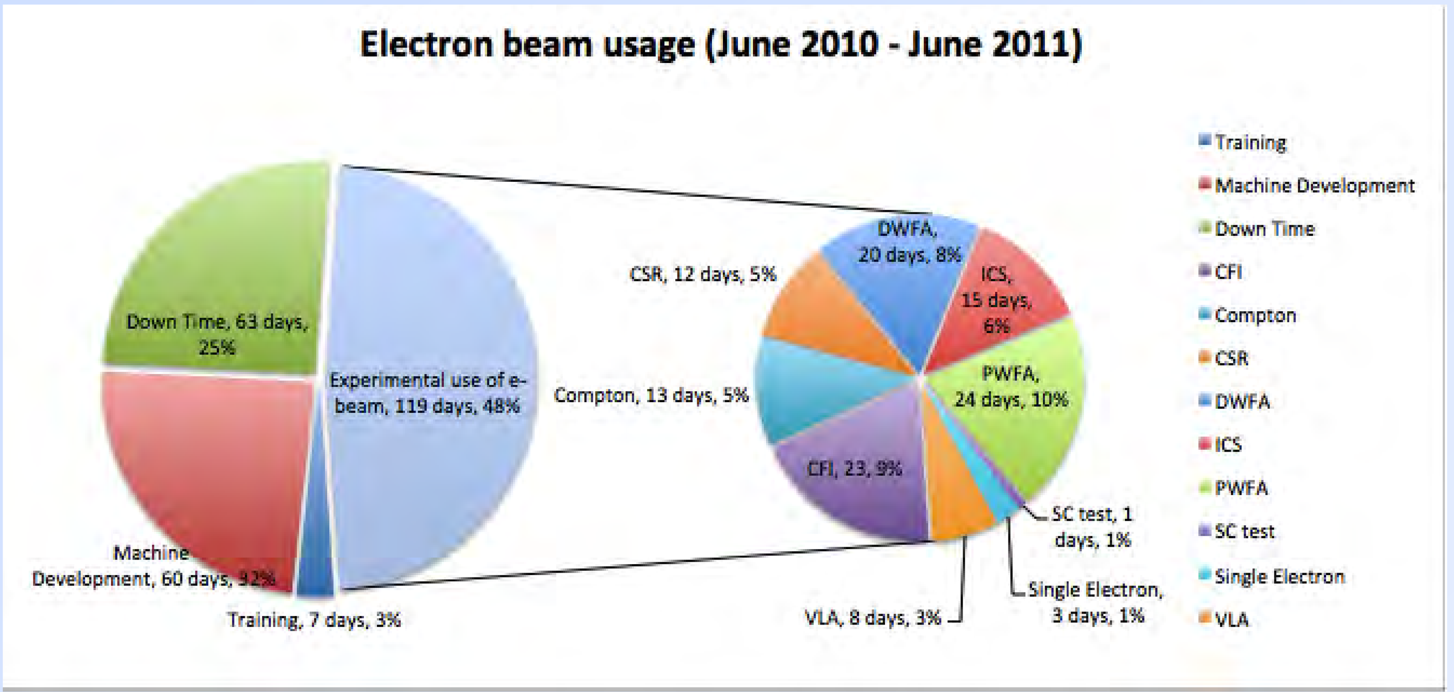
ACCELERATOR TEST FACILITY

- The ATF is the only proposal-driven, advisory committee reviewed, USER FACILITY for long-term R&D into the Physics of Beams in the world.
- The ATF features:
  - High brightness e[-] gun, 85 Mev Linac
  - High power lasers beam-synchronized at the picosec level (Unique TW CO2 laser)
  - High brightness X ray source
  - 4 beam lines + controls
- In-house R&D on photoinjectors, lasers, diagnostics, computer control and more (~3 Phys. Rev. X / year)
- The ATF serves the whole community: National Labs, universities, industry and international collaborations.
  - Experiments are funded by HEP, BES, NSF, DOD, SBIR, STIR, LDRD
  - ATF contributes to Education in Beam Physics. (~2 PhD / year)
- ATF: A Unique resource world-wide in the comprehensive nature of the facilities.
- Supported by both HEP and BES.

ATF operations: This year highlights

The ongoing program of user experiments capitalizes on the unique ATF infrastructure comprising a high-brightness 85MeV linac and a Terawatt picosecond CO_2 laser employed separately or in combination. Nineteen current experimental activities were presented and evaluated by the ATF Program Advisory Committee at the User's Meeting in October 2010. The Program Advisory Committee was chaired by Wim Leemans of LBNL and included well-known researchers from universities and national laboratories.

ATF systems were operated for a total of 206 run-days during last twelve months. This included 119 days of experiments that require electron beam only, 67 days of accelerator development and training, 30 days for experiments that exclusively use the CO_2 laser beam, 50 days of CO_2 laser development and training and 18 days for experiments that require the interaction of electron and CO_2 laser beams. Over the past year, 34 users from 13 institutions have been setting up and conducting their experiments at the ATF. Experimental results for 3 PhDs were collected. Below are highlights on the last-year milestone research.



ATF experimental program summary

High Gradient / X band option at ATF
- 3fs resolution longitudinal diagnostics
- Energy spread silencer
- High gradient experiments with high brightness e[-] beam
- Testing high gradient S-band structures

Plasma WFA
- Bunch train (completed)
- High transformer ratio measurement (shaped train and triangular bunch)
- Efficiency optimization
- Weibel instability studies
- Holographic characterization of wake fields from two bunch and "train"

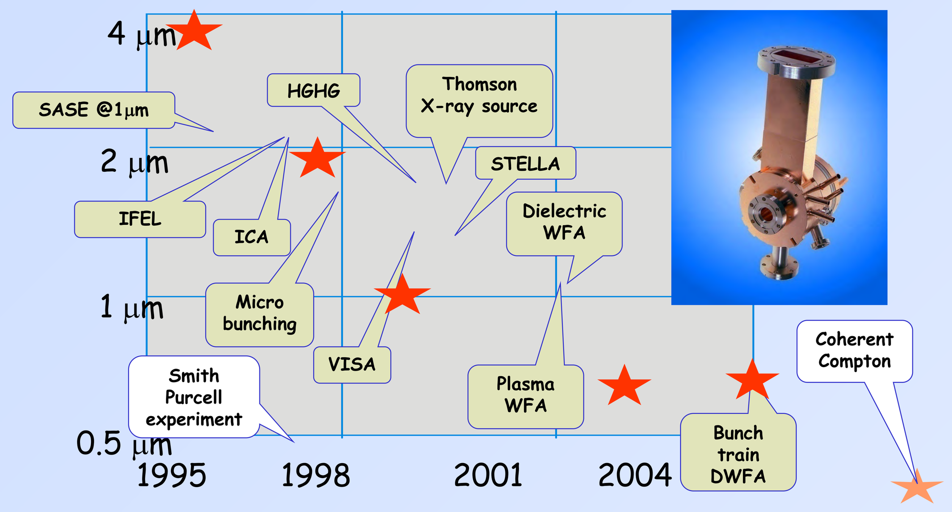
Dielectric WFA
- Bunch train – narrow band THz generation (completed)
- High transformer ratio measurement (shaped train and triangular bunch)
- Medium range between ANL and FACET beams

CO2 laser development (5TW near term, 10-20TW later)
- Short pulse seeding using new Ti:Sapphire laser system
- Stretched pulse amplification
- Controlled dual pulse structure (for Ion beam generation)
- Recirculation cavity

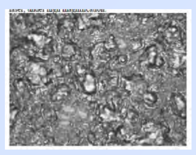
Laser Generated Ion beams
- Studies of monoenergetic ion beams generation with controlled dual pulse structure
- Ion beam energy encrease to 5, 10 and 20MeV.
- Experimental program with generated beams

Compton back scattering generated X ray beams
- High intensity/brightness single shot experiments
- Fast diffraction pump probe experiment
- Multibunch interaction with CO2 laser for ILC/CLIC polarized e[+] source
- Multibunch interaction with UV laser for DOD tests

1.6 Cell RF gun / Emittance

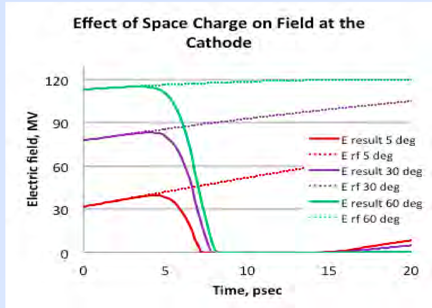


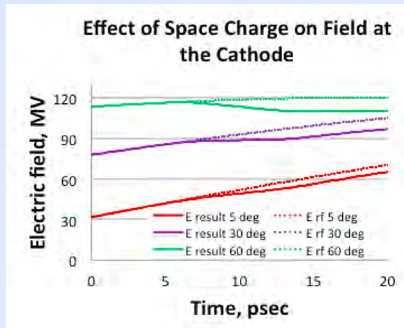
Laser cleaning of the cathode to improve quantum efficiency was developed at ATF and benefited many programs including FEL. Different beams after cleaning with RF (on the left) and without RF(on the right) were generated.

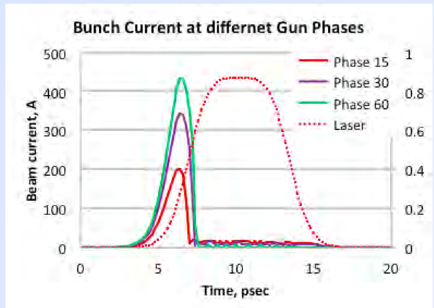


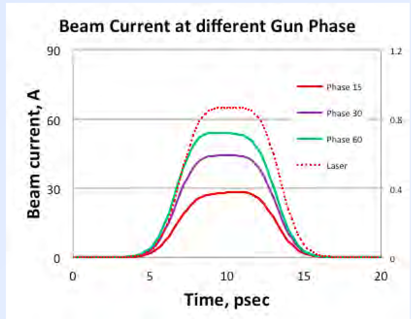
Cathode surface after laser cleaning with RF ON

Normal operation for low emittance

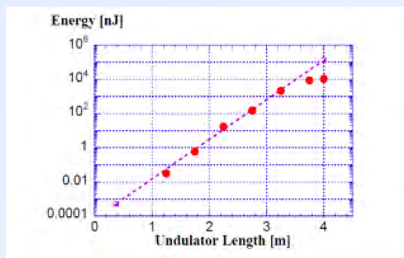


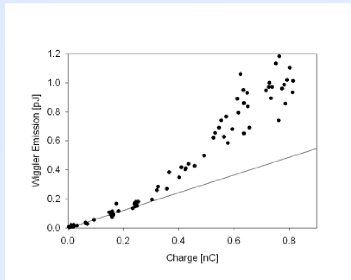






1997 first observation of short wave SASE. high QE, current, emittance 2.4 μm





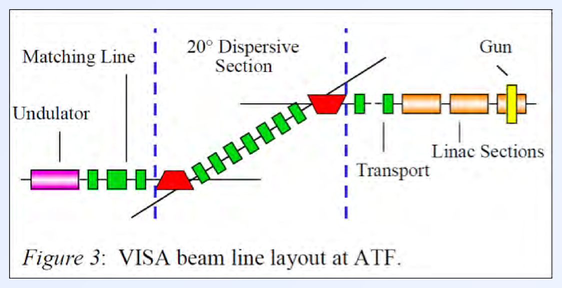
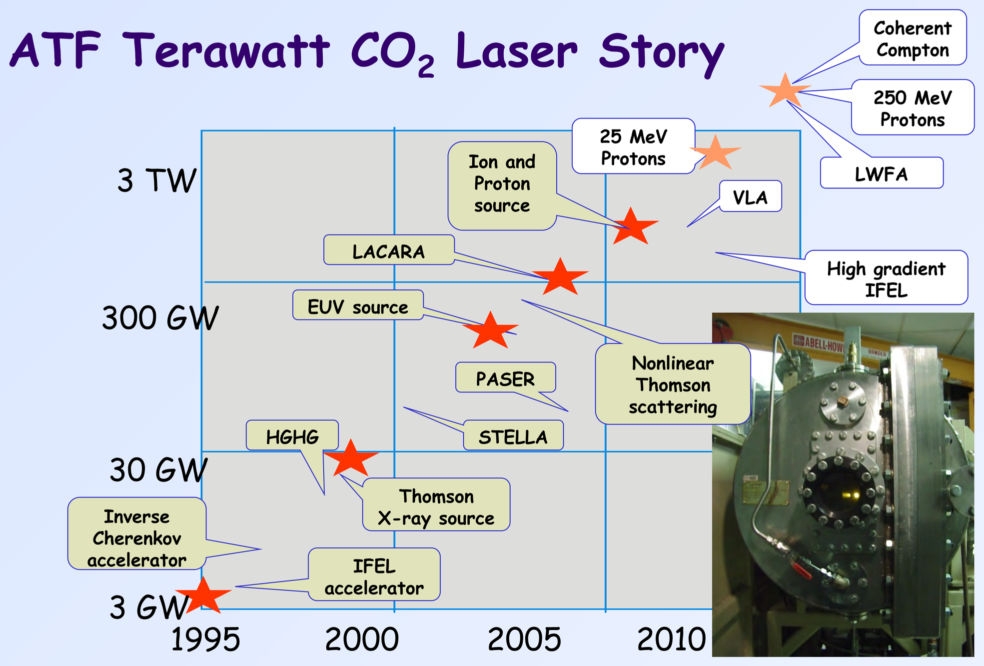


Figure 3: VISA beam line layout at ATF.

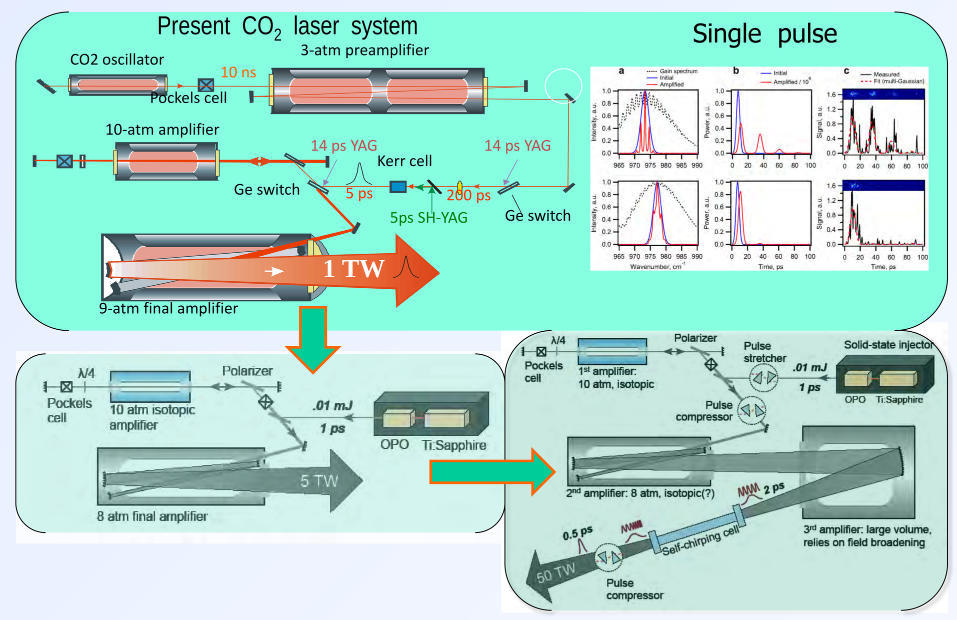
Facility upgrades

- The X band klystron was successfully tested at SLAC and is in transit to Brookhaven. This new capability will allow unprecedented characterization and control of the longitudinal phase space. It will open access for users to X band powered high gradient accelerator structures with high brightness electron beam.
- Partial replacing of regular CO_2 gas with isotopes allowed for the first time single-pulse laser amplification improving the ATF's CO_2 laser system utility for users' experiments.
- Seed 1micron solid state laser system currently generating the facility's electron bunches and providing synchronization between electron bunches and CO_2 laser pulses is approximately 20 years old and at its ultimate performance limits. A replacement process is underway to provide enhanced performance and increased reliability, while maintaining the high availability current users rely on. Higher brightness electron bunches will be made possible by this upgrade through the use of ultrafast laser technology, allowing shaping of the laser pulse on the sub-picosecond time scale. Furthermore, the highly stable synchronization and femtosecond pulse durations promised by the new laser will expand the range of experiments possible as well as bring the facility to the state-of-the-art in beam diagnostic capabilities.
- Ongoing project – replacing the conventional 5-ps seed pulse generator with all solid-state femtosecond OPO shall allow improvement of the ATF's CO_2 laser performance by an order of magnitude.
- A host of further innovations, including chirped pulse amplification that has been never attempted for this class of lasers, have been put into a proposal submitted to the BNL directorate. This upgrade shall bring the ATF laser to sub-petawatt power range to support super-strong field experiments and applications, including debris-free sources of high-fidelity ion beams for cancer therapy.

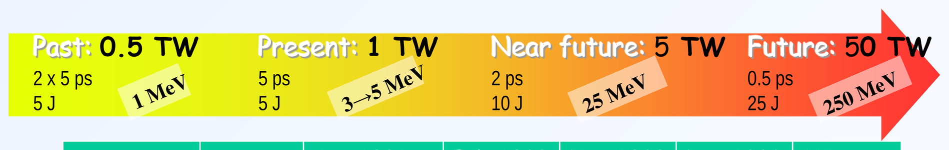
ATF Terawatt CO_2 Laser Story



Path towards multi-TW femto-sec CO_2 laser



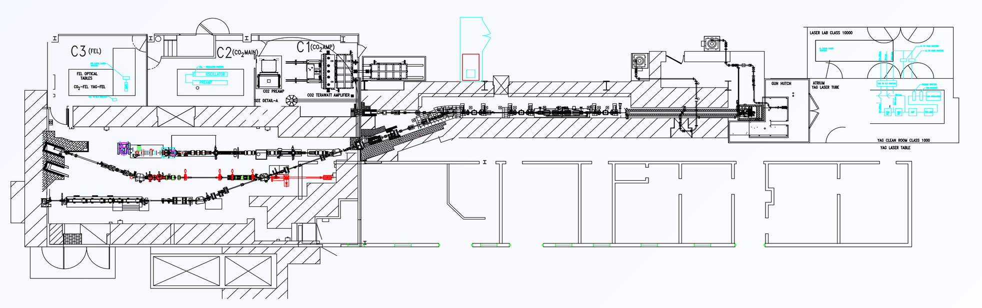
CO2 upgrade path



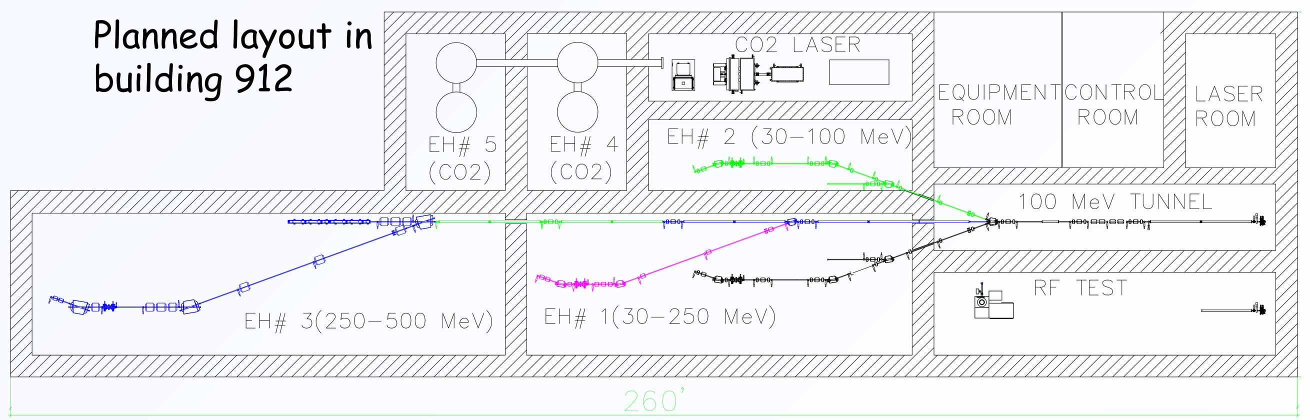
		Apr.2009	Feb.2010	Nov.2010	Dec.2011	???
Energy	[J]	5	5	5	10(IV)	25 (V)
Duration	[ps]	2 x 5 (I)	5(II)	5	2(IV)	0.5 (V)
Power	[TW]	0.5	1	1	5	50
a_0		1.2	1.7	2.2(III)	5	16
E_p	[MeV]	1.5			25	250

Plan for more spacious ATF

Existing layout in building 820



Planned layout in building 912



Goals:

- Address "space issue" at ATF
- Shielded space for medical experiments with ion beams
- Improve efficiency with number of separate experimental halls
- Allow for future grows

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Office of Science
U.S. DEPARTMENT OF ENERGY
Brookhaven Science Associates, LLC under Contract No. DE-AC02-98CH10886 with the U.S. Department of Energy.
BROOKHAVEN NATIONAL LABORATORY

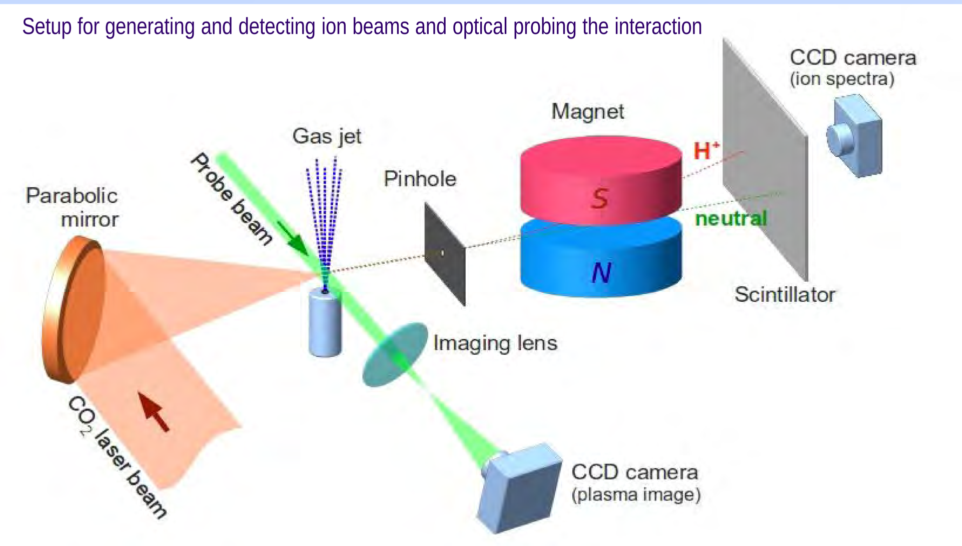
MONOENERGETIC ION BEAM GENERATION

COMPTON BACK SCATTERINGX RAY SOURCE

PLASMA AND DIELECTRIC WAKE FIELD ACCERATION

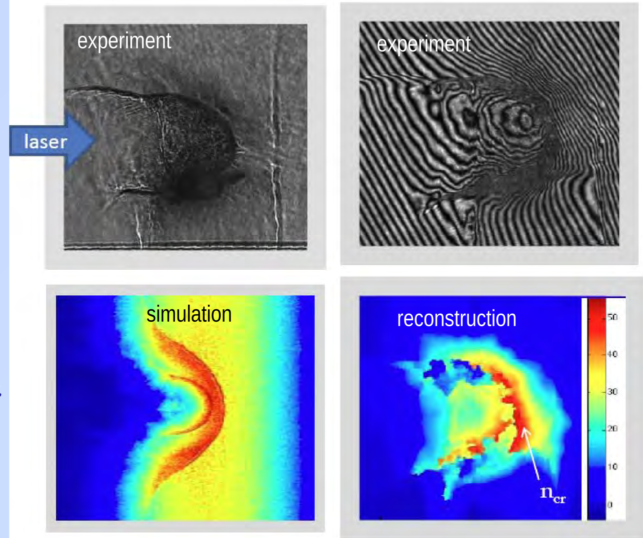
CSR SHIELDING EXPERIMENT

Proton beams with a CO_2 laser focused on a hydrogen gas jet

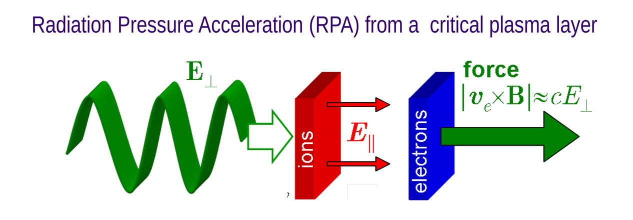


Benefits from combining gas jet with a CO_2 laser

- At λ =10 μm, $n_{cr} = \varepsilon_0 m\omega_0^2/e^2 = 10^{19} cm^{-3}$ 100 times lower than for a glass laser. Gas-jets easy to make at this density allowing to operate in the most efficient, near-critical regime.
- Gas jet :
  - allows easy switching between under-critical and over-critical regimes by changing backing pressure;
  - pure (compared to solid targets which become quickly covered in impurities);
  - can employ H, He and other species difficult to make in other targets;
  - allows changing target material quickly;
  - can run at high repetition rate.
- Plasmas critical for CO_2 are optically transparent, allowing diagnostic of interaction.

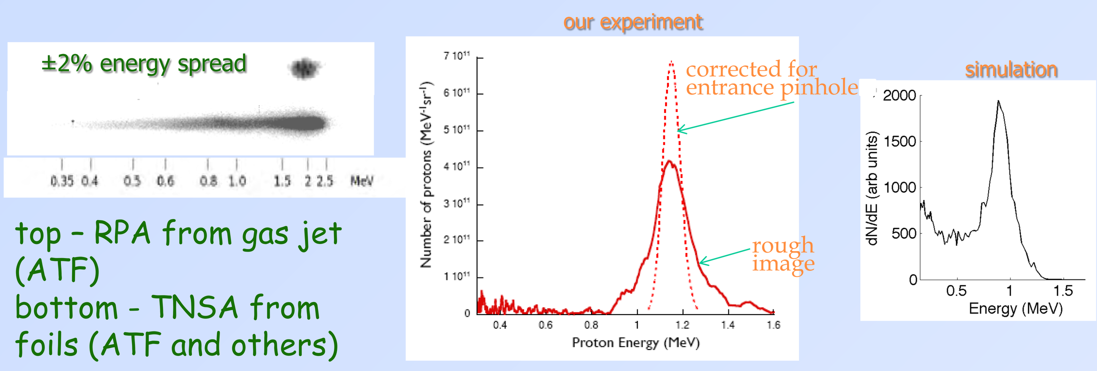


- Optical probing confirms development of a plasma shock wave at a critical density moved by the laser's radiation pressure.
- The circular polarization of the laser beam,
- the occurrence of the effect simultaneously with observed critical plasma layer moving through the gas jet,
- and especially, the monoenergetic spectrum
- indicate that the ATF experiment met conditions for the RPA regime never successfully demonstrated, even with the most powerful solid-state lasers.



Artist's view of laser-based therapy

Proton spectra

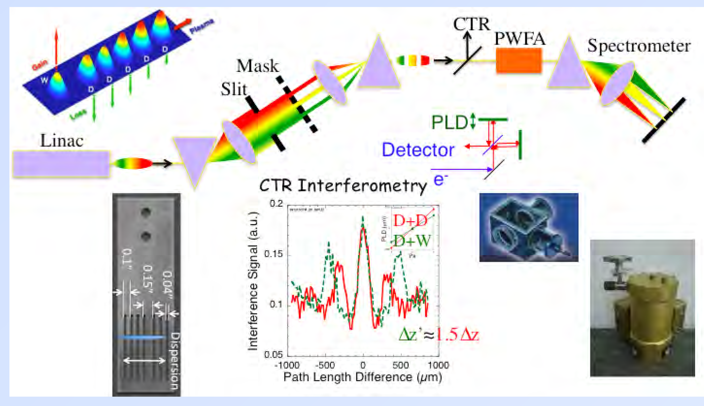


top - RPA from gas jet (ATF)
bottom - TNSA from foils (ATF and others)

According to RPA scaling, 100X increase in laser intensity leads to 200 MeV protons

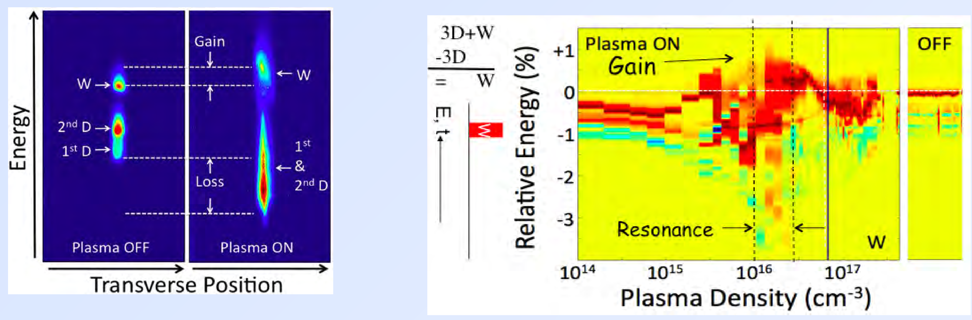
- Our beams are free from impurities (pure proton beams),
- have high spectral- brightness (>10× previous reports),
- narrow energy-spread (> 2× narrower than from micro-targets),
- and high contrast (>20× than previously reported).

Beam shaping with mask



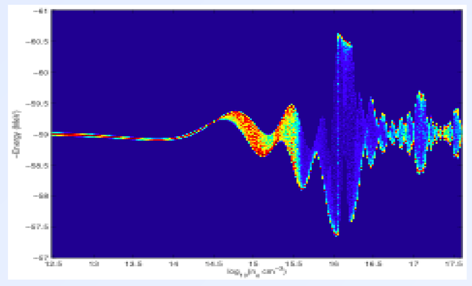
Simplified schematic of the mask principle (not to scale), and three quadrupole magnets are omitted.

Multibunch Plasma Wakefield



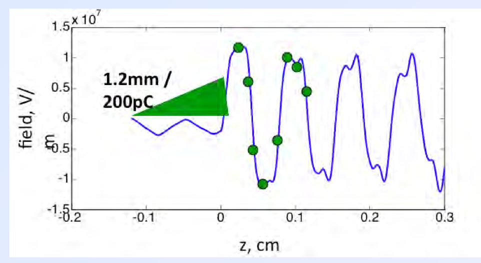
Left: energy of the train of two drive bunches followed by a witness bunch with the plasma off. The effect of CSR is to redistribute the charge in the spectrum, but not in time.
Right: energy of the train at low plasma density (non-resonant, ~10^{15}cm^{-3}), the two drive bunches lost energy, while the witness bunch gained energy.

Resonance clearly observed, $n_{e,\,res} \approx 1.4 \times 10^{16}$ cm^{-3}, as expected. Very similar to 2D calculations:

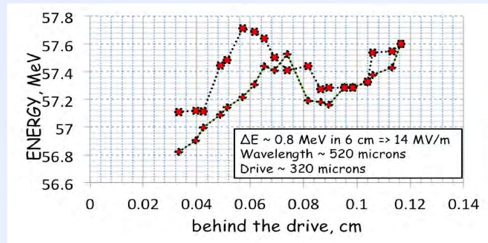


Transformer ratio with triangular bunch (DWFA)

Position of witness beam is adjusted to map wakefield

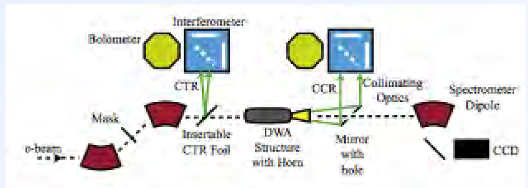


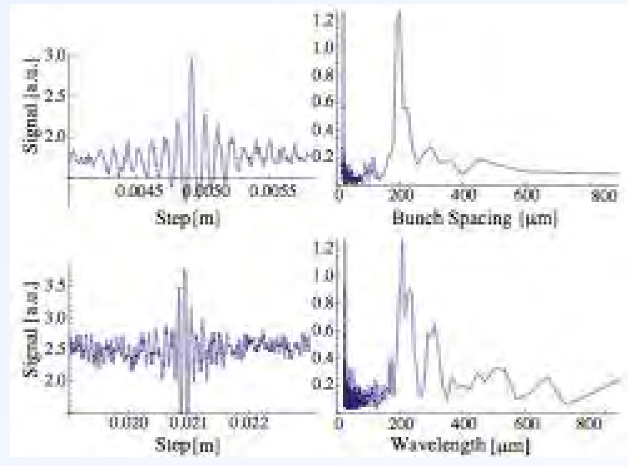
Experimental observations:



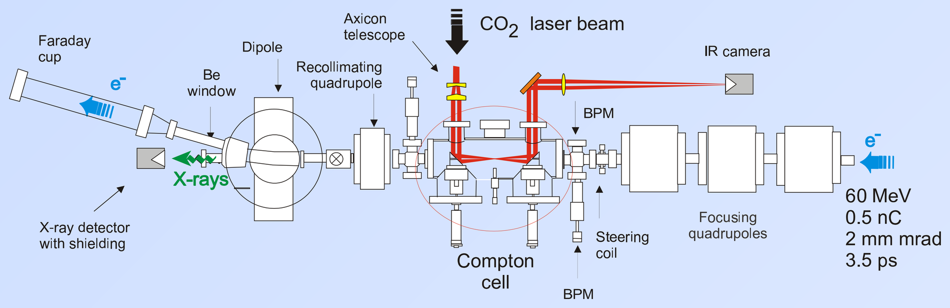
Resonant excitation of coherent Cerenkov radiation in dielectric lined waveguides

The observation of coherent Cerenkov radiation in the terahertz regime emitted by a relativistic electron pulse train passing through a dielectric lined cylindrical waveguide was reported. With this technique, modes beyond the fundamental are selectively excited by use of the appropriate frequency train.
The spectral characterization of the structure shows preferential excitation of the fundamental and of a higher longitudinal mode.

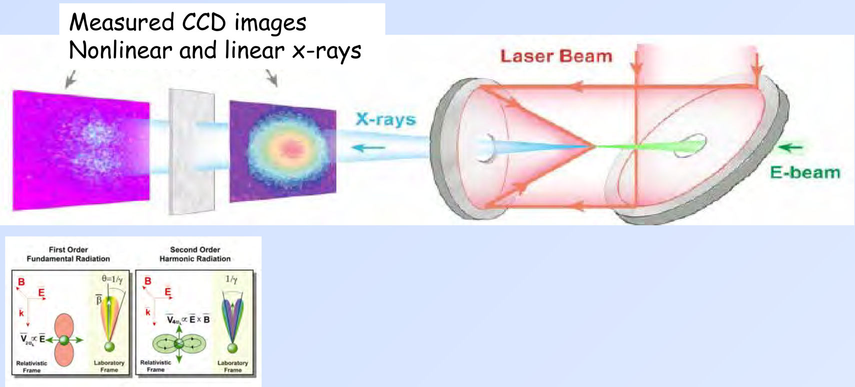




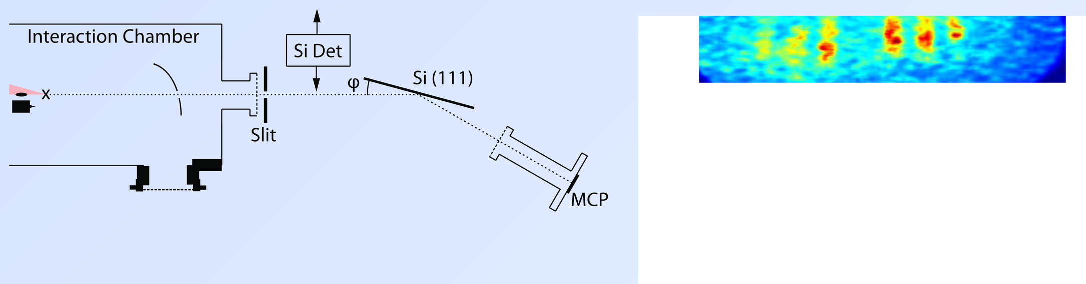
Compton X ray source diagram



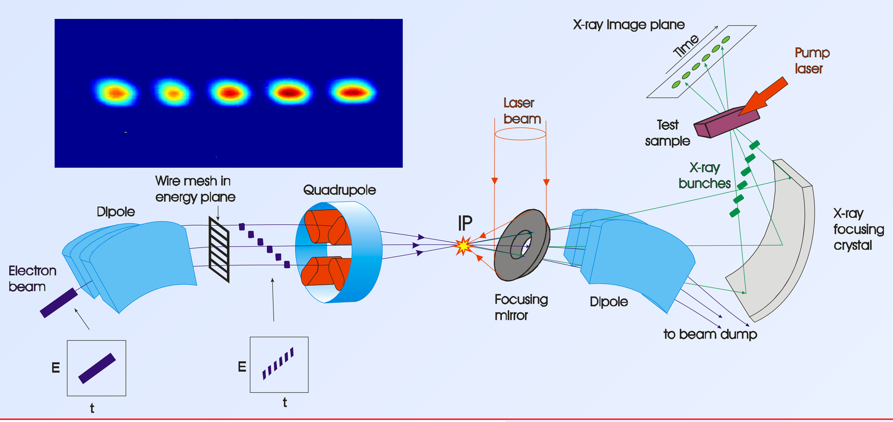
Second harmonic observation



Single shot fast diffraction



Idea of X ray 100fs frame movie camera

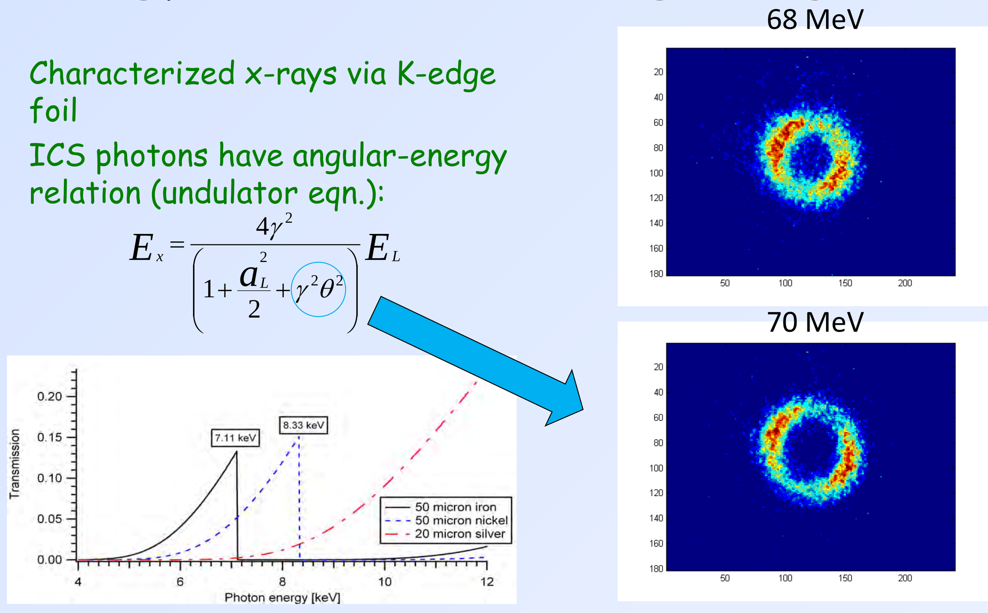


Energy Measurement Using K-edge

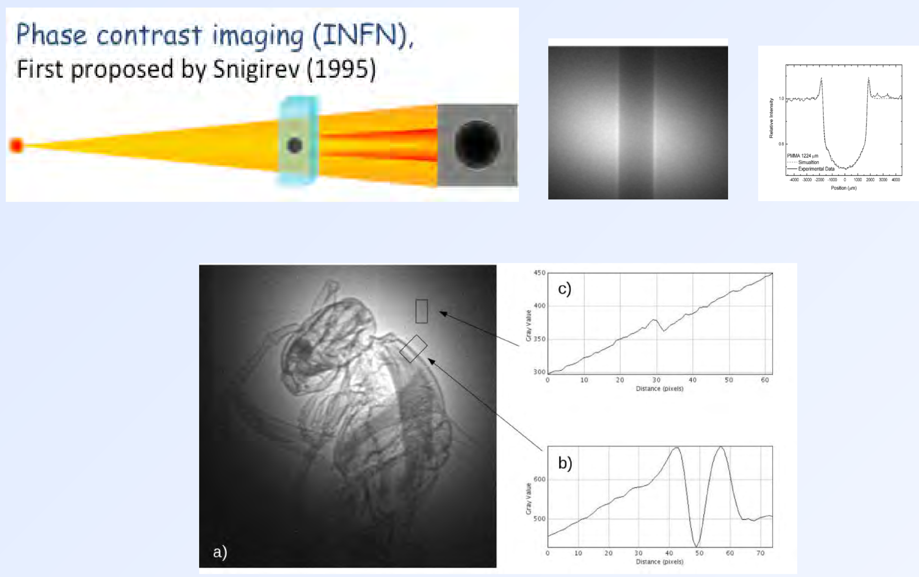
Characterized x-rays via K-edge foil

ICS photons have angular-energy relation (undulator eqn.):

$$E_x = \frac{4\gamma^2}{\left(1+\frac{a_L^2}{2}+\gamma^2\theta^2\right)} E_L$$



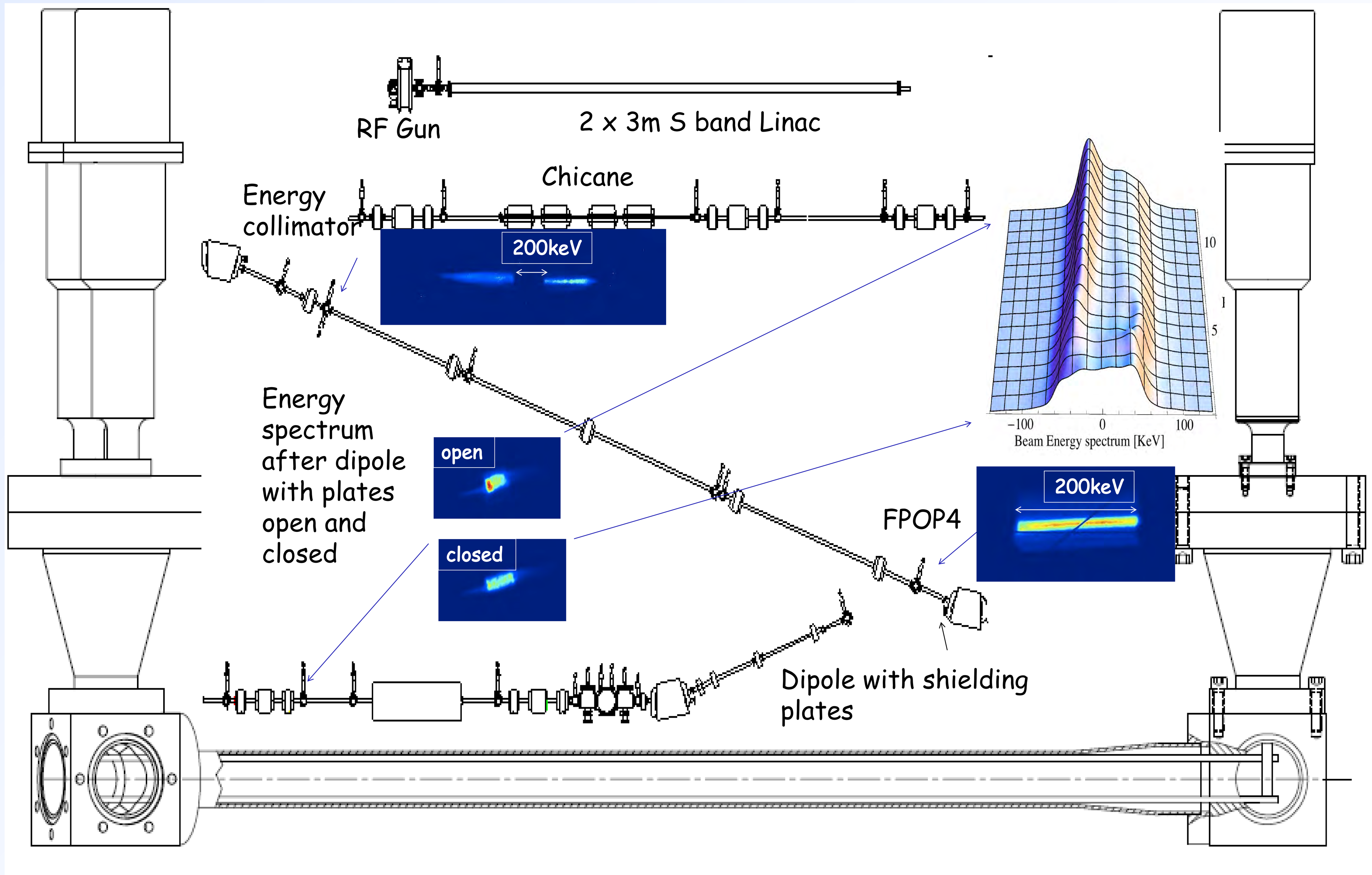
Single shot phase-contrast imaging



10^7 X-rays per beamlet are expected with 1% energy spread, 0.3 mrad divergence, 35μm source size and 100fs RMS duration.

This correspond to peak brightness of 10^{23} ph/sec/mm^2/mrad^2/0.1%

Measured beam energy spectrum vs. gap between the shielding plates.



CONCLUSIONS

Clear experimental observation of suppression of the longitudinal CSR wake in a dipole magnet by two conducting plates was recorded. At very small gaps we observed the suppression of both the energy loss and energy spread induced by CSR. Our analytical results are in good qualitative agreement with observations. This experimental proof of CSR suppression is very important for future ERLs.

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