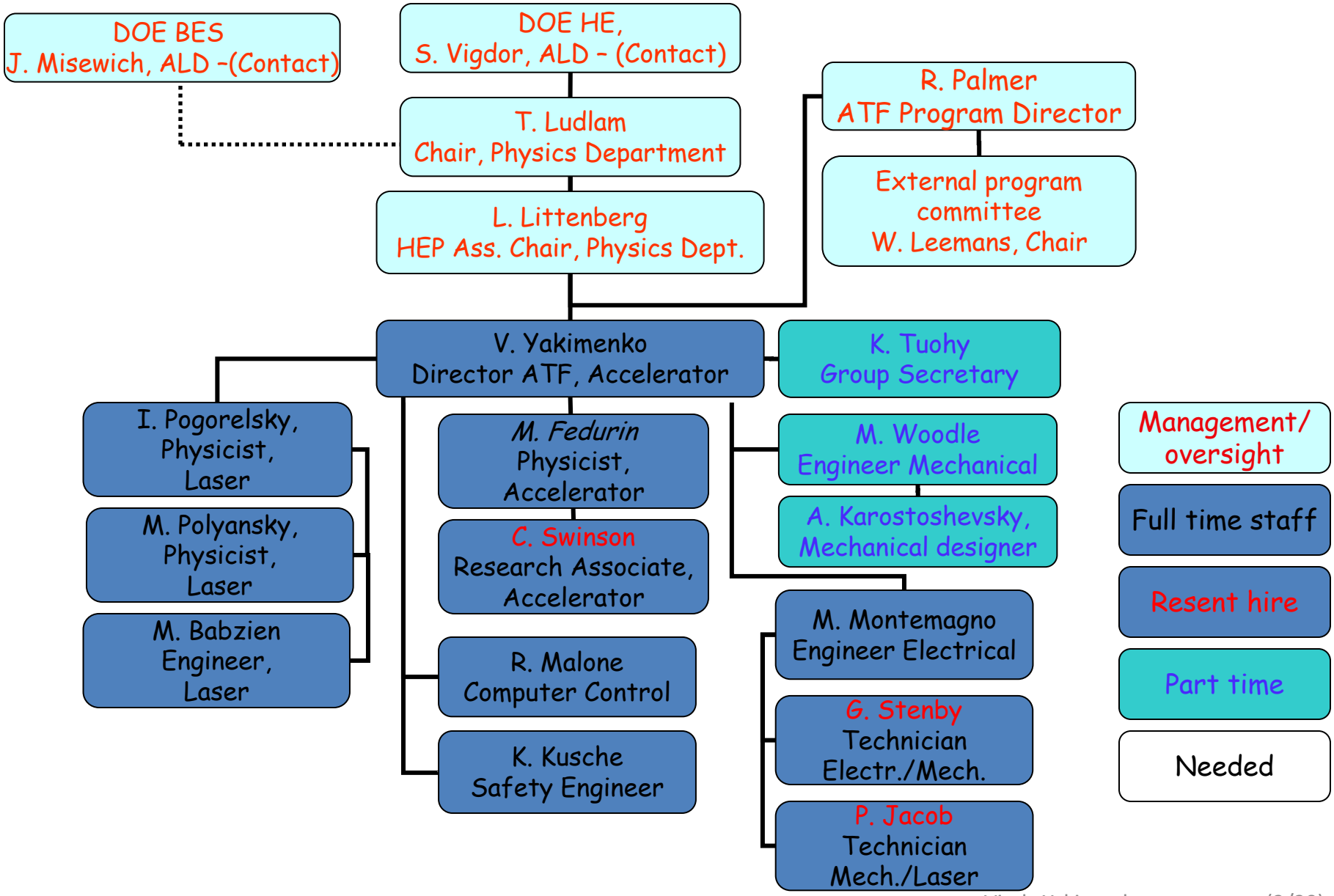
Accelerator Test Facility

Vitaly Yakimenko

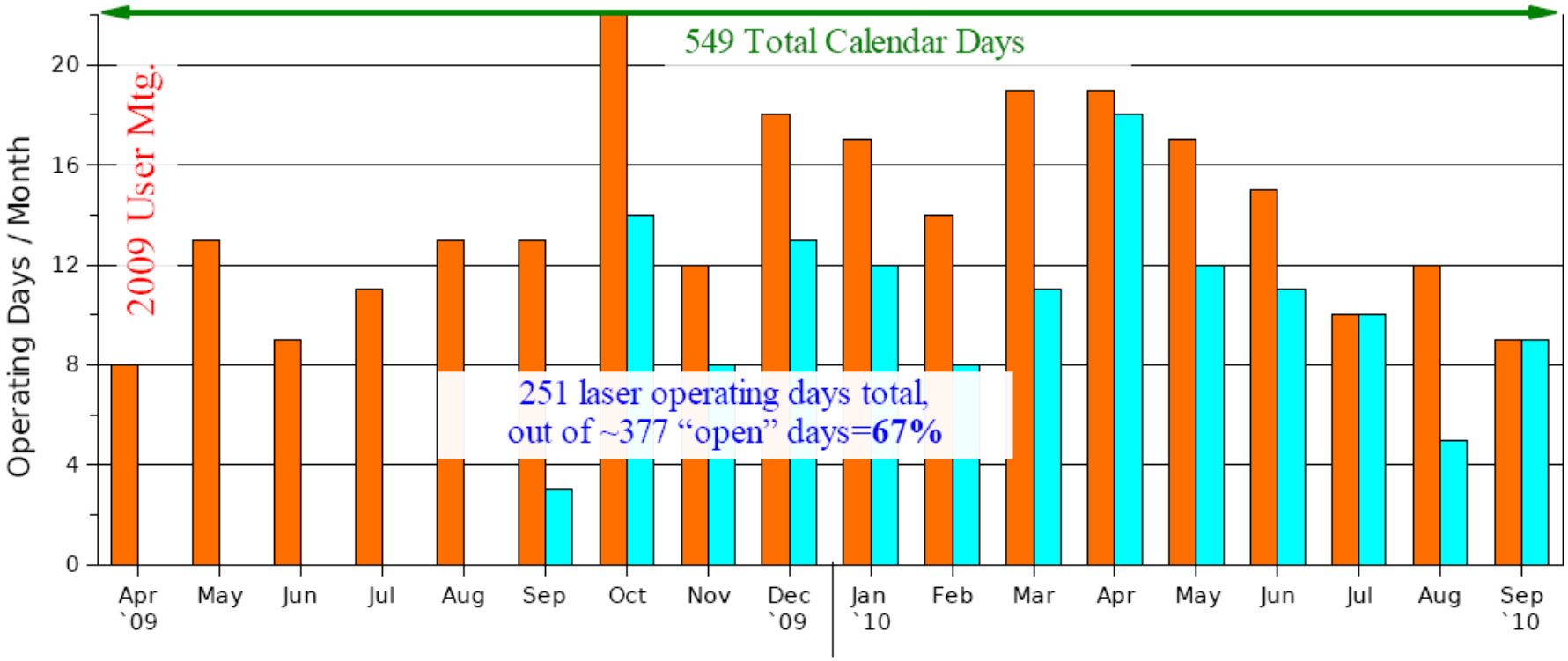
October 6-7, 2010

ATF User meeting

ATF Organization Chart



Operations statistics



Nd:Yag Laser and e-beam operational days are plotted.

CO2 operations were requiring Nd:Yag beam in April-August'09.

Days with paralel operation of CO2 and e-beam experiments are counted as one.

2009 Modulator fire at ATF

- Fire started due to failure of the high voltage capacitor in the pulse forming network of the Linac modulator.
- The modulator was completely destroyed
- Replacement modulator was built ~6 month before the fire (cost of parts ~$100K)
- Recertification, cleanup, upgrades (~$60K)
- Interlock systems disabled power to minimize chance of fire and made it safe for fire fighters.
- Operator on duty followed instructions prioritizing personal safety.
- Factors affecting the outcome were:
  - No high voltage trained person was in the building at the time of the capacitor failure. (Both of the planned hires)
  - Replacement capacitors were ordered 2 days before the fire (at ~25% of the specified life time).
- Lasers were not affected and after recertification of interlocks restarted operations within days
- e-beam operation were halted from February till September 2009.

New capabilities

- CO2 laser now delivers 4J, 4ps, 1 TW single pulse beam
- 90 MeV electron beam is delivered to Compton interaction
- <0.5degree RF phase stability is demonstrated over 1 hour
- Multichannel Frame grabber system including GigE and PI EM CCD (Electron Multiplication= Single photon) cameras is available
- …

- Updated User and Students Room

I-Q vector modulators upgrade

Gun I-Q modulator:

- New software control was developed and recalibrate for new software control

	Old control	New control
rms(ΔA)	0.140 dB	0.031 dB
max(ΔA)	0.475 dB	0.098 dB
rms($\Delta\phi$)	0.851°	0.316°
max($\Delta\phi$)	2.73°	1.22°

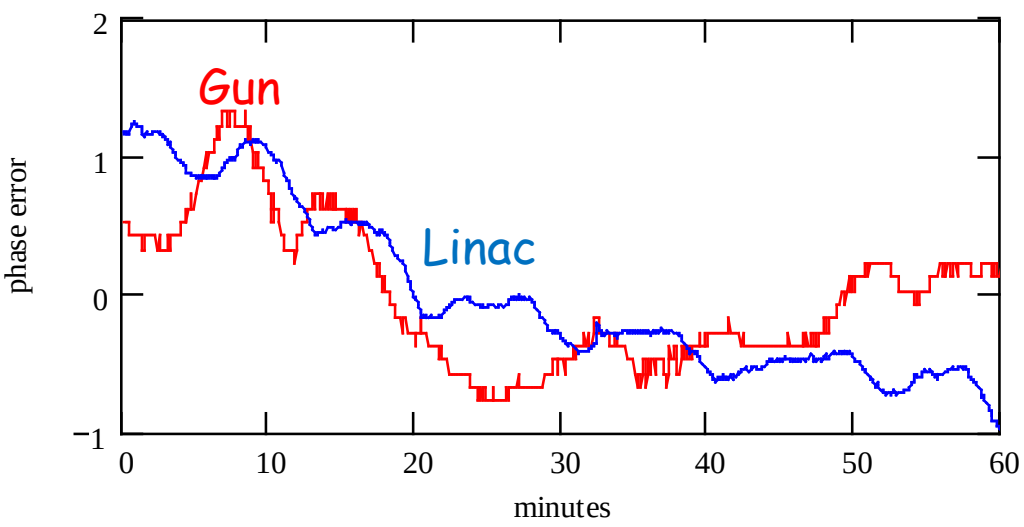
Linac I-Q modulator :

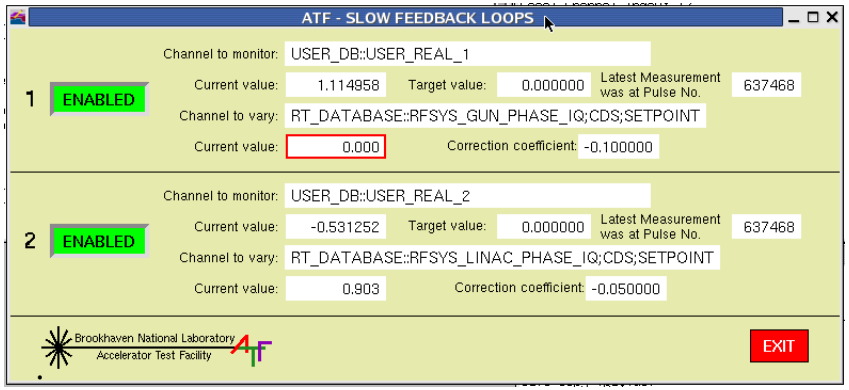
- Old I-Q was replaced
- New software control was developed and recalibrate for new software control

	Old I-Q and control	New I-Q and control
rms(ΔA)	0.159 dB	0.022 dB
max(ΔA)	0.401 dB	0.078 dB
rms($\Delta\phi$)	0.694°	0.134°
max($\Delta\phi$)	2.70°	0.565°

Control system (feedback)

- Multibuch slicing demanded tighter stability in gun and linac phases, beyond normally acceptable slow drifts.
  - Solution: Implement computer feedback loops to compensate
  - Results: Successful runs of multibunch PWFA and DWF experiments





Cameras

An excellent example of synergy between ATF's Users and Staff

"Basler Scout scA1400 gm"

- 1392 x 1040 pixels; 12-bit
- GigE Vision open standard network interface

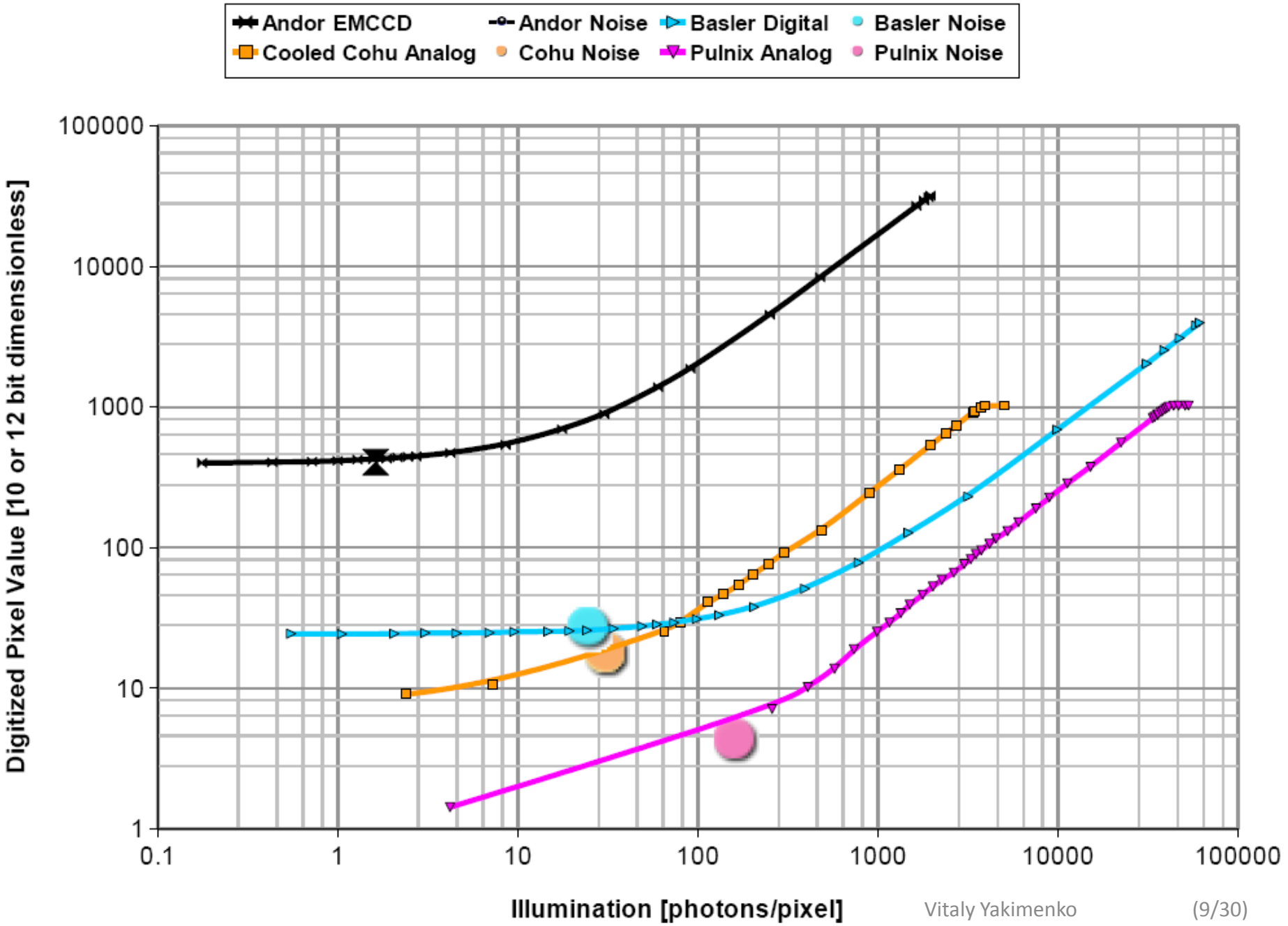
"Princeton Instruments ProEM"

- 1024 x 1024 pixels; 16-bit
- TCP/IP network interface; proprietary protocol

PWFA experiment had need for video cameras with higher dynamic range.

- Solutions:
  - User / ATF staff collaborated to select new, higher dynamic range, reputable yet economical camera
  - Users purchased cameras
  - ATF resolved vendor issues, integrated cameras into unified vendor-neutral frame grabber/control system framework
- Results
  - Improved diagnostic for many experiments
  - New cameras now available to all users

CCD Camera Responsivity Comparison



Control system (Frame grabbers)

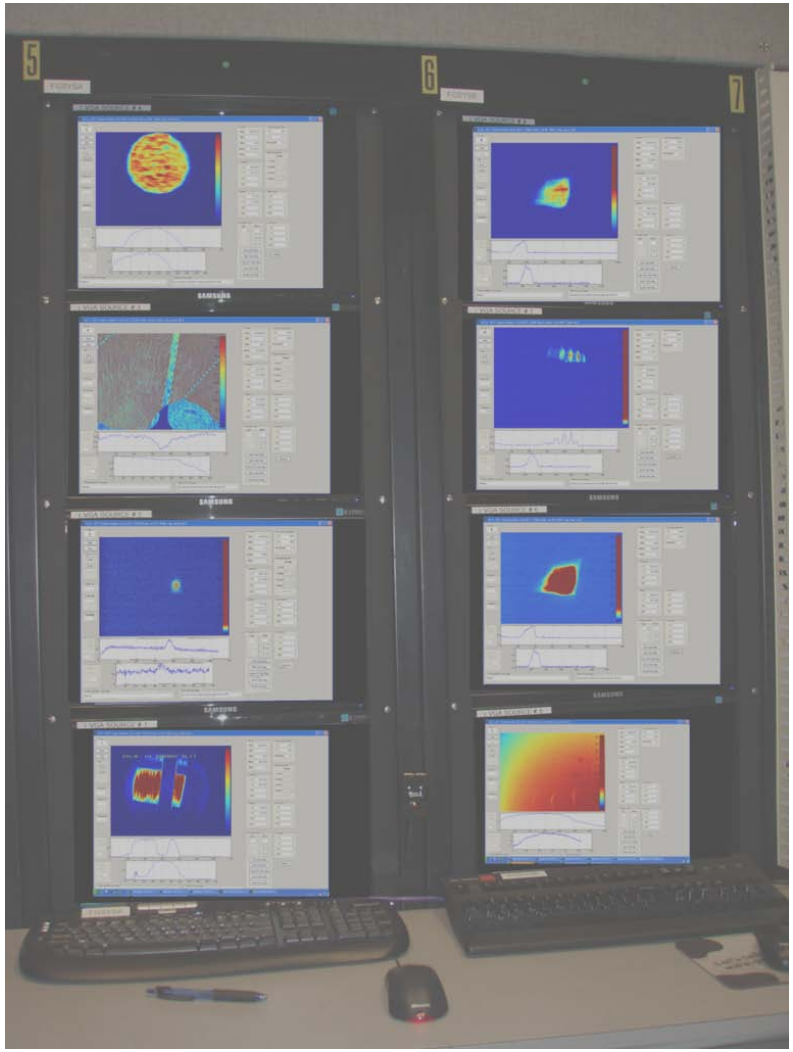
Need to upgrade driven by increased sophistication of user experiments, and the need to make video display management more user-friendly

Problems:

- Old systems was 2 single-channel 8-bit analog frame grabbers; in use since late 90s.
- Normal trigger for frame grabbers was e-beam timing; Alternative triggers (CO2 laser, plasma, etc.) required manual cable re-patching
- User experiments called for need to capture multiple images in parallel per beam pulse (e.g., image of high energy slit, plasma, etc.)

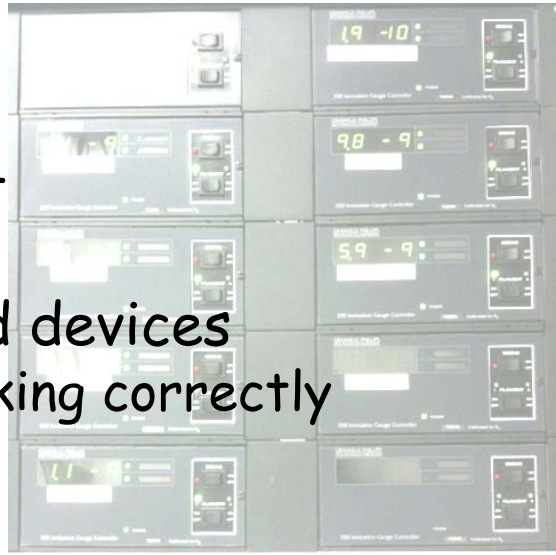
Solutions:

- 8 new independent 10-bit analog frame grabbers
- Support for networked cameras (GigE Vision and PVCAM-based)
- New switching system to route triggers (e-beam, CO2, user-defined) to any frame grabber or camera
- Video can be routed to monitors in MCR, EH, CO2, FEL areas



Other New / Improved Capabilities and Plans

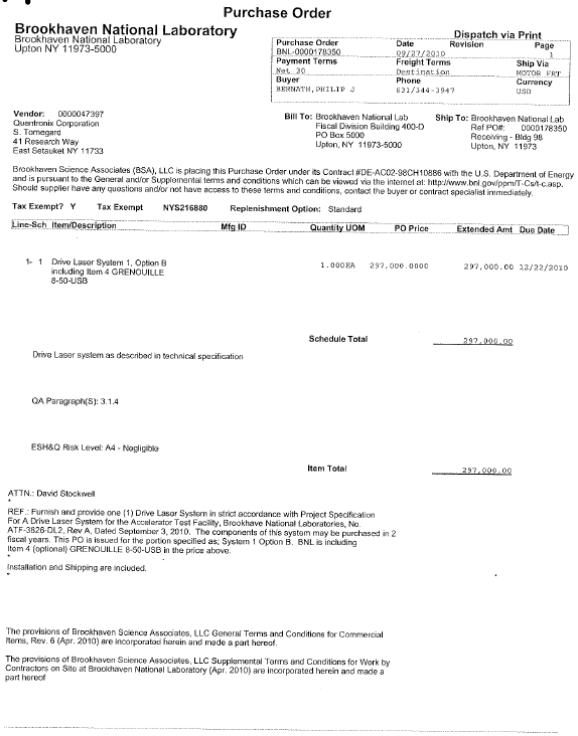
- Laser system logging PC collect data locally, but also feeds main control system



- New vacuum system controllers, interlocks
  - Control, readback, and setpoint management
- Extended support for users' RS-232 based devices
  - More channels; handle complicated handshaking correctly
- Future work:
  - Upgrade of the control system main computer
  - Mathematica interface to control system for automated data acquisition

Planned/Funded upgrades

- **X band**
  (delivery: December'10; testing: January; Operations: May'11)
  - support infrastructure at ATF is nearly complete: Modulator, shielding wall penetrations for waveguide, low level RF…
  - Will allow for well characterized properly compressed electron beam.
  - X band power requiring devices can run at ATF:
    - Extreme resolution deflector cavity
    - Breakdown effects on high brightness beam
    - Photoinjector
- **Ti:Sf:**
  (delivery: February; CO2 operations: May)
  - CO2 seed simplification
  - x10 CO2 beam intensity upgrade
  - Plasma diagnostics for Multi-bunch PWFA



Purchase Order

Brookhaven National Laboratory
Brookhaven National Laboratory
Upton NY 11973-5000

Dispatch via Print

Purchase Order	Date	Revision	Page
BNL-0000178350	09/27/2010		1
Payment Terms	Freight Terms		Ship Via
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BERNATH, PHILIP J	631/344-3947		USD

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Bill To: Brookhaven National Lab
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Upton, NY 11973

Brookhaven Science Associates (BSA), LLC is placing this Purchase Order under its Contract #DE-AC02-98CH10886 with the U.S. Department of Energy and is pursuant to the General and/or Supplemental terms and conditions which can be viewed via the internet at: http://www.bnl.gov/ops/T-Cert-c.asp. Should supplier have any questions and/or not have access to these terms and conditions, contact the buyer or contract specialist immediately.

Tax Exempt? Y Tax Exempt NYS216880 Replenishment Option: Standard

Line-Sch	Item/Description	Mfg ID	Quantity UOM	PO Price	Extended Amt	Due Date
1- 1	Drive Laser System 1, Option B including Item 4 GRENOUILLE 8-50-USB		1.000EA	297,000.0000	297,000.00	12/22/2010

Schedule Total 297,000.00

Drive Laser system as described in technical specification

QA Paragraph(S): 3.1.4

ESH&Q Risk Level: A4 - Negligible

Item Total 297,000.00

ATTN.: David Stockwell

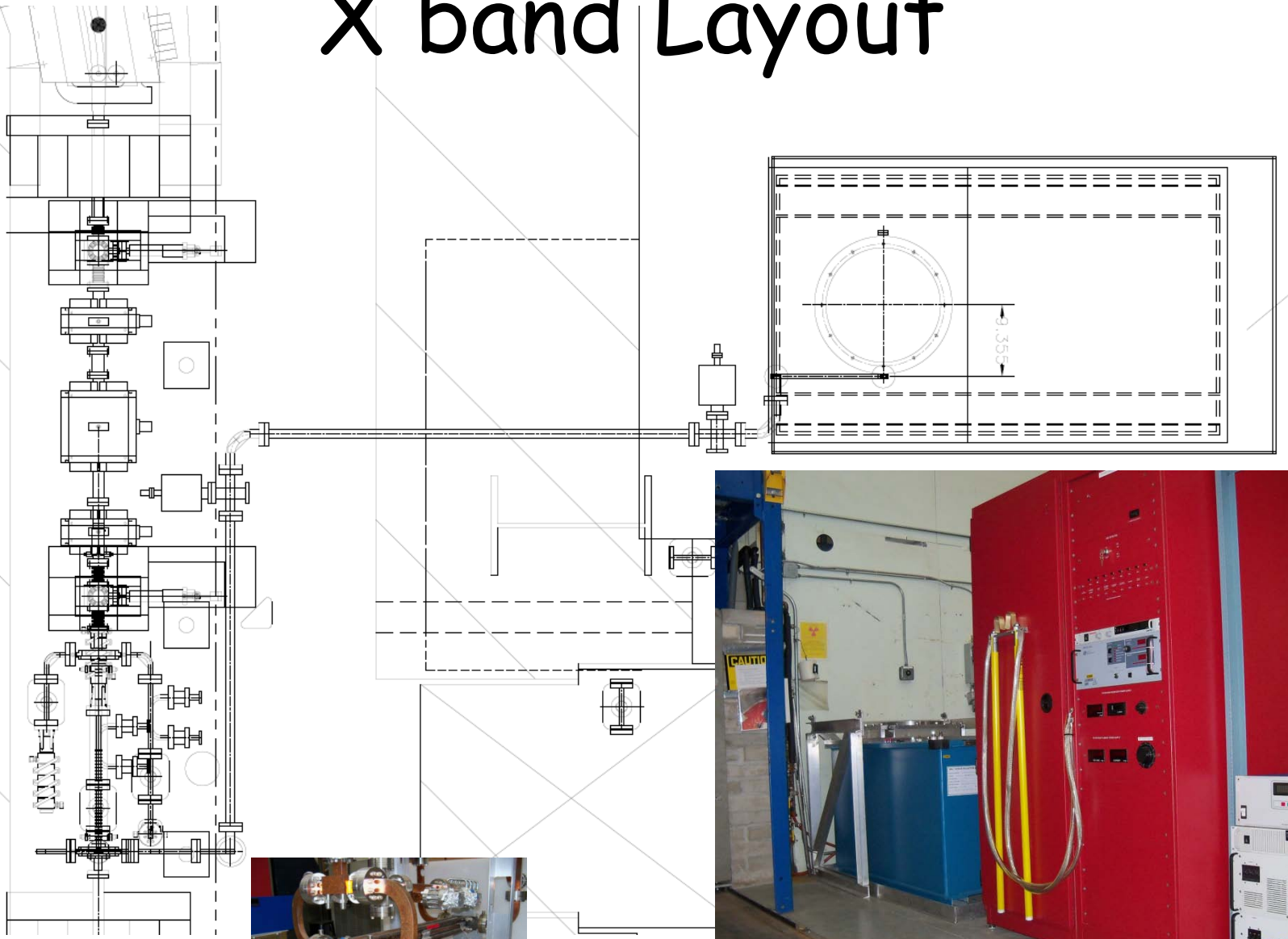
REF.: Furnish and provide one (1) Drive Laser System in strict accordance with Project Specification For A Drive Laser System for the Accelerator Test Facility, Brookhave National Laboratories, No. ATF-3826-DL2, Rev A, Dated September 3, 2010. The components of this system may be purchased in 2 fiscal years. This PO is issued for the portion specified as; System 1 Option B. BNL is including Item 4 (optional) GRENOUILLE 8-50-USB in the price above.

Installation and Shipping are included.

The provisions of Brookhaven Science Associates, LLC General Terms and Conditions for Commercial Items, Rev. 6 (Apr. 2010) are incorporated herein and made a part hereof.

The provisions of Brookhaven Science Associates, LLC Supplemental Terms and Conditions for Work by Contractors on Site at Brookhaven National Laboratory (Apr. 2010) are incorporated herein and made a part hereof

X band Layout



X band (progress at SLAC)

- Section with couplers, loads, … was delivered to ATF in December'09.

- Klystron will go to bake this week
- Bake takes 3 weeks
- RF processing takes about 2 months

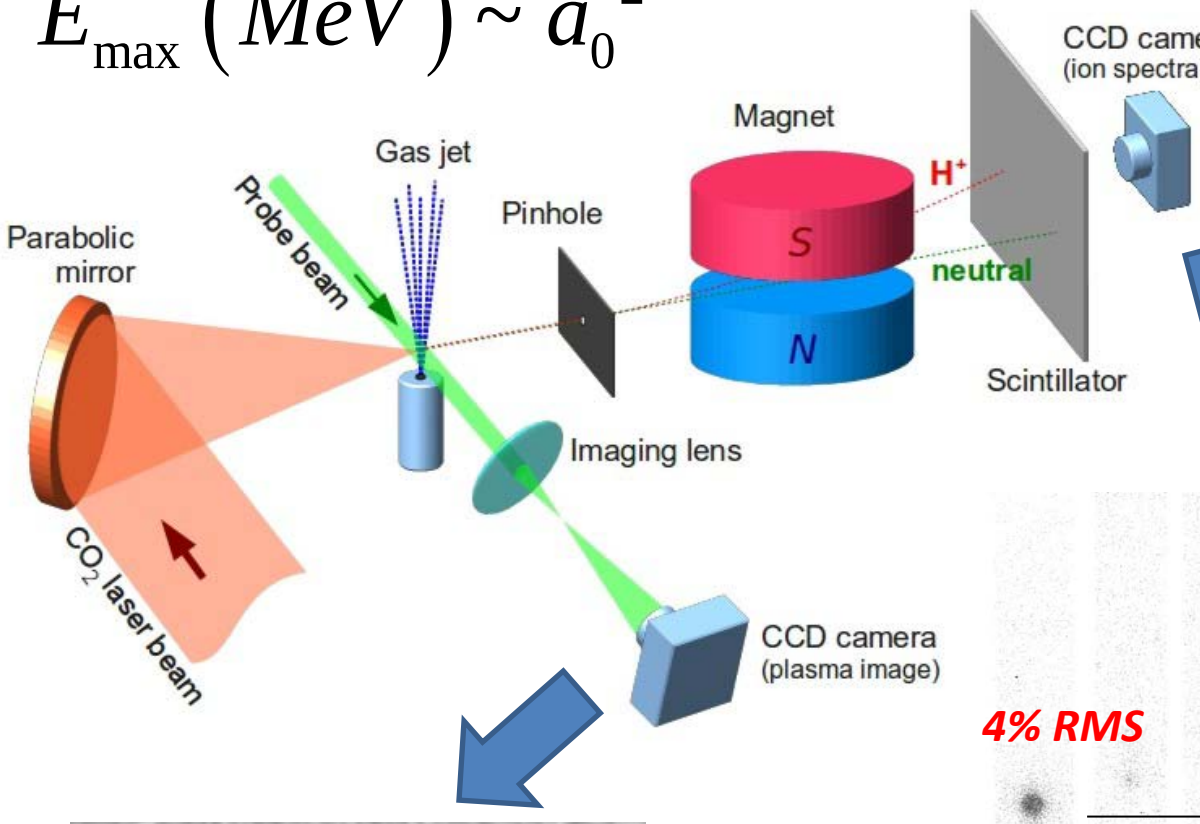
- Should be delivered to ATF in December

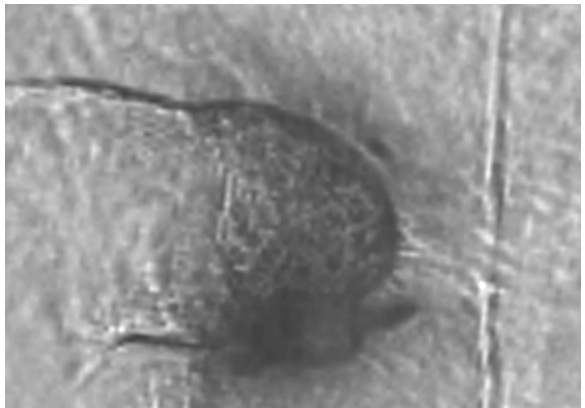
Motivations for long term facility development

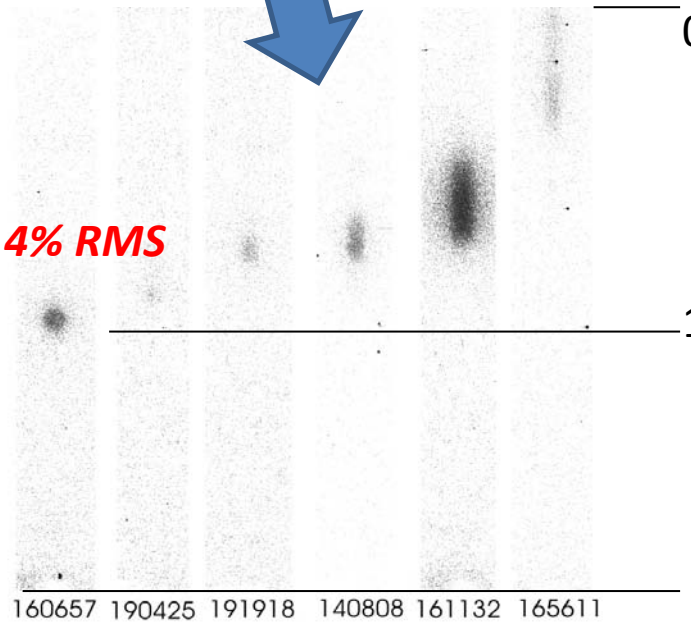
- Ion beams generated by RPA (CO_2 laser, experimental stations, space)
- Coherent Compton or FEL with Laser Undulator (CO_2 Laser and photo injector)
- PWFA and DWFA with high density microbunched beam (energy upgrade)

Monoenrgetic ion beam by Radiation Pressure Acceleration from H_2 gas jet

$$E_{\max}\left(MeV\right) \sim a_0^{\,2}$$







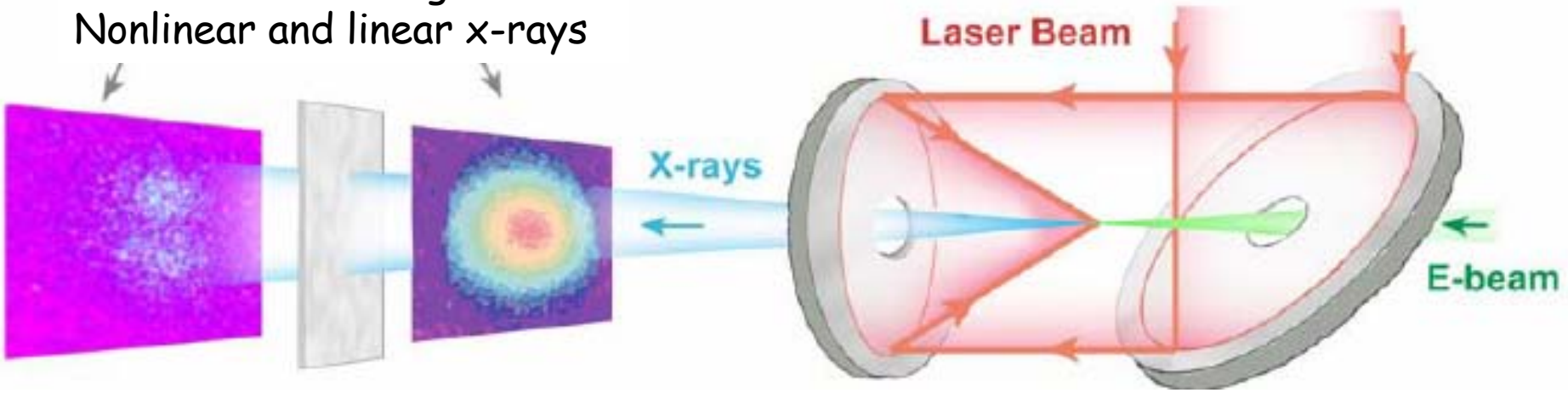
CO2 upgrade path

		Apr.2009	Feb.2010	Nov.2010	Nov.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		5	25	250

I. laser pulse was split into two due to imperfect amplification spectrum
II. isotopic mixture was used to demonstrate single pulse amplification
III. improved laser focusing is expected to increase laser intensity
IV. Ti:Sf seed laser is purchased (Sep.2010) to shorten CO2 seed to 1 ps. Shorter seed would allow for better laser energy extraction.
V. Additional amplification stage and/or laser pulse plasma chirping/compression need to be developed to reach this stage (not funded)

Coherent Compton or FEL with Laser Undulator

Measured CCD images
Nonlinear and linear x-rays



N_X/N_{e^-} ~ 0.35 in experiments at ATF/ no Coherence

Can the e-beam/laser interaction over few mm lead to electrons bunching and coherent interaction?

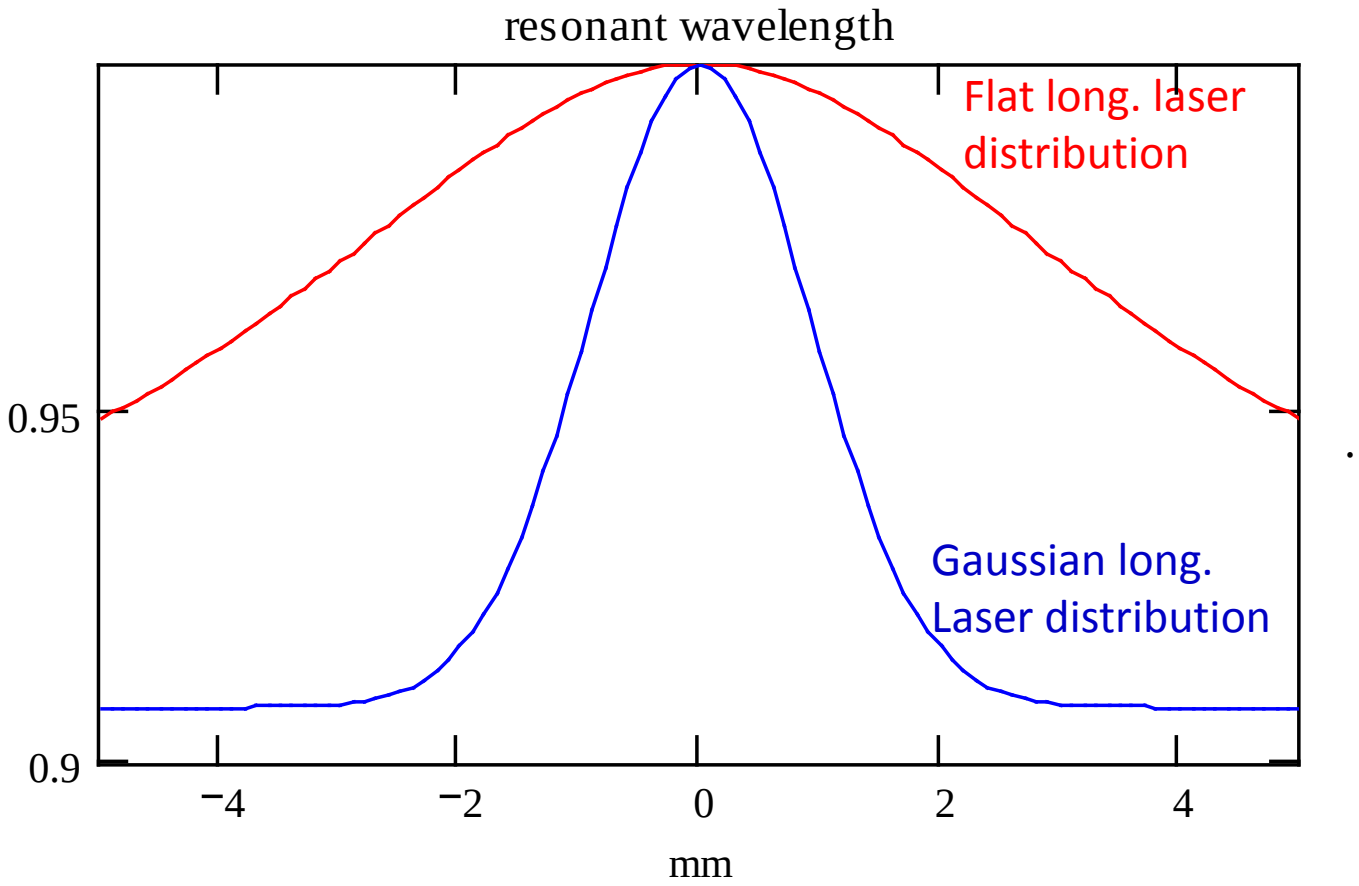
X ray FEL in 5mm

C. Pellegrini at SLAC FLS workshop: " yes, but e-beam brightness and lasers are very challenging"

Summary of numbers for LFEL

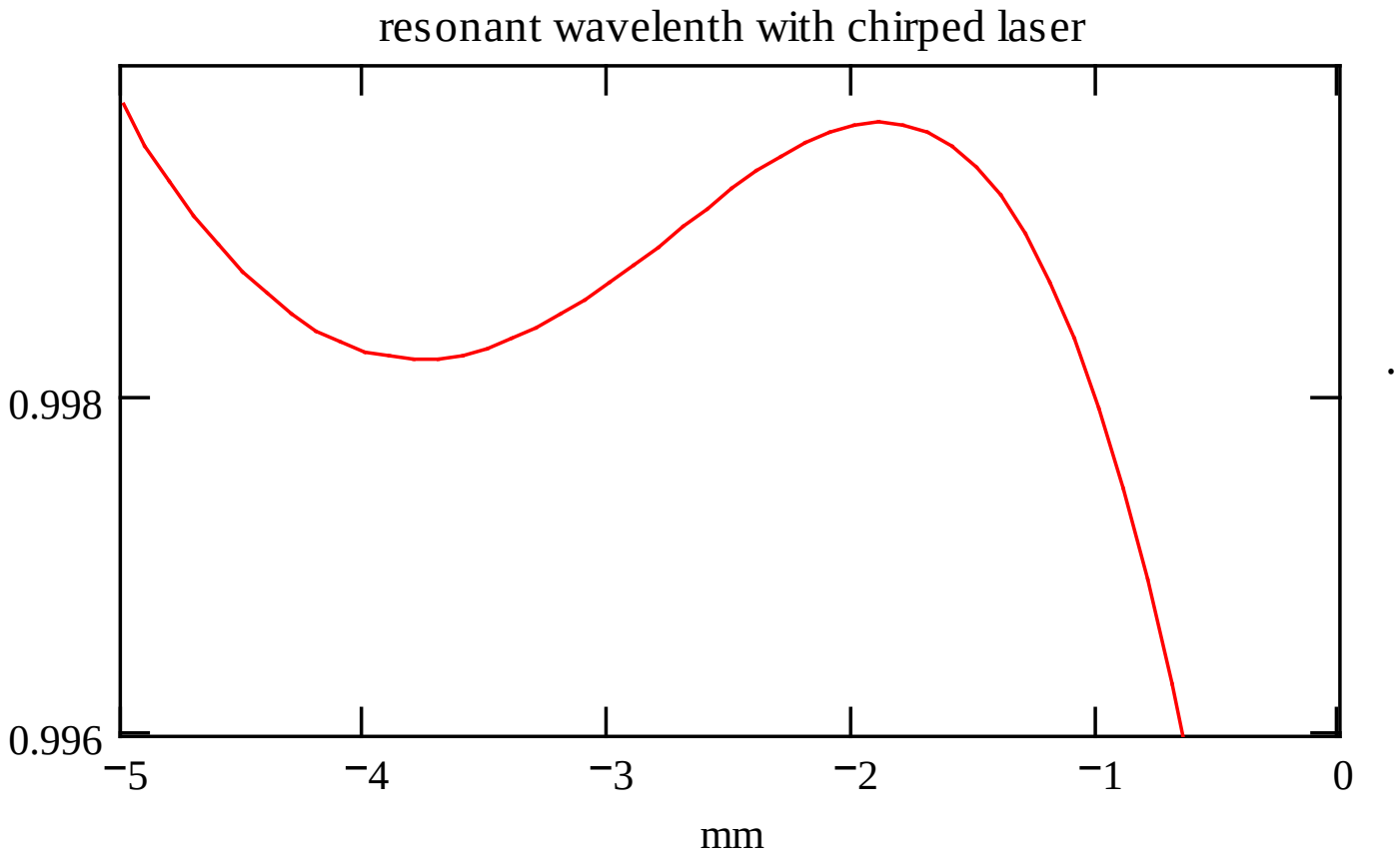
Electron beam energy	$E_e = 77.3\,\mathrm{MeV}$
3D emittance	$\varepsilon_{nc} = 30.7\,\mathrm{nm}$
Electron beam current	$I_e = 1.5\,\mathrm{kA}$
Laser wavelength:	$\lambda_{laser} = 10.6\,\mu\mathrm{m}$
Laser energy	$E_{laser} = 30\,\mathrm{J}$
Laser duration (e2e flattop):	$\tau_{laser} = 30\,\mathrm{ps}$
Saturation length	$L_{sat}(3\mathrm{mm}) = 4.8\,\mathrm{mm}$
Number of x rays per electron	$\frac{E_e}{E_X(3\mathrm{mm})} \cdot \rho(3\mathrm{mm}) = 8.6$
X ray energy:	$E_X(3\mathrm{mm}) = 10\,\mathrm{KeV}$

Resonant wavelength variation



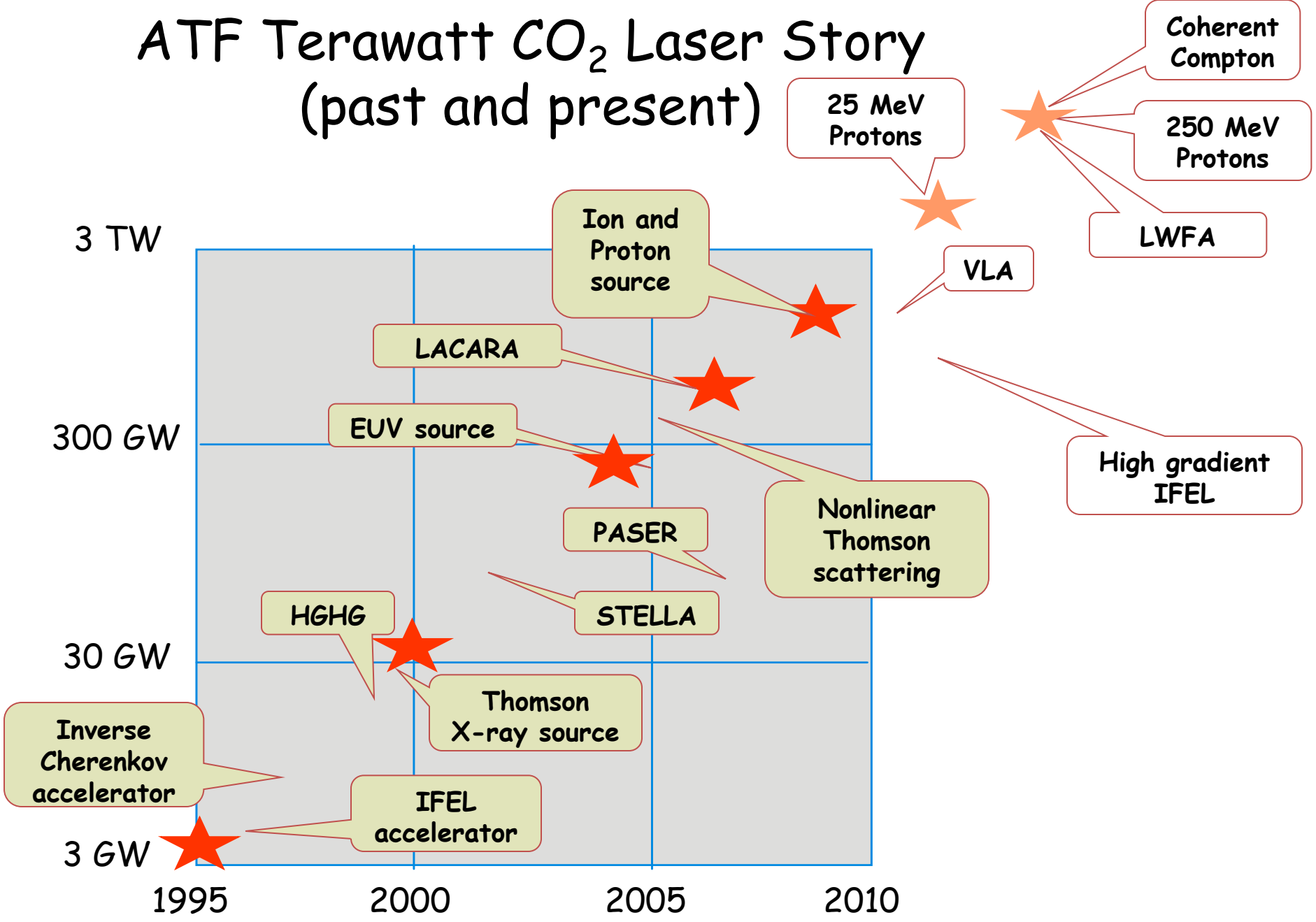
~2% wavelength variation due to change in the laser intensity is not acceptable

One can chirp the laser:

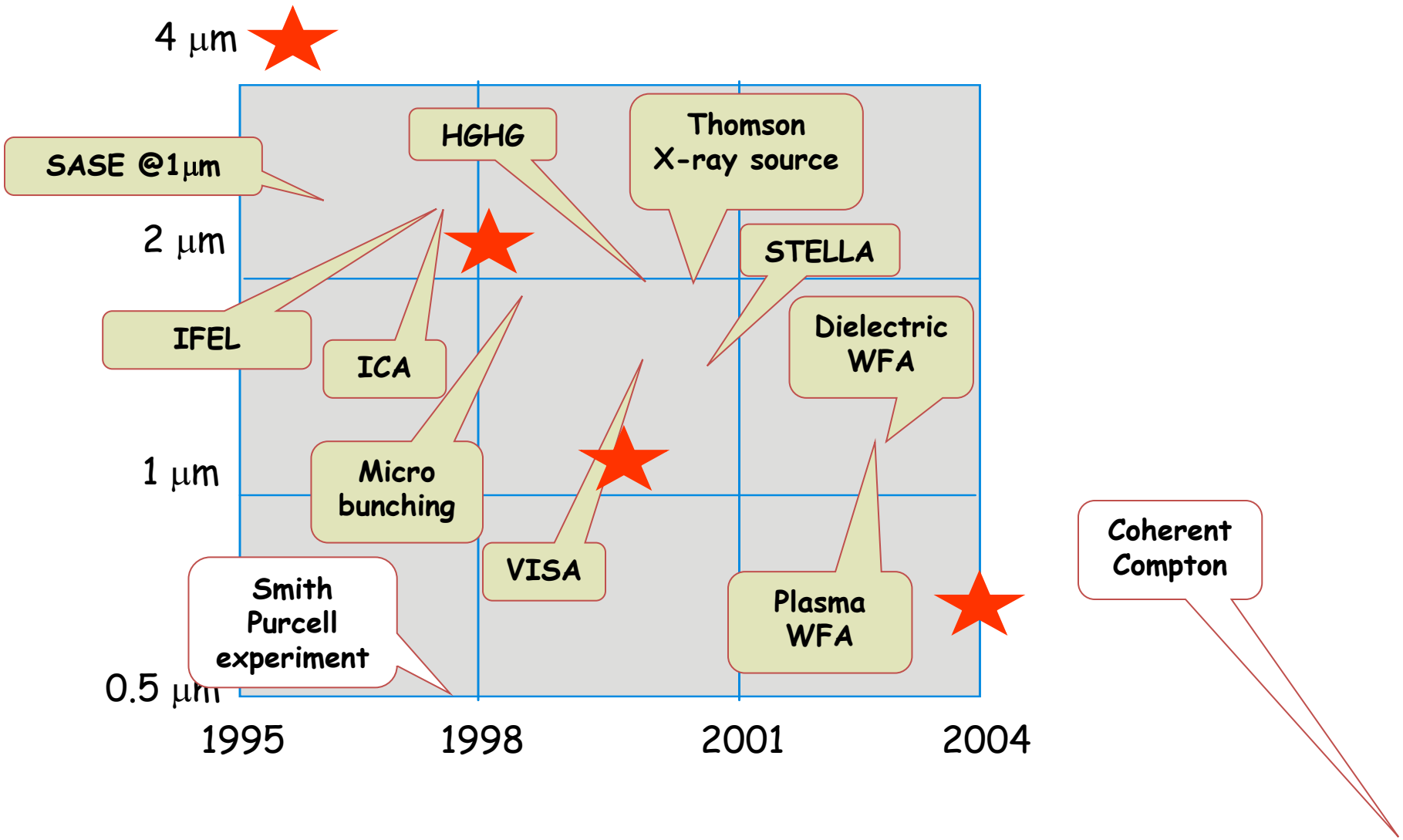


~6% laser chirp (0.5 ps BW) will keep wavelength within 0.1% over the gain length.
Combination of chirping and longitudinal shaping is needed.

ATF Terawatt CO_2 Laser Story (past and present)

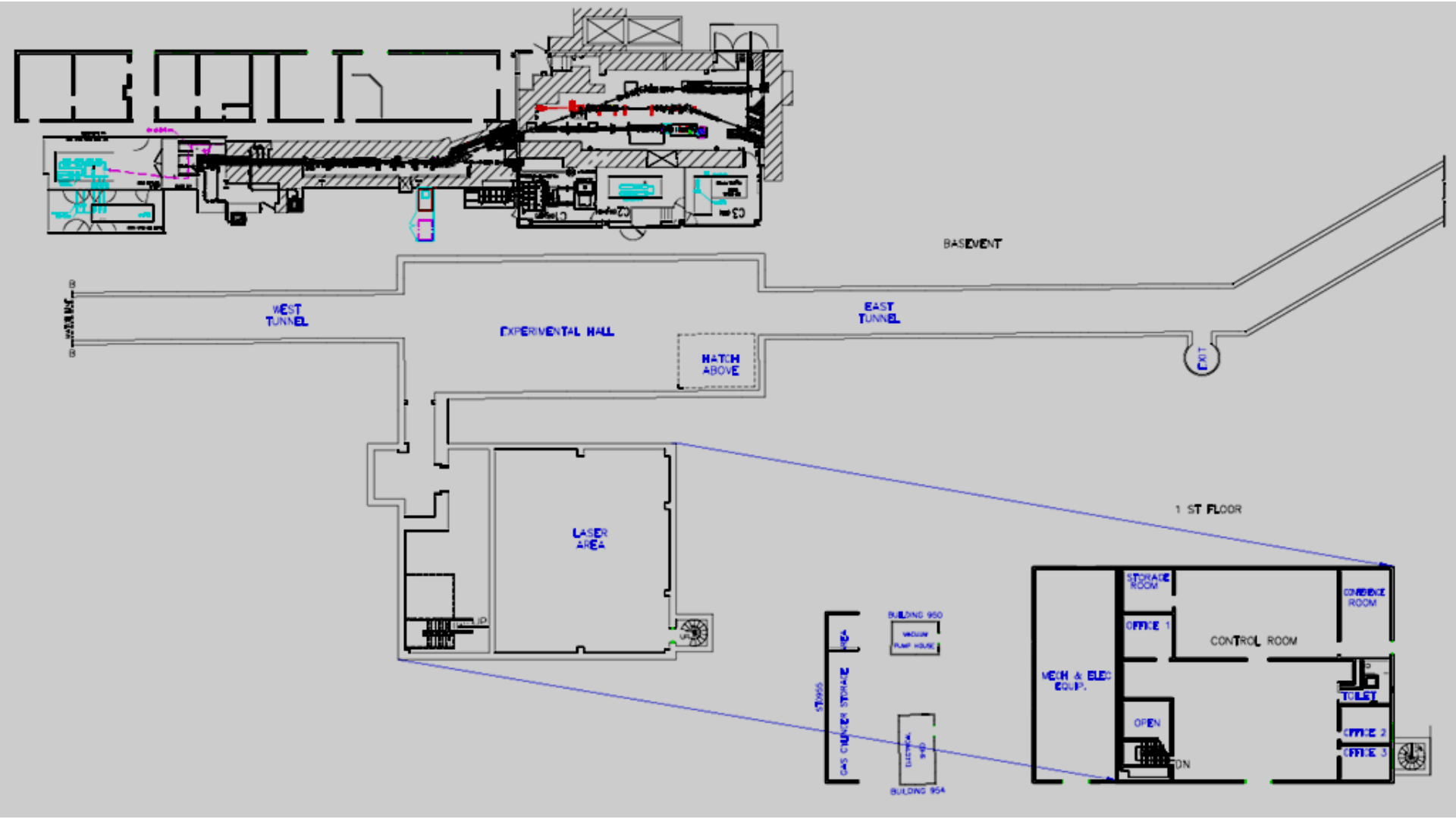


Emittance


4 μm
2 μm
1 μm
0.5 μm
1995
1998
2001
2004
SASE @1μm
HGHG
Thomson X-ray source
STELLA
IFEL
ICA
Dielectric WFA
Micro bunching
VISA
Smith Purcell experiment
Plasma WFA
Coherent Compton

Space issue

Example of Bldg.939



Plans (unfunded)

- Photo injector laser replacement with Ti:Sf based system
  - Simplified maintenance, operations
  - Longitudinal shaping
- Photo injector R&D
- ATF move into new building
  - Reasonable experimental hall
  - Space for CO2 experiments
  - Energy upgrade to ~300 MeV
    - Over-dense regime
    - Reduce relative effects of wake fields (CTR, CSR, …)
- CO2 power upgrade to 50J/500fs (plasma chirping/optical pumping…)
  - 500MeV protons RPA (Medical, DTRA,…)
  - "High charge" LWFA electrons

Schedule of this meeting

Title	Start	duration	PI	Institut.	Substitute Presenter	type	Funded	run days
10/6/2010	8:30							
Executive session	8:30	0:30						
ATF talks	9:00							
ATF Status and plans	9:00	1:00	Vitaly Yakimenko	ATF		facility	HEP/BES	
New Ti:Sf laser	10:00	0:20	Marcus Babzien	ATF		facility	HEP	
CO2 laser R&D	10:20	0:20	Mikhail Polyanskiy	ATF		facility	HEP/BES/LDRD	
coffee	10:40	0:30						
Ion beam generation	11:10							
Monoenergetic ion beam generation from a gas jet	11:10	0:20	Zulfikar Najmudin	Imperial College	Igor Pogorelsky	Status report	EU/HEP	25
Waivelength scaling in experiments with foils	11:30	0:20	Peter Shkolnikov	SBU		Status report	EU/HEP	36
Studies of post-solitons in laser/plasma interaction	11:50	0:15	Peter Shkolnikov	SBU		Status report	HEP	2
Study of hot electron transport and subsequent ion acceleration	12:05	0:10	Victor Malka	LOA	Igor Pogorelsky	Status report	EU	
Diagnostics	12:15							
Single shot interferometer	12:15	0:15	Gerard Andonian	UCLA		proposal	SBIR	
Fiber-meshed beam profile diagnostics	12:30	0:15	James Rosenzweig	UCLA	Alex Murokh	proposal	SBIR	
Working lunch	12:45	1:00						

Title	Start	duration	PI	Institut.	Substitute Presenter	type	Funded	run days
Compton	13:45							
single shot phase contrast measurement	13:45	0:15	Massimo Carpinelli	INFN		status report	EU	8
Fast Compton	14:00	0:15	James Rosenzweig	UCLA	Oliver Williams	status report	NSF	6
IGS	14:15	0:20	Alex Murokh	Radia Beam		proposal	DTRA	1
Inverse Free Electron Laser	14:35							
High gradient IFEL	14:35	0:10	Pietro Musumeci	UCLA		status report	NSF/HEP	
IFEL with recirculated laser	14:45	0:20	Alex Murokh	Radia Beam	Pietro Musumeci	proposal	DTRA	
coffee	15:05	0:30						
Beam manipulation/testing	15:35							
Coherent synhrotron radiation shielding experiment	15:35	0:20	Dmitry Kayran	BNL/CAD		status report	NP	20
Single electron beam generation	15:55	0:15	Sebastian White	BNL/PO		FS/SE report	HEP	7
Fast detector testing	16:10	0:20	Sebastian White	BNL/PO		proposal	HEP	3
RHIC Stochastic Cooling pick-up test	16:30	0:15	Blackler, Ian	BNL/CAD		FS/SE report	NP	2
Delta undulator magnet beam test at ATF	16:45	0:15	Alexander Temnykh	Cornell		FS/SE report	BES	6
Executive session	17:00	1:00						
Break	18:00	0:30						
Dinner	18:30							

10/7/2010		8:30							
Executive session		8:30	0:30						
Plasma wake field									
	Status of the multi-bunch PWFA	9:00	0:20	Patric Muggli	USC		status report	HEP	23
	Optical Measurement of Plasma Wave Structure Produced by the Multi-bunch Driven PWFA	9:20	0:15	Rafal Zgadzaj	UT		status report	HEP	6
	Progress toward the Current Filamentation Instability (CFI) experiment	9:35	0:15	Brian Allen	USC		status report	NSF	1
Dielectric wake field		9:50							
	DWF as a radiation source	9:50	0:20	James Rosenzweig	UCLA	Gerard Andonian	proposal	HEP	11
	high gradint DWFA with microbunched beam	10:10	0:20	Alexei Kanareykin	Euclid Techlabs		proposal		
coffee		10:30	0:30						
X band/high gradient		11:00							
	X-band deflector	11:00	0:10	James Rosenzweig	Radia Beam	Alex Murokh	status report	SBIR	
	High gradient S-band linac	11:10	0:15	Alex Murokh	Radia Beam		proposal	SBIR	
	Surface wave accelerator and surface Cherenkov radiation source based on SiC	11:25	0:25	Gennady Shvets	UT		proposal	HEP	
Other		11:50							
	Experimental Study of Electron-Beam Micro-bunching Dynamics and Shot-Noise Suppression Effect	11:50	0:15	Avi Gover	Technion	Timur Shaftan	proposal update	Israel	
	Laser Acceleration in Vacuum	12:05	0:15	David Cline	UCLA	Lei Shao	proposal update	HEP	
Working lunch		12:20	1:00						
Executive session		13:20	1:00						
Adjourn		14:20							

Conclusions (past)

- CO2 laser at TW level with a well characterized single pulse operations.
- Very stable (fraction of a degree over an hour) RF operations
- Diagnostics capability improved

- Mono energetic protons observed from a gas jet

Conclusions (6-12 month plans)

- X band power will be available
  - Highly compressed e-beam
  - Longitudinal e-beam characterization
  - User experiments with X band power…
- Ti:Sf laser system
  - ~5-10 TW CO2 laser beam
  - Plasma diagnostics

Conclusions (1-5 years)

- Space upgrade
  - Better conditions in e-beam experimental hall
  - Experimental hall for laser experiments
  - Experiments with ~50 MeV protons
- CO2 laser upgrade
  - chirping/compression
  - New amplification stage
- e-Beam energy upgrade
  - Blow out regime in multibuch PWFA
  - Overcoming limit of wake fields, space charge…

Thank You