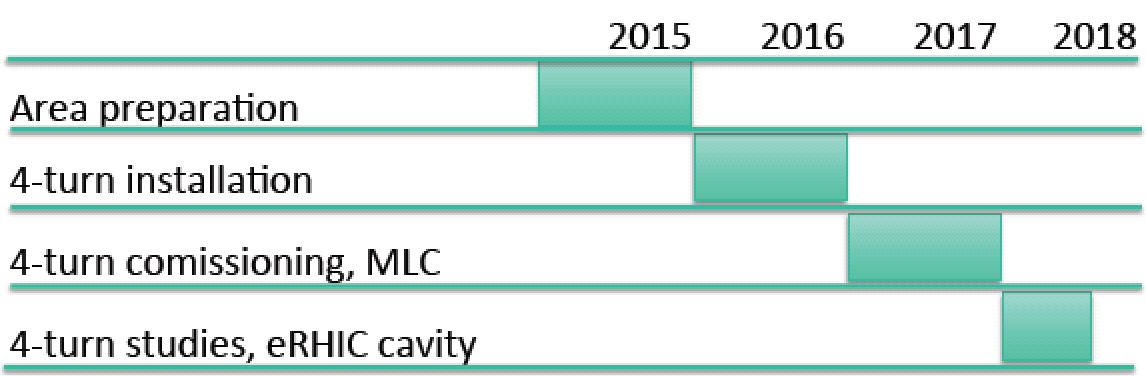
A possible draft schedule

CLASSE

Start 2015 – Start 2016: Cleaning out of experimental area, and injector and MLC test

Start 2016 – Start 2017: Install 4-turn ERL-FFAG for 23.5, 41, 58.5, and 76 MeV.

Start 2017 – Mid 2018: Commissioning of 1 to 4 turn ERL and accelerator physics studies. Replace Cornell's MLC with BNL's eRHIC prototype cavity, tuned to 433MHz. Perform high-current experiments, including HOM heating studies. Study the multi-turn BBU threshold for eRHIC cavities.



Georg.Hoffstaetter@cornell.edu

bERLinProの状況

- SRF Gun の開発は進行中 (at HoBiCaT)。なかなか大変そう。
- 各コンポーネントのインピーダンス計算などは全部やっている
- 最終的には 100 mA 目指す (2020年)

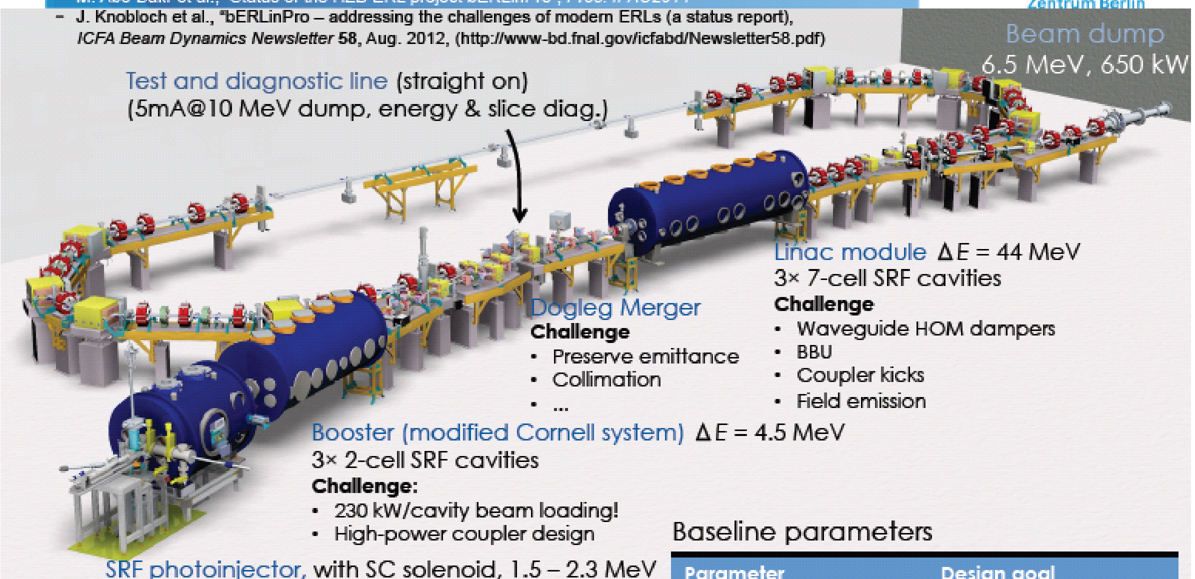
2

bERLinPro layout

J. Knobloch, 2015-06-08

HZB Helmholtz Zentrum Berlin

- M. Abo-Bakr et al., "Status of the HZB ERL project bERLinPro", *Proc. IPAC2014*
- J. Knobloch et al., "bERLinPro – addressing the challenges of modern ERLs (a status report), *ICFA Beam Dynamics Newsletter* 58, Aug. 2012, (http://www-bd.fnal.gov/icfabd/Newsletter58.pdf)



SRF photoinjector, with SC solenoid, 1.5 – 2.3 MeV

Challenge:
- 30 MV/m CW operation with CsK$_2$Sb cathode
- Cathode performance @ 100 mA
- Dark current/halo control
- Emittance compensation
- ...

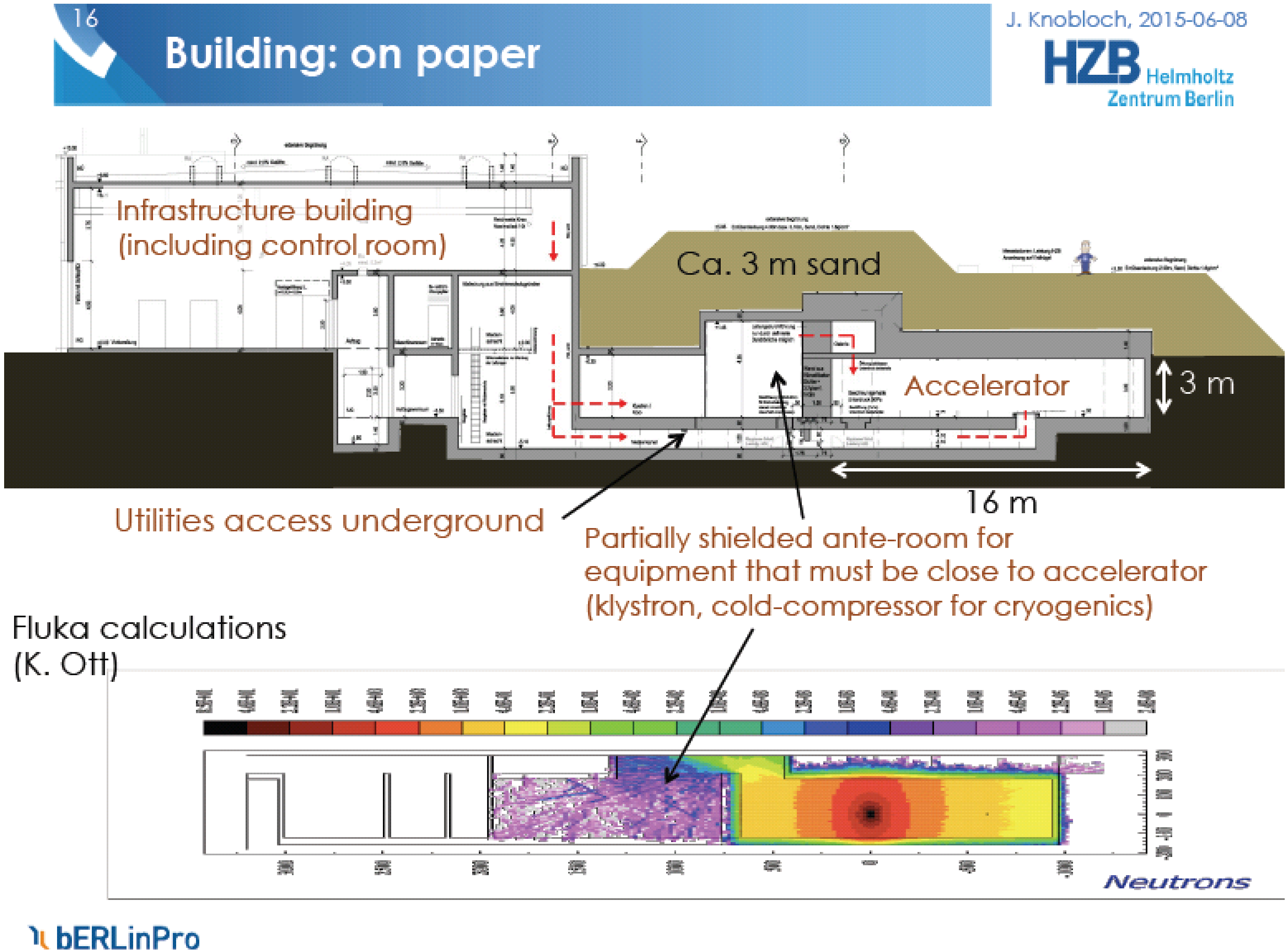
Facility is fully funded
(Helmholtz Assoc., HZB and State of Berlin)

Baseline parameters

Parameter	Design goal
max. beam energy	50 MeV
max. current	100 mA (77 pC/bunch)
frequency	1.3 GHz
normalized emittance	1 mm (ca. 0.5 mm sim.)
bunch length (straight)	2 ps or smaller (100 fs)
losses	$< 10^{-5}$

建物の構造

- 全体を地下に配置して、土を盛る。実に正しい。



建設の現状

- 2015年２月から建設開始。穴を掘っているMovieあり。

17

Building: in reality

J. Knobloch, 2015-06-08

HZB Helmholtz Zentrum Berlin

Construction commenced 11-Feb-2015

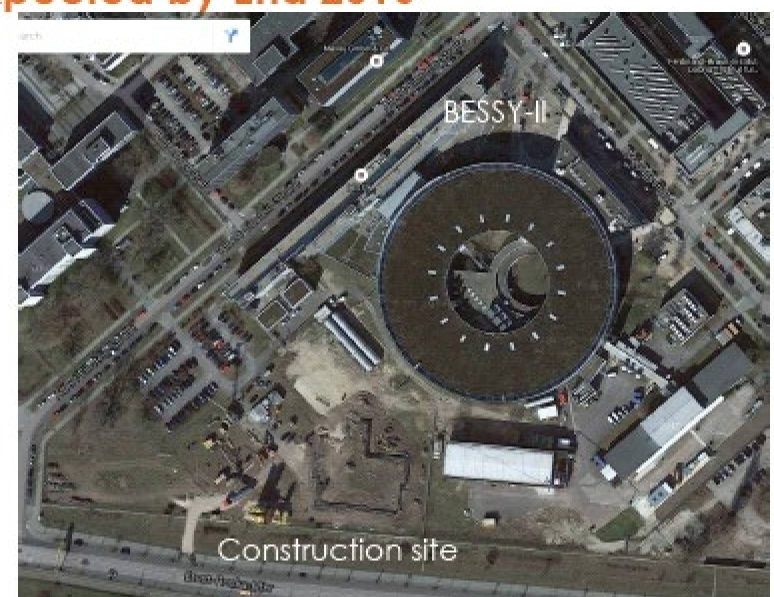
Underground construction complicated at Berlin site

- Sandy soil
- Ground water at only 1.5 m below grade
- Very strict water regulations in Berlin

→ Complicated and costly water management scheme

Building occupancy expected by End 2016

Quality control of concrete



bERLinPro

WG3 について

- 小ネタは色々あるが、ハイライトとなるようなものは多くない

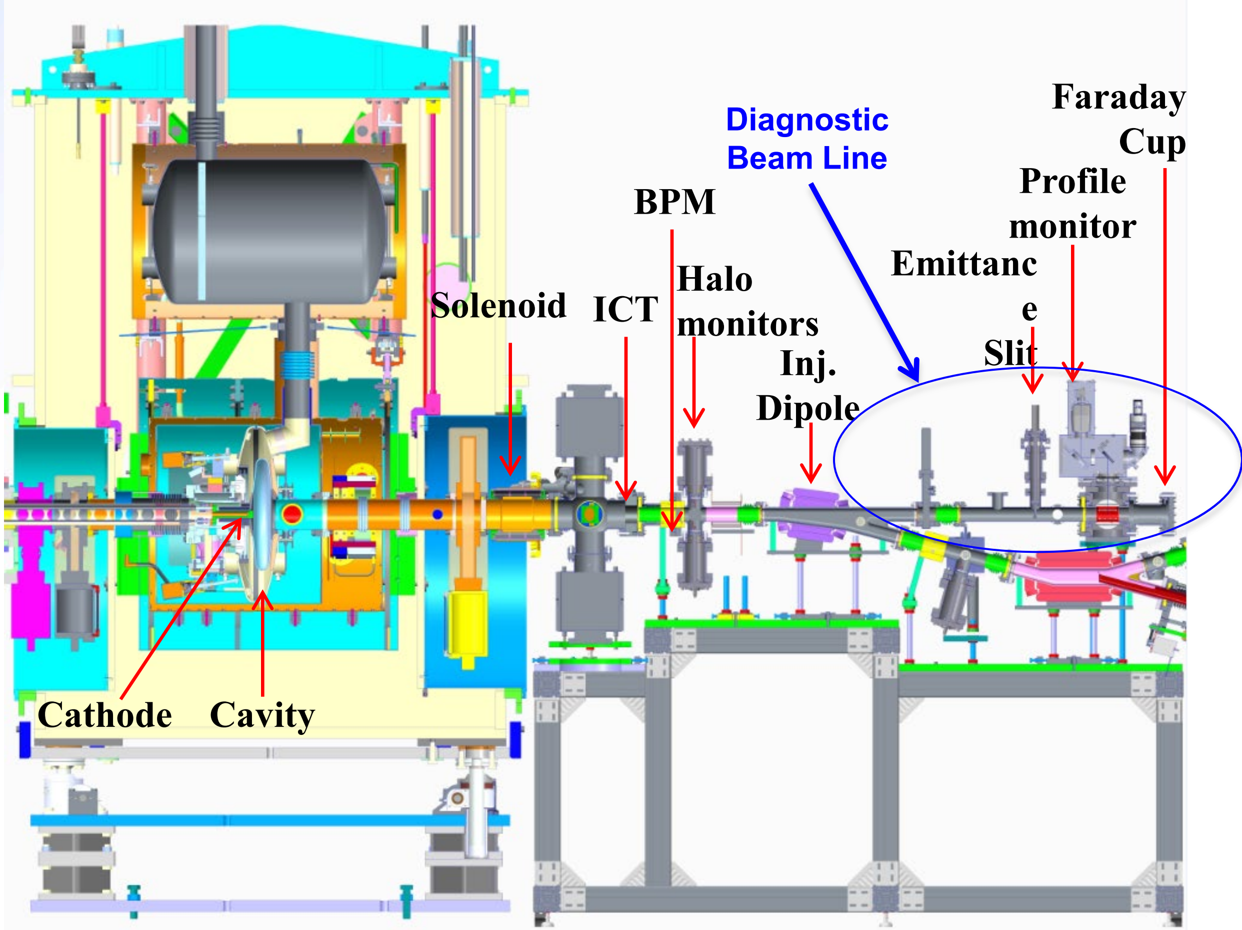
- BNLでのコミッショニング開始
- Cornell での大電流ビーム診断

が面白いので、これらを紹介する。
詳細はそれぞれの発表資料を参照

Injection & Diagnostic Beam Line

- ICT (5:1 turns ratio,~ 6%/μs droop) + BCM-IHR electronics (10kHz)
- BPM
- Scraper
- Emittance Slit
- Profile Monitor
- Faraday Cup

  SS flange on ceramic break with copper mesh noise shield
- DCCTs *(not pictured)*
  - Zig-Zag & Extraction

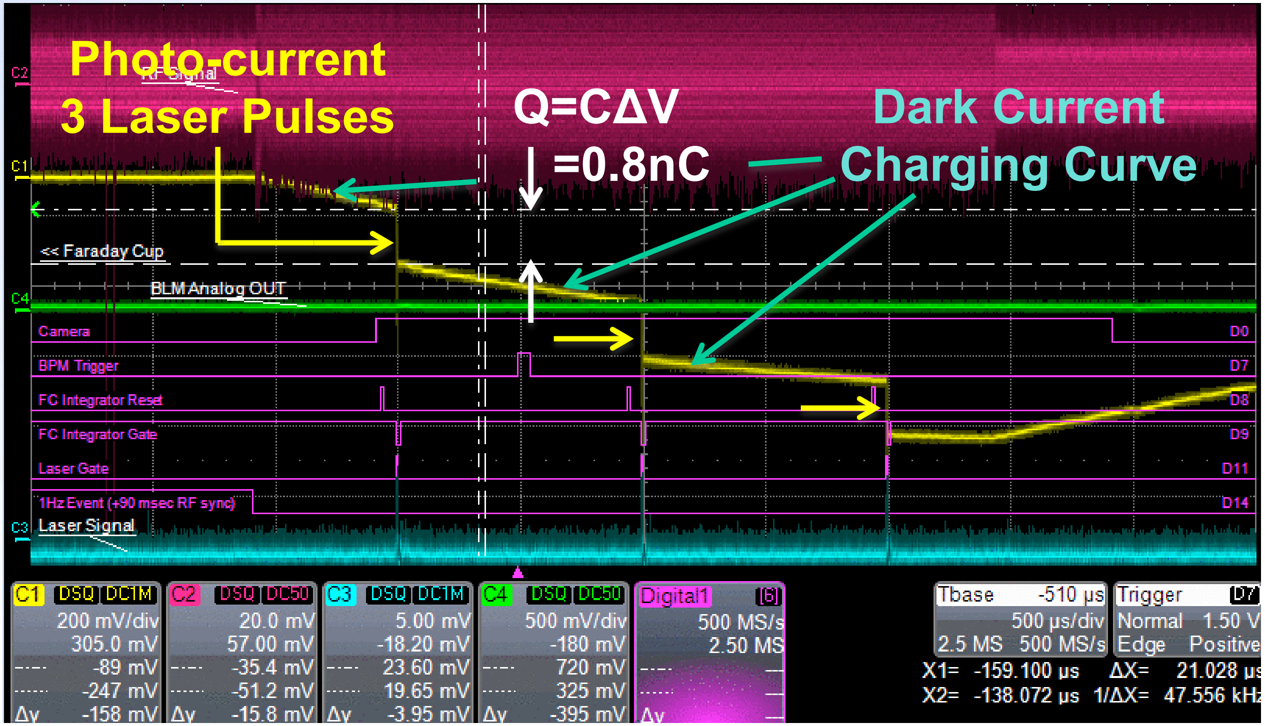


Diag. B/L Faraday Cup – PHOTO-CURRENT

- ΔV for each beam current pulse gives the charge.
- $Q = C\,\Delta V$

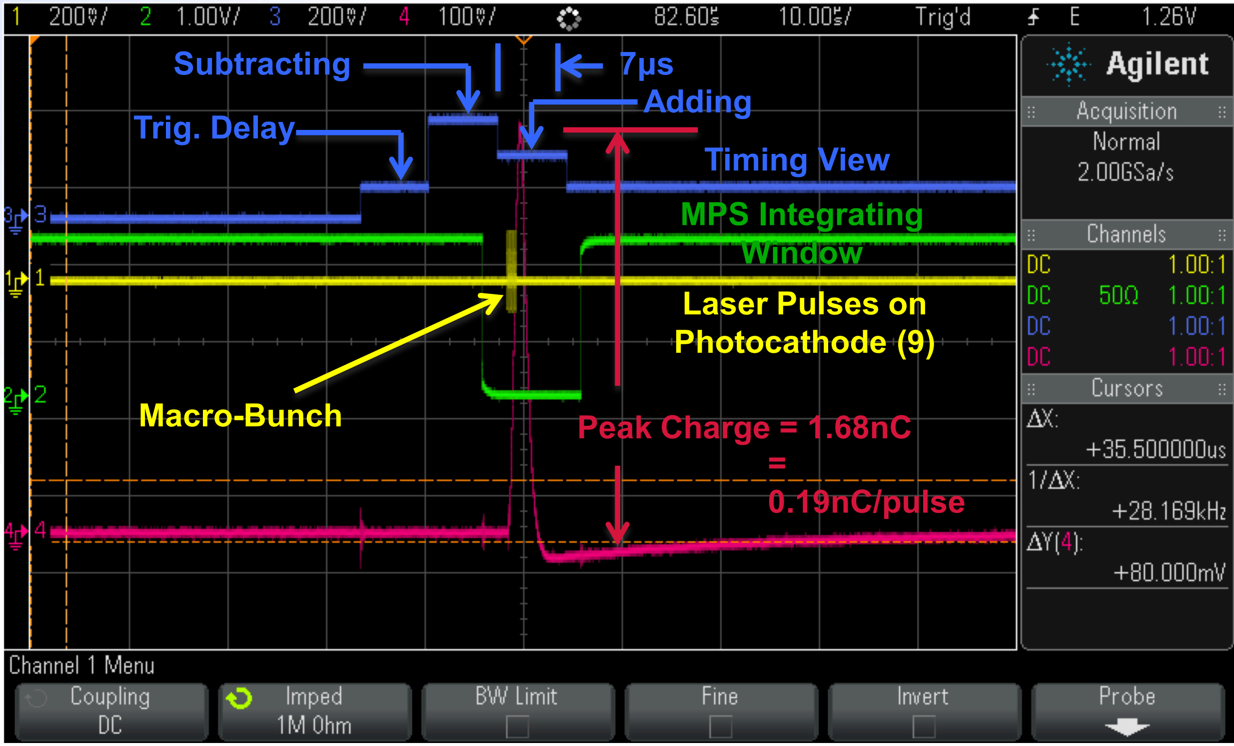
  $=(5nF)(158mV)$

  $=0.8nC$
- Superimposed on Dark Current curve



Injection – Integrating Current Transformer

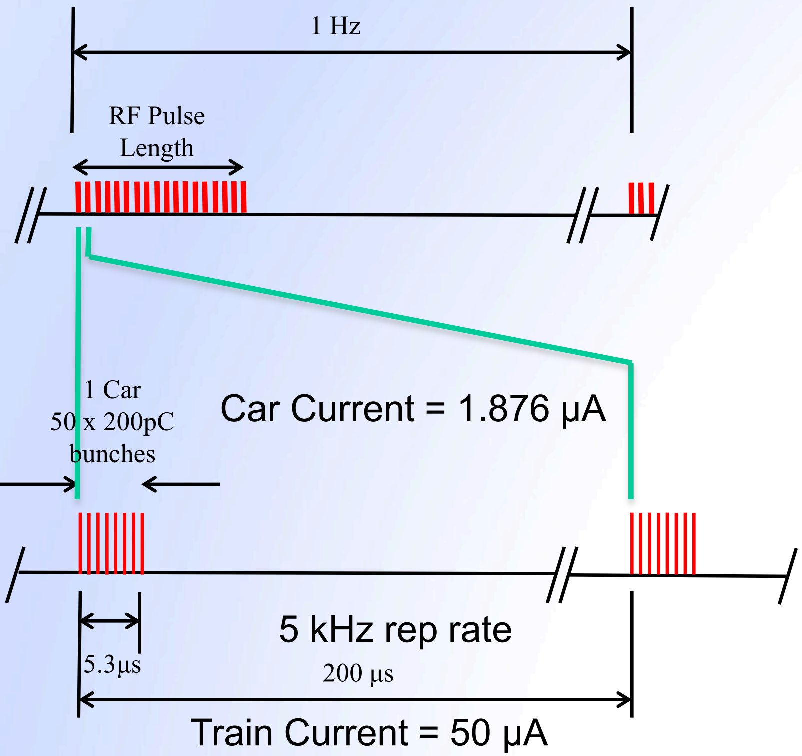
- 7μs Integration window
- 1μs macro bunch
- 9 pulses with 9.38MHz spacing and 44mW
- 1.68nC total charge
  - 0.19pC per bunch
  - (550pC$_{max}$ demonstrated using 4W laser pulses)



Bunch Patterns– ICT vs DCCT

Pulse Structure for ICT

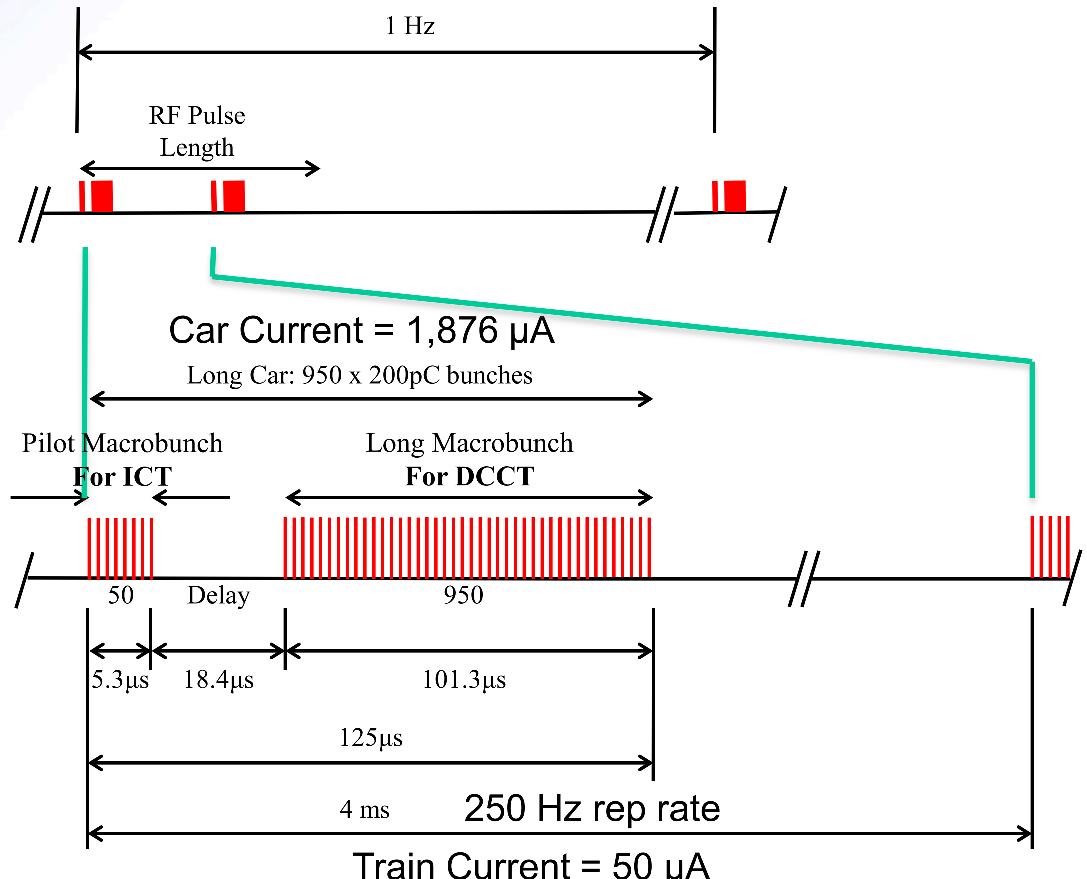
ICT is gated around the Car



Pulse Structure for ICT + DCCT

ICT is gated through the Pilot macro pulse

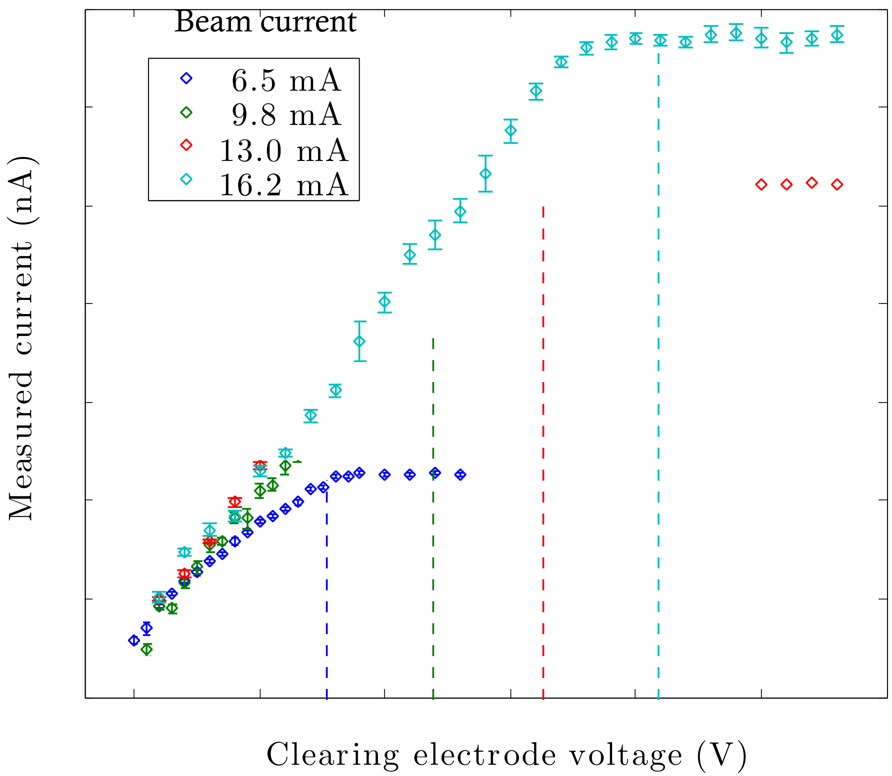
DCCT is sampled at the end of the Long macro pulse

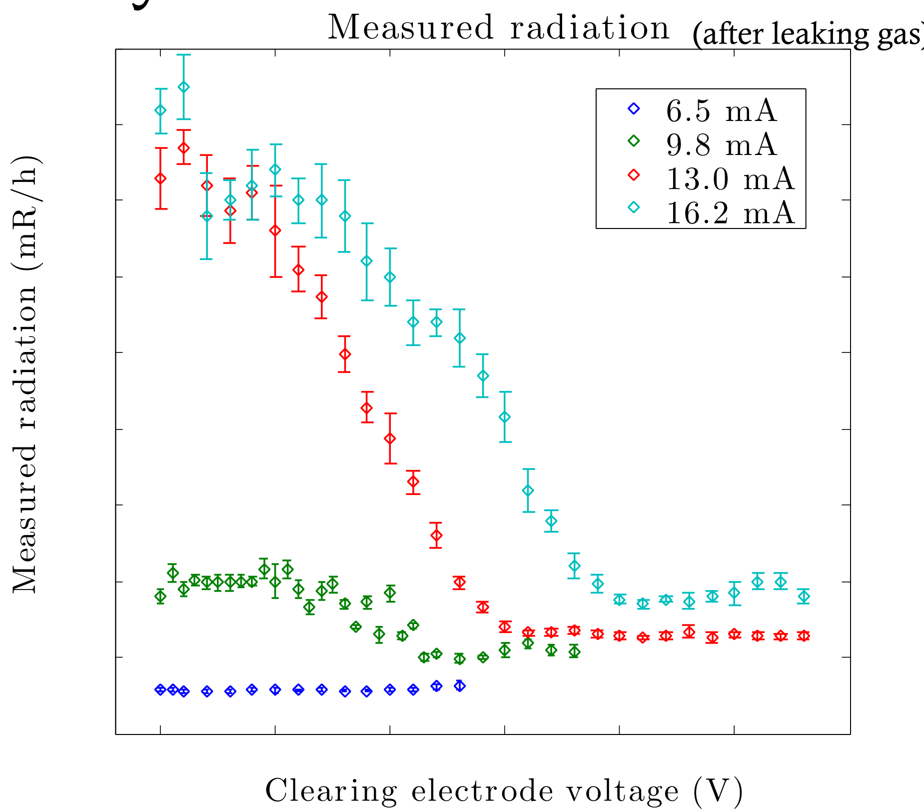


Ion studies in the Cornell ERL photoinjector

- First experimental studies of ions in a high current linac
- We observe that ions increase radiation significantly when approaching 70 mA
- Explored three mitigation options
  - Clearing electrodes
  - Beam shaking
  - Bunch gaps

Clearing electrodes significantly reduce the trapped ion density



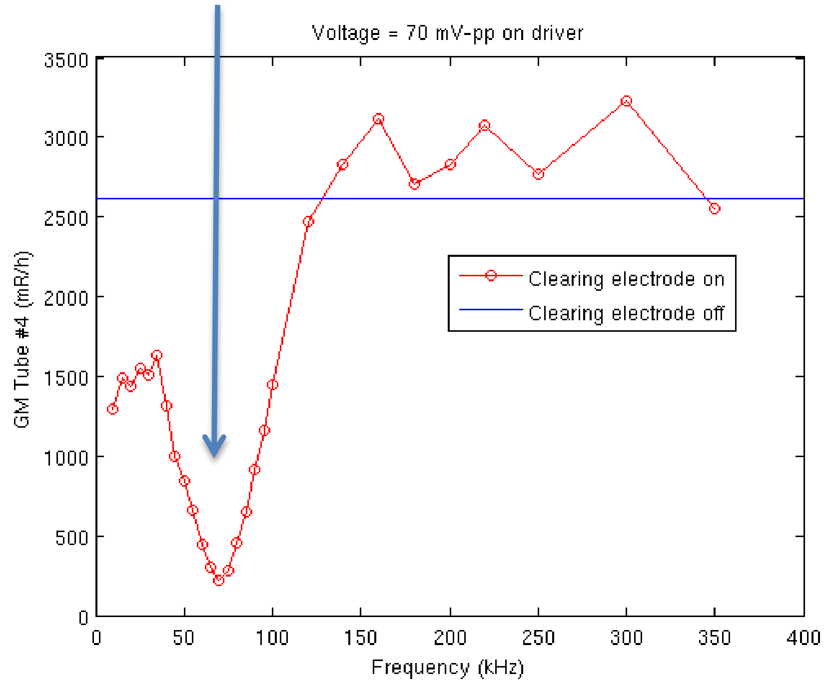


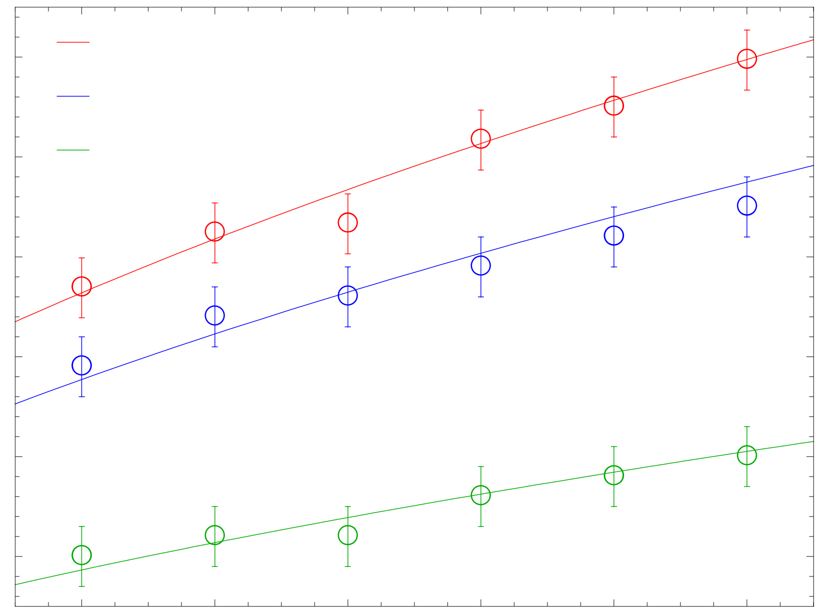
$$V_{electrode} \geq \frac{I}{2\pi\epsilon_0 c}\frac{d}{\sigma_b}$$

Necessary clearing electrode voltage can be predicted

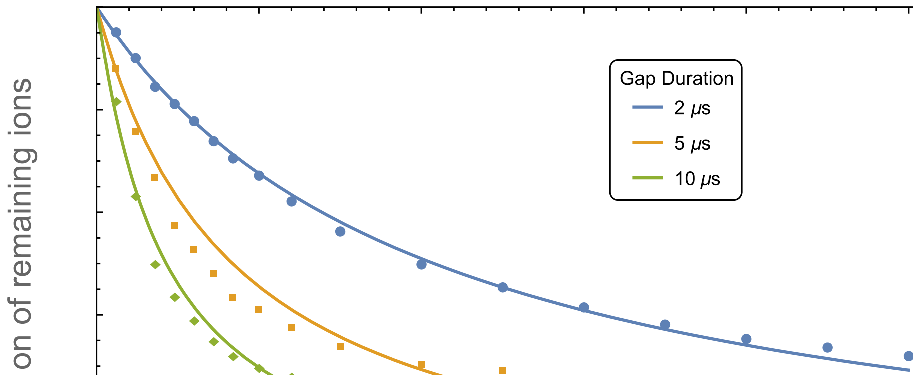
Shaking the beam at an ion's oscillation frequency resonantly clears them out (and reduces background radiation)

$$\omega_{ions} = \sqrt{\frac{2r_p c}{e} \frac{I_{beam}}{A_{ion}\sigma_{beam}^2}}$$





Introducing short bunch gaps also clears ions



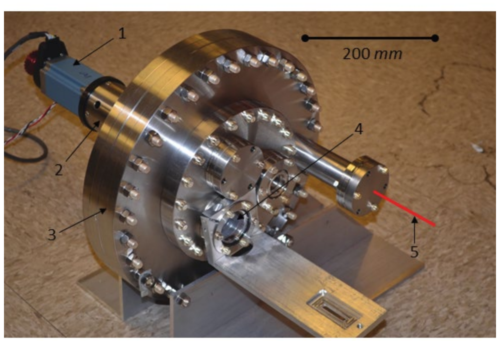
The minimum required gap length is much shorter than predicted by theory. Merits further study to understand why this is the case.

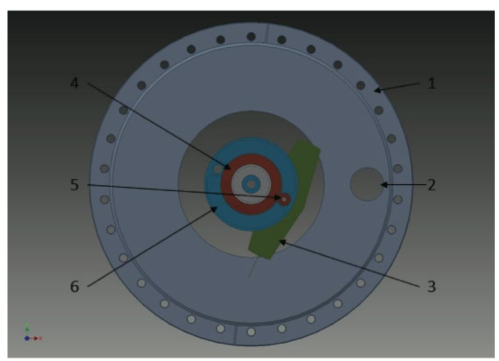
	Data	Extrapolation
Reduction in beam current	1%	30%
Reduction in ions	70%	99%

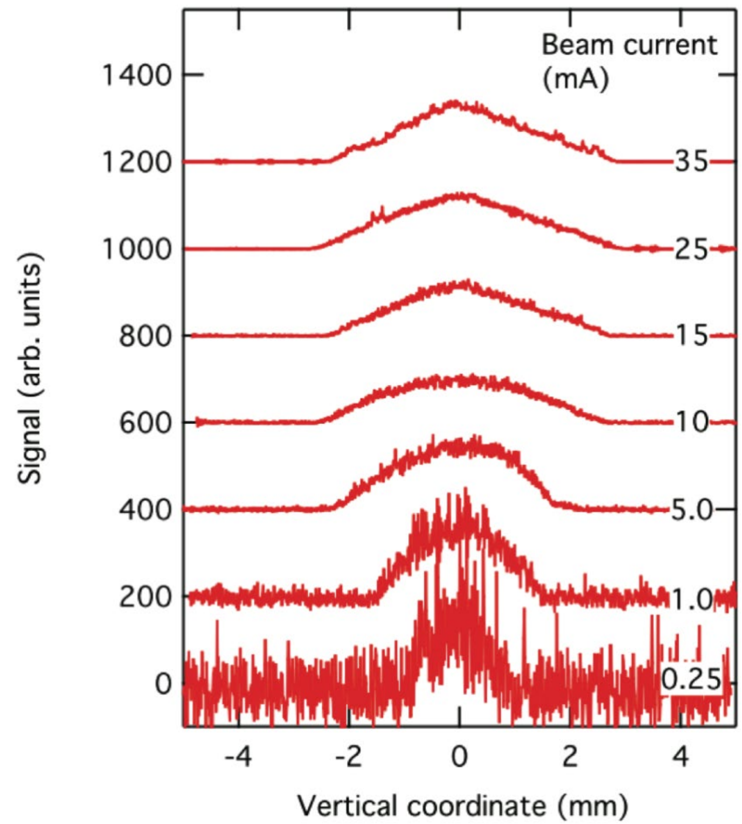
$$\omega_{ions} = \sqrt{\frac{2r_p c}{e}\frac{I_{beam}}{A_{ion}\sigma_{beam}^2}}$$

Rotating wire scanner for high beam currents

- Works up to 20 m/s to avoid melting
- Cheap (< $5000)
- Compact (~35 cm / 14")
- Quick to build and implement







WG3に関するコメント・議論等

- ファラデーカップとICTとの間に相違がある
  - 絶縁の問題？
  - DCCTで測定できるようになったらまた検証
- Jlabでは、セラミックスを直接見るようなＣＴ類はインストールしない方針にしている
- Differential DCCT については開発途上

- インターロック用途にICTを使用
  - ICTで電荷量を測定し、パルスカウンタと併用

- Rotating wire scanner のインピーダンスは不明。CWビームに与える影響はあるか？

- WG4 とのジョイントセッションで、ビームを大電流に持っていくやり方について議論
  - Peak Current 一定にしてパルスを増やしていく
  - ビームパターンは一定にして、電荷を増やしていく、等

WG4：SRF

- 阪井さんの報告を参照

WG5 : Applications

- WG5 Summary Report より

ERL applications talks

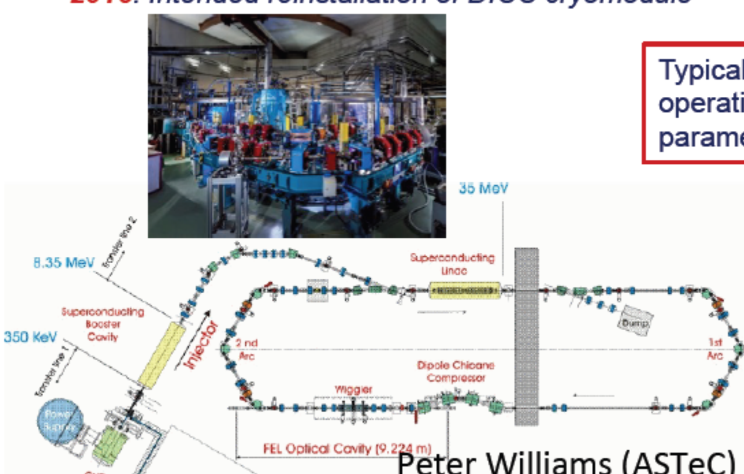
- Operational facilities/science cases
  - **10 Years of ALICE: From Concept to Operational User Facility, P. Williams**
  - **Science cases on ERL as a synchrotron light source, H. Kawata**
  - **Nuclear and High-Energy Physics Experiments with Cornell's FFAG ERL, M. Perelstein**
- Colliders/Nuclear physics
  - ERL-based Electron-Ion Colliders, V. Ptitsyn
  - Current Status of the MESA Project, R.Heine
  - ERL facility at CERN for applications, E. Jensen
  - A Lepton Energy Recovery Linac Scalable to TeV, V. Litvinenko
  - Using ERLs for Coherent electron Cooling, I.Pinayev
  - ERL for low energy electron cooling at RHIC (LEReC), J.Kewisch
- Light sources/ FELs/γ-ray sources
  - The Femto-Science Factory: A Multi-turn ERL-based Light Source, T. Atkinson
  - Design work of the ERL-FEL as the high intense EUV light source N. Nakamura
  - ERL as FEL driver, Y.Jing
  - Ultra-High Flux of X-ray/THz Source based on Asymmetric Dual Axis Energy Recovery Configuration, I. Konoplev
- γ-ray sources
  - Laser Compton Sources Based On Energy Recovery Linacs , R. Hajima
  - ERL as high intensity mono-energetic γ-ray sources, V. Yakimenko
  - An Inverse Compton Scattering Beamline for High-Energy, Time-Resolved X-ray Scattering Studies of Materials, G.Hoffstaetter

ALICE

- 詳細はプレゼンファイルを参照してください。Gun, RF, Cryo の問題が多くあって大変だったという印象。

The Evolution of the ALICE ERL-FEL at Daresbury

- **2000**: Proposed **4GLS** CW ERL driven VUV FEL as user facility (100mA, 600 MeV)
- **2003**: **E**nergy **R**ecovery **L**inac **P**rototype **funded** (pulsed 10 mA in 100us macropulse @ 10 Hz, 35 MeV)
- **2005/6**: Installation & commissioning of 350 keV DC photocathode **gun**, 120W **cryosystem**, 2 SC **Linacs**, recirculation **transport** & oscillator **IR-FEL**. **First beam August 2006**
- **2007**: Problems with gun, RF, cryo
- **2008**: Fixing problems, then **full energy recovery** (initially at reduced gun voltage, linac gradient)
- **2009**: Gun Kr plasma cleaning & leak chasing, RF conditioning & LLRF optimisation
- **2010**: He processing of linac to mitigate FE, then **first lasing of IR-FEL** with full ER at 27 MeV
- **2011**: Diagnosing FEL radiation, Electro-optic bunch length measurements,
- **2012**: **Gun upgrade** -> 325 kV design voltage achieved -> **beam quality** much improved
- **2013**: Installation of DICC 7-cell cryomodule, module & cryo faults -> revert to original linac
- **2012 – 2015**: **Understanding** of machine through transverse & longitudinal beam dynamics studies, **stability of operation** through active feedback, DLLRF, high-level software
- ***2016**: Intended reinstallation of DICC cryomodule*



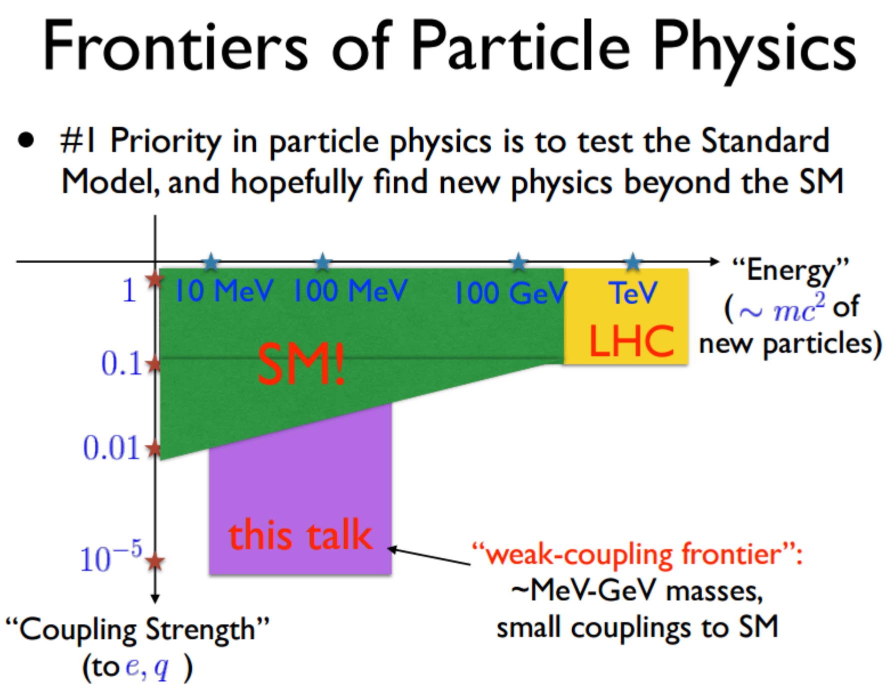
Peter Williams (ASTeC)

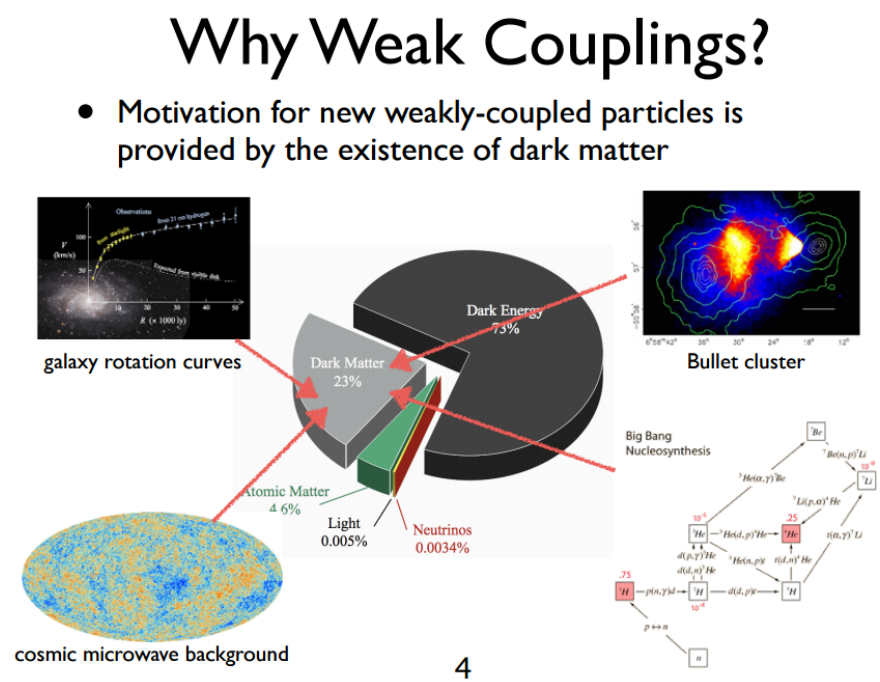
Typical operational parameters

Full Energy (MeV)	24-27
Injector Energy (MeV)	6
Bunch Charge (pC)	60 – 80
Micropulse rep. rate (MHz)	16.25 / 32.5
Radiation Macropulse length (μs)	85 + 15 startup
Number of micropulses / macropulse	1400 / 2800
Macropulse rep. rate (Hz)	10
FEL Wavelength range (μm)	5.5 – 11
Micropulse energy at sample (μJ)	2
Peak power at sample (MW)	2
Av. Power within macropulse at sample (W)	20
Av. Power at sample (mW)	40
Linear polarisation	>95%
Power stability	~0.2 – 1 %

Particle Physics

- Nuclear and High-Energy Physics Experiments with Cornell's FFAG ERL
  - Maxim Perelstein (Cornell University)
- ERLの大電流を使えば rare process の高精度測定が可能に





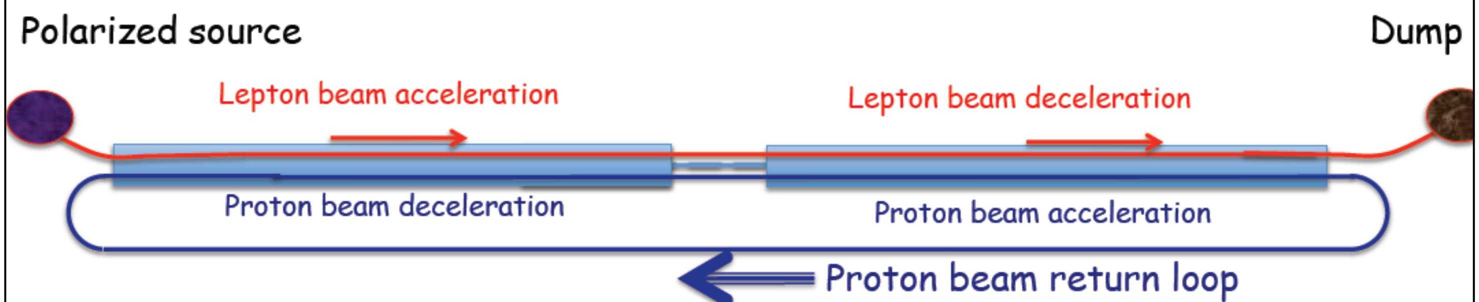
Intense Electron Beams Workshop at Cornell : June 17-19 / 2015
http://www.classe.cornell.edu/NewsAndEvents/IEBWorkshop/
https://indico.classe.cornell.edu/event/38/other-view?view=standard

Colliders/Nuclear Physics

- A Lepton Energy Recovery Linac Scalable to TeV
  - V.N. Litvinenko

Natural option of high energy high current ERL: proton beam is used to carry the energy

100% energy recovery



Energy flux is carried out by a proton beam

Synchrotron radiation is reduced ~10^{13} fold to watt level

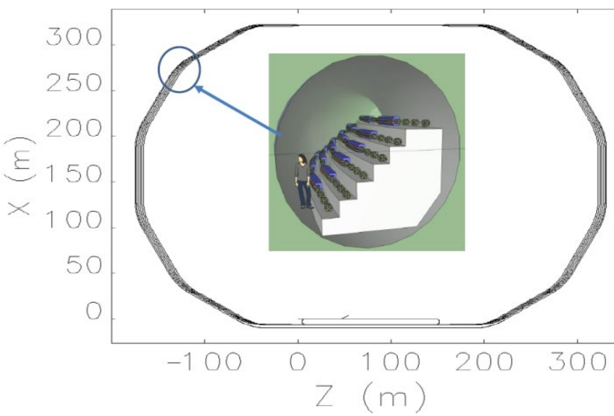
$$P_{SR}[W] = 7.79 \frac{E_p^4[TeV] \cdot I[A]}{R[km]}$$

V.N. Litvinenko, ERL 2015, Stony Brook University, June 10, 2015

SR Source

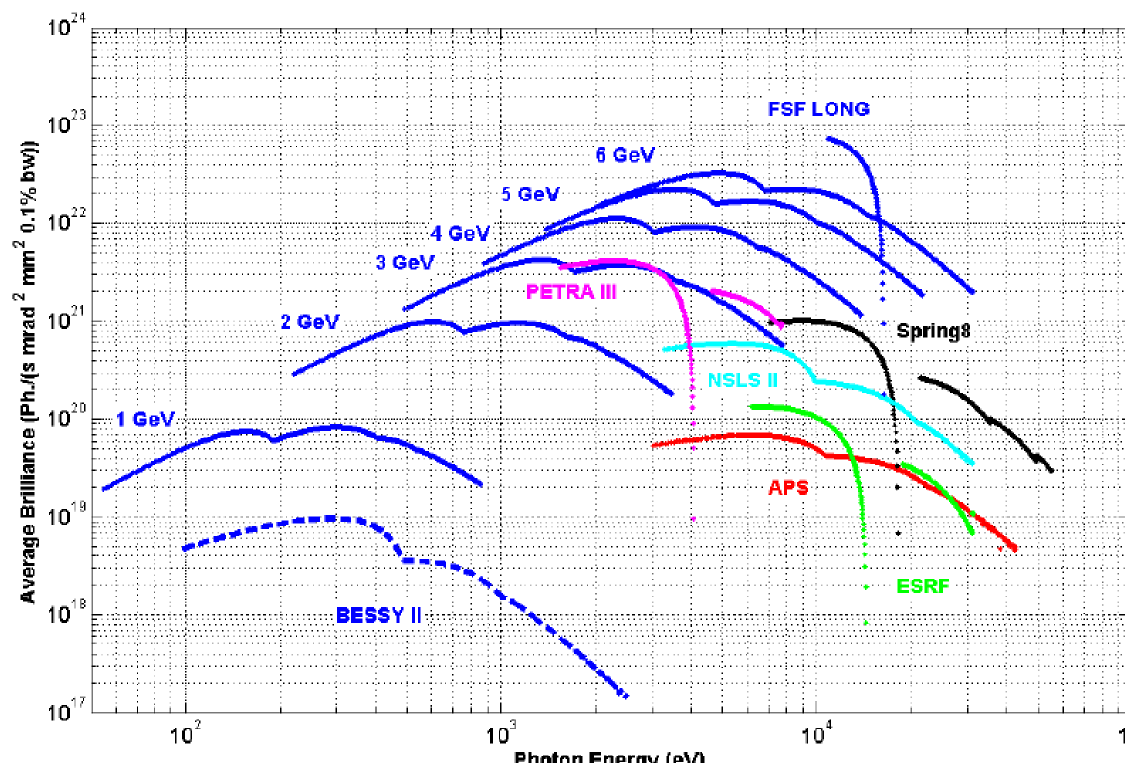
- The Femto-Science Factory: A Multi-turn ERL-based Light Source
  - Terry Atkinson (HZB)

Start-to-End Geometry



Spectral Brightness

- Comparison with existing 3rd generation light sources



その他、全体を通して

- ビームハローとコリメーションについての議論
  - WG2の discussion session + 休憩時間やバンケットで議論
  - KEKのCW運転時のロスは興味を持たれたようだ
  - カソードのQEが高いとテールを長く引く。タイミングもずれるが、それ以上に空間電荷効果の効き具合が違うため、コアに合わせるとテール部分は発散する。両方を同時に輸送できる解は困難
  - コリメータを入れるとwakeの問題で大電流で問題が生じる？

Unwanted Beam Workshop (HUB, HZB, HZDR) を開催予定