XTOD Breakout

August 10, 2004
1.5 Breakout

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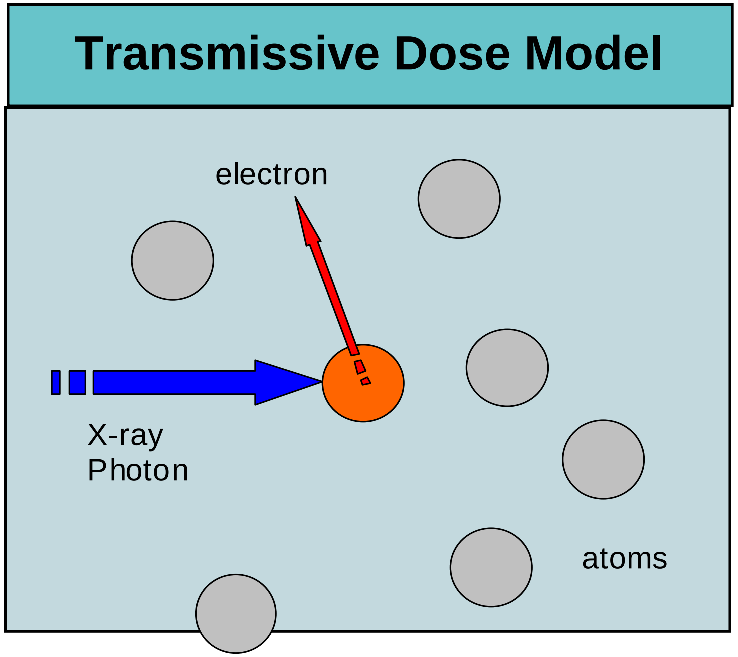
Outline

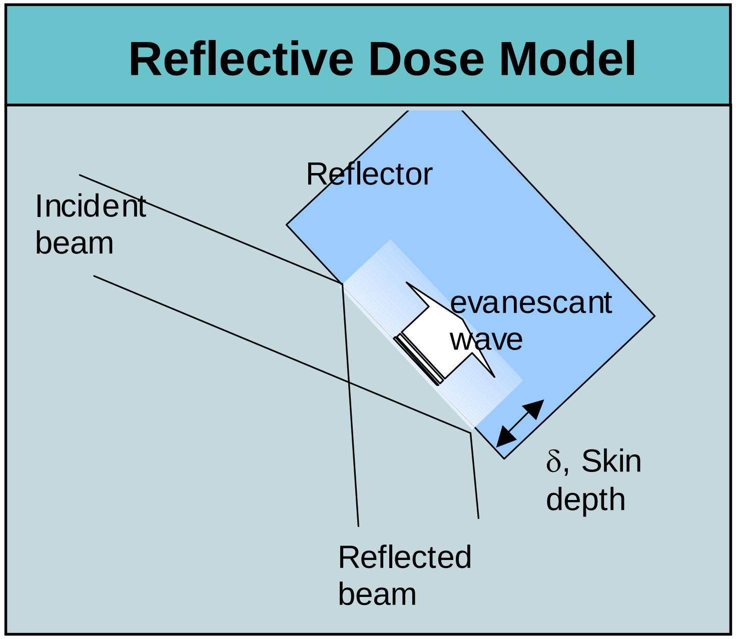
- **Beam Models and Dose**
- **Diagnostics and Front-End Optics**
- **Simulation and modeling**
- **Programmatics**
- **Future work and conclusions**

Beam Models and Dose

We can calculate the dose at normal incidence



Transmissive Dose Model



Reflective Dose Model

Dose at normal incidence

$$\overline{Dose} = E_{photon} \cdot \rho_{photon} \cdot \sigma_{photoion}$$

Peak photon density

Dose to reflective optics is less, but model dependent

FEL beam power levels estimated from M. Xie formalism

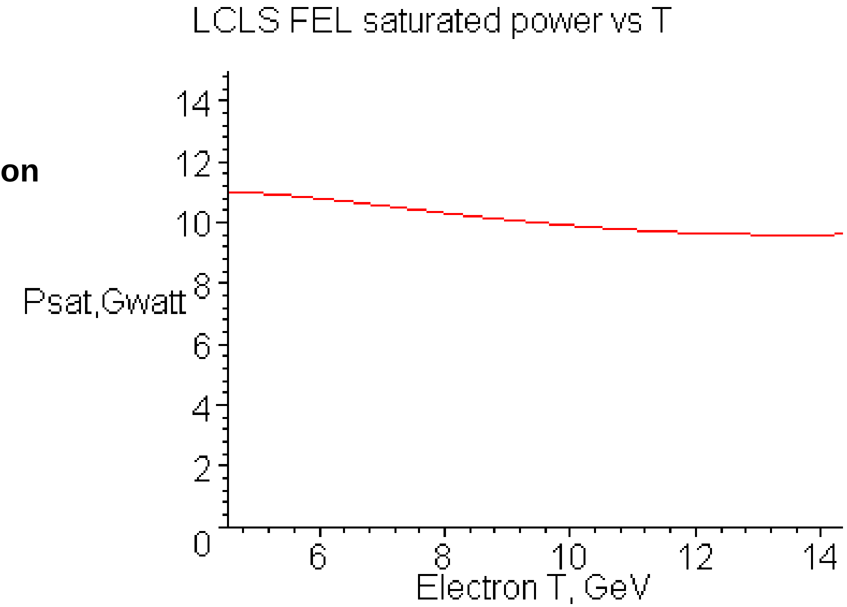
Saturated power

$$Psat = 1.6 \cdot \rho \cdot \frac{L_{G1D}}{L_{G3D}}$$

FEL ρ parameter

$$\rho = \left[\frac{K \cdot \Omega_p \cdot \lambda_w \cdot F_1(K)}{8 \cdot \pi \cdot c \cdot \sqrt{2} \cdot \gamma} \right]^{2/3}$$

Roughly 10 Gwatts power at all photon energies



Approximate FEL shape and divergence as Gaussian beam in optics

$$E(x,y,z,t) = p\cdot\frac{w_0^2\cdot k}{w_0^2\cdot k + 2\cdot i\cdot(z-z_0)}\cdot e^{-i\cdot(\omega\cdot t - k\cdot(z-z_0))}\cdot e^{-\frac{x^2+y^2}{w(z)^2}}\cdot e^{\frac{1}{2}\cdot\frac{i\cdot(x^2+y^2)}{R(z)}}$$

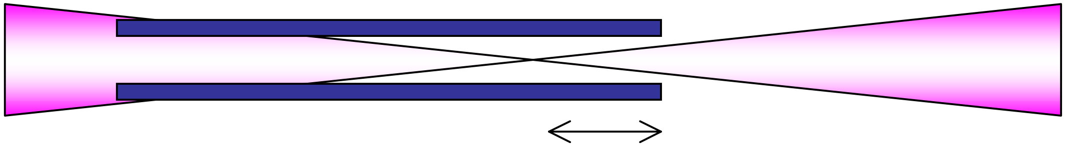
$$0 \le t \le 233\cdot fs$$

Amplitude is given in terms of saturated power level

$$|p|^2 = 4\cdot\frac{P_{sat}}{\sqrt{\varepsilon_0/\mu_0}\cdot w_0^2\cdot\pi}$$

Z dependent phase and width functions

$$R(z) = \frac{1}{4}\cdot\frac{w_0^4\cdot k^2 + 4\cdot(z-z_0)^2}{(z-z_0)\cdot k} \qquad w(z) = \frac{\sqrt{w_0^4\cdot k^2 + 4\cdot(z-z_0)^2}}{w_0\cdot k}$$

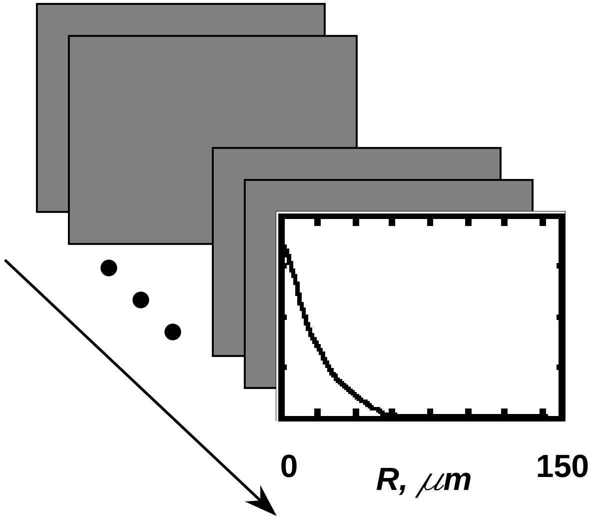


Origin is one Rayleigh length in front of undulator exit

$$z_0 = z_{Exit} - L_{Rayleigh}(\lambda)$$

Photon levels also predicted by numerical simulations

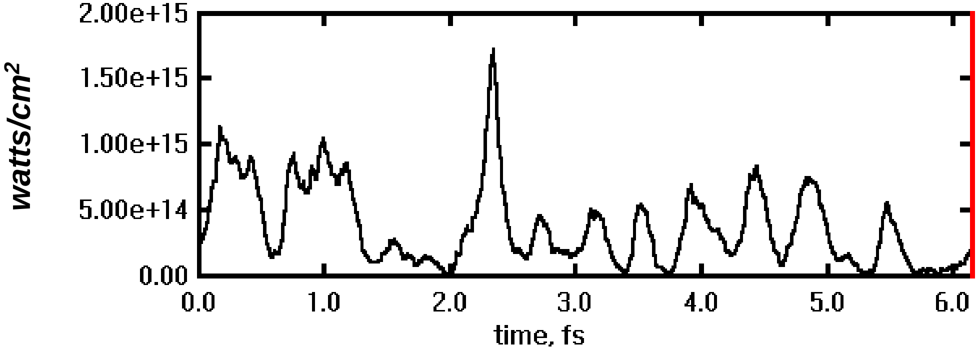
GINGER provided radial distributions of complex numbers representing the envelope of the Electric Field at the undulator exit.



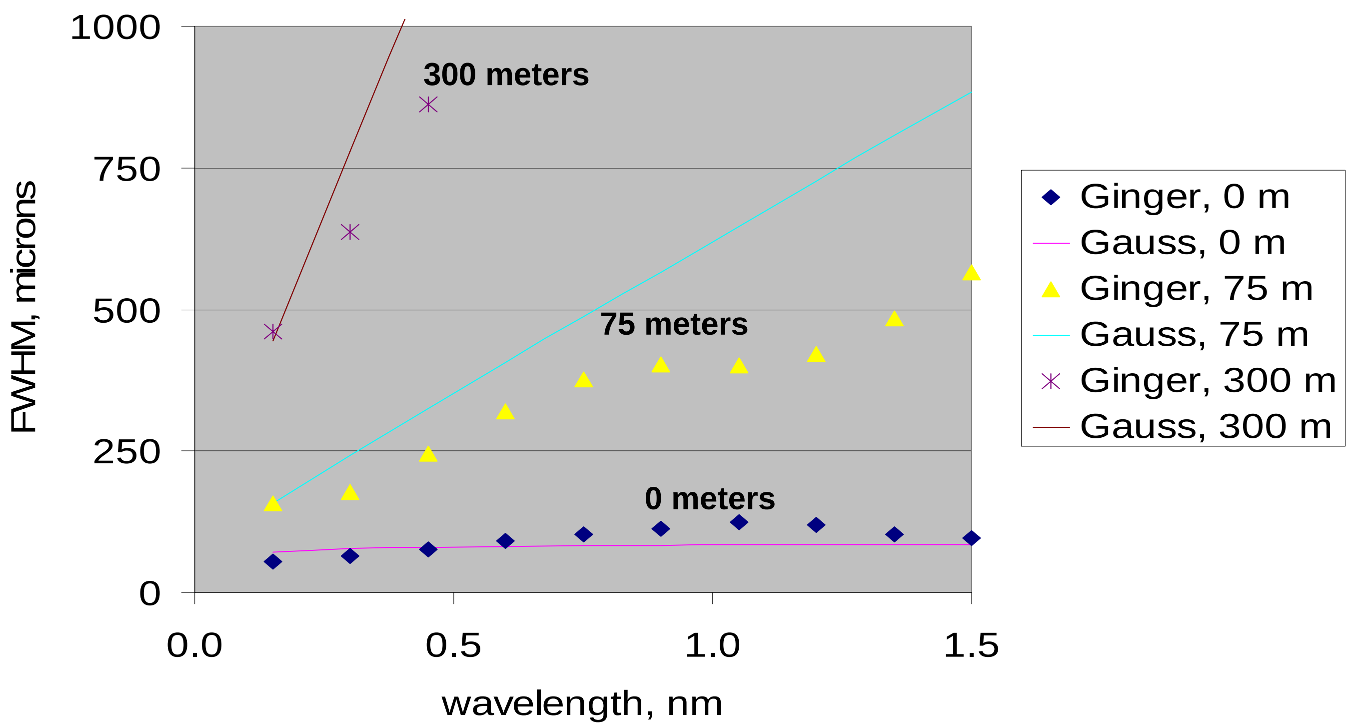
Samples are separated in time by

$n = 16$ **wavelengths.**

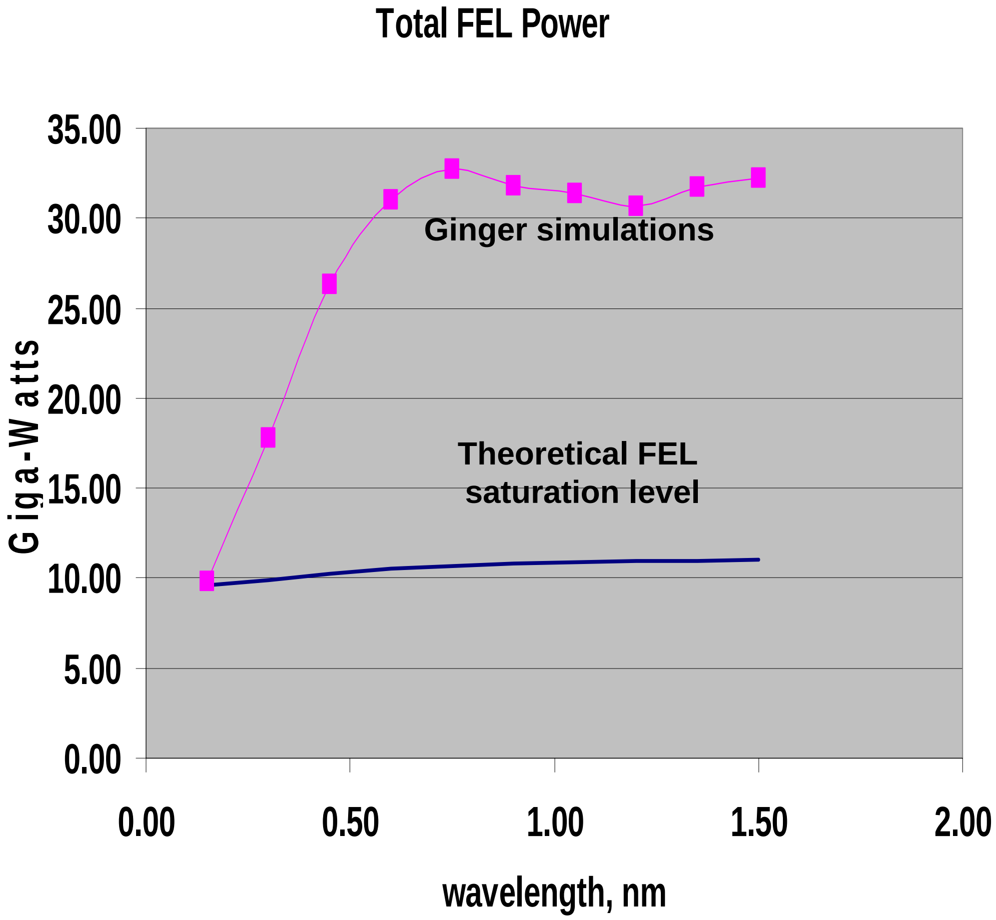
Electric Field Envelope Power Density vs time at R = 0



Gaussian FWHM are good approximations to FWHM of numerical simulations



Theoretical and numerical power levels agree to x 3



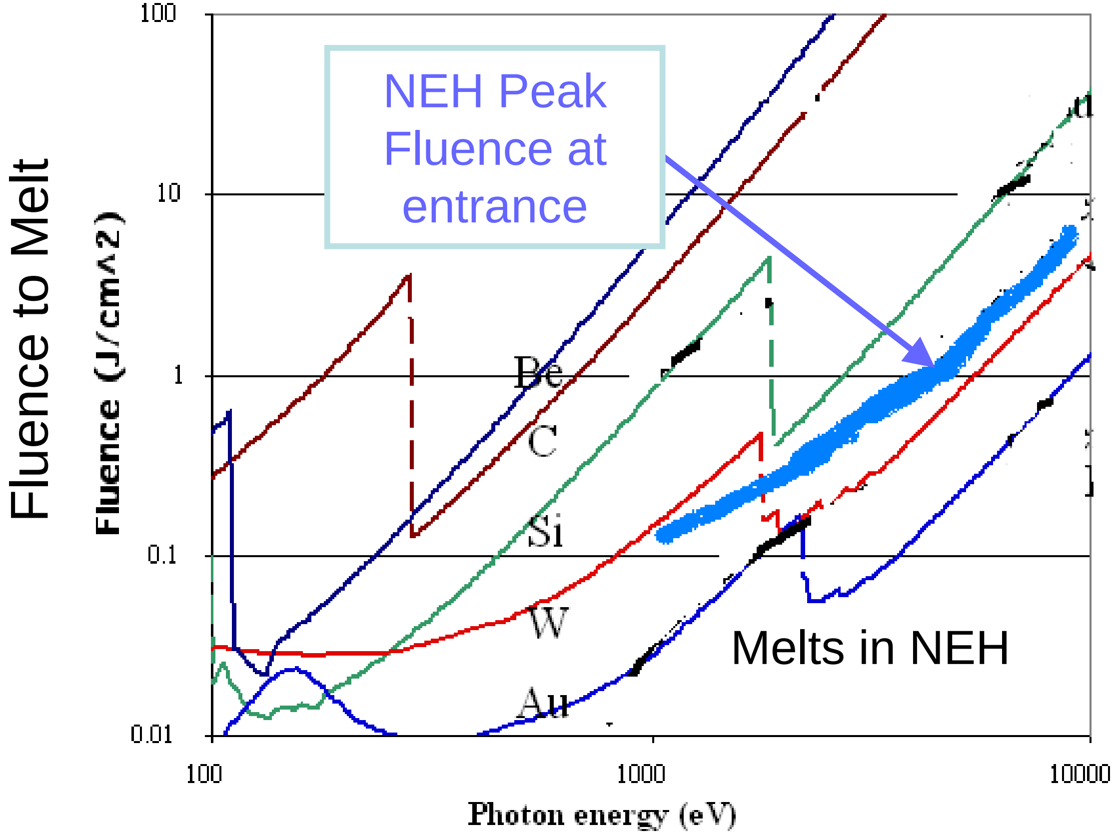
- 10 Ginger simulations were run at different electron energies but with fixed electron emittance through 100 meter LCLS undulator.
- The Ginger runs at the longer wavelengths were not optimized, resulting in significant post-saturation effects. Results at longer wavelengths carry greater uncertanty.

Calculated dose at entrance to NEH

Element	Z	dose (eV/atom)		
		melt	NEH H1	
			1000 eV	8000 eV
Beryllium	4	0.58	0.013	0.000
Diamond	6	2.13	0.062	0.002
Aluminum	13	0.20	0.072	0.058
Silicon	14	0.91	0.100	0.078
Copper	29	0.44	0.183	0.142
Molybdenum	42	1.24	0.993	0.649
Tin	50	0.14	1.873	1.292
Tungsten	74	1.06	1.316	1.341
Lead	82	0.14	2.016	2.042

Doses should be compared to dose needed to melt

Material suitability a strong function of photon energy

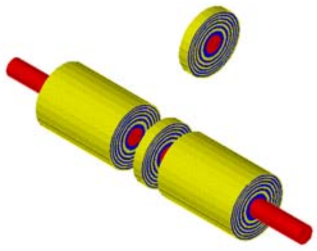


NEH Peak Fluence at entrance

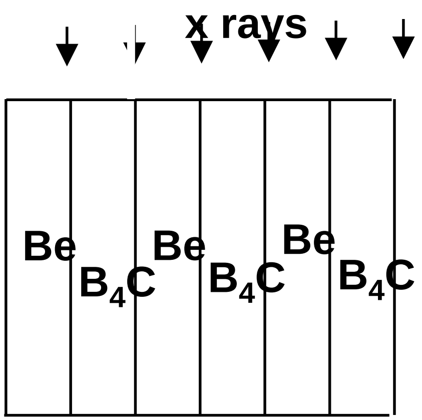
Melts in NEH

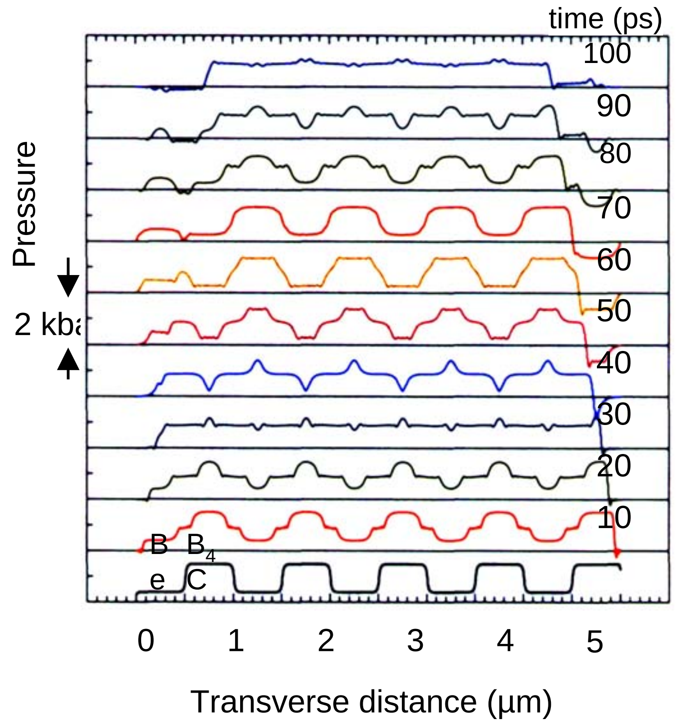
Low Z materials such as Be, C, B_4C and Si will survive at least > 1 shot in the NEH

We can perform hydrodynamic calculations for specific optics



Pressure in a zone pate of Be-B_4C, 8 keV photons, NEH

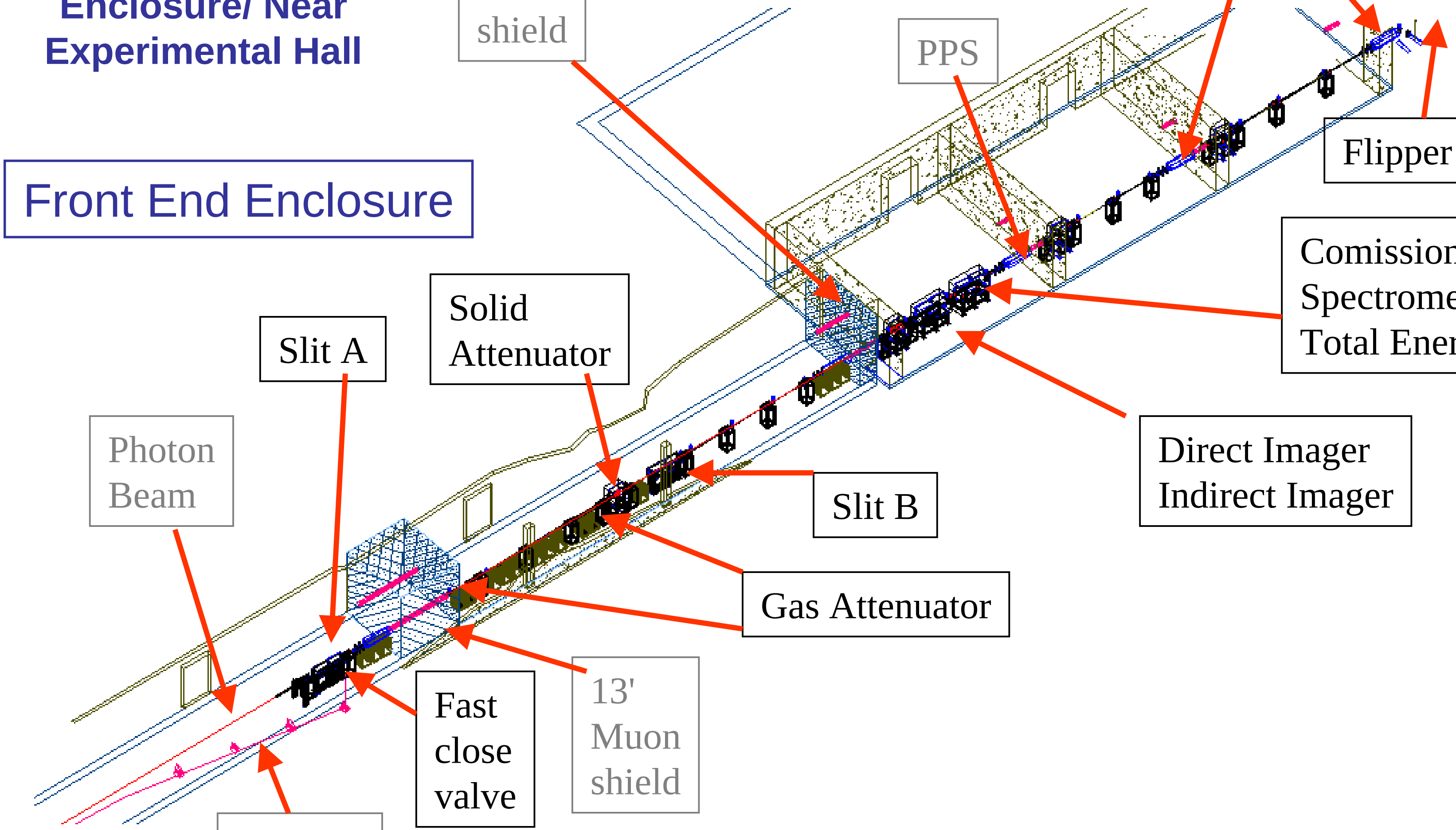




In this case pressures < 2 kbr are inconsequential

Diagnostics and Front-End Optics

1.5 Scope: Front End Enclosure/ Near Experimental Hall



Front End Enclosure

NEH

4' Muon shield

PPS

PPS

Flipper Mirror

Comissioning: Spectrometer, Total Energy

Slit A

Solid Attenuator

Photon Beam

Slit B

Direct Imager
Indirect Imager

Gas Attenuator

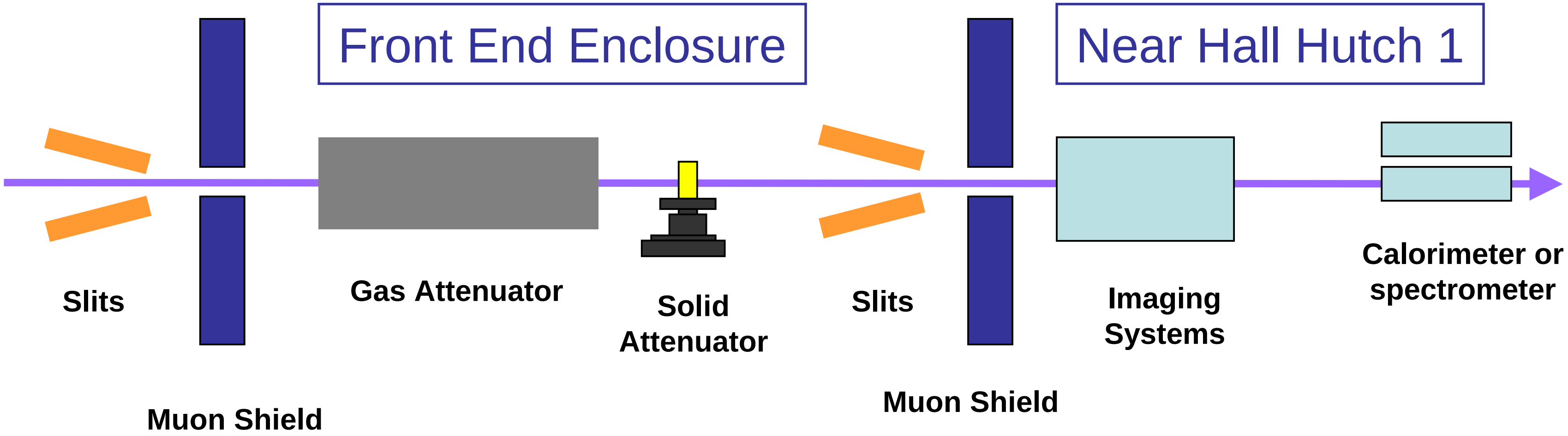
Fast close valve

13' Muon shield

Electron Beam

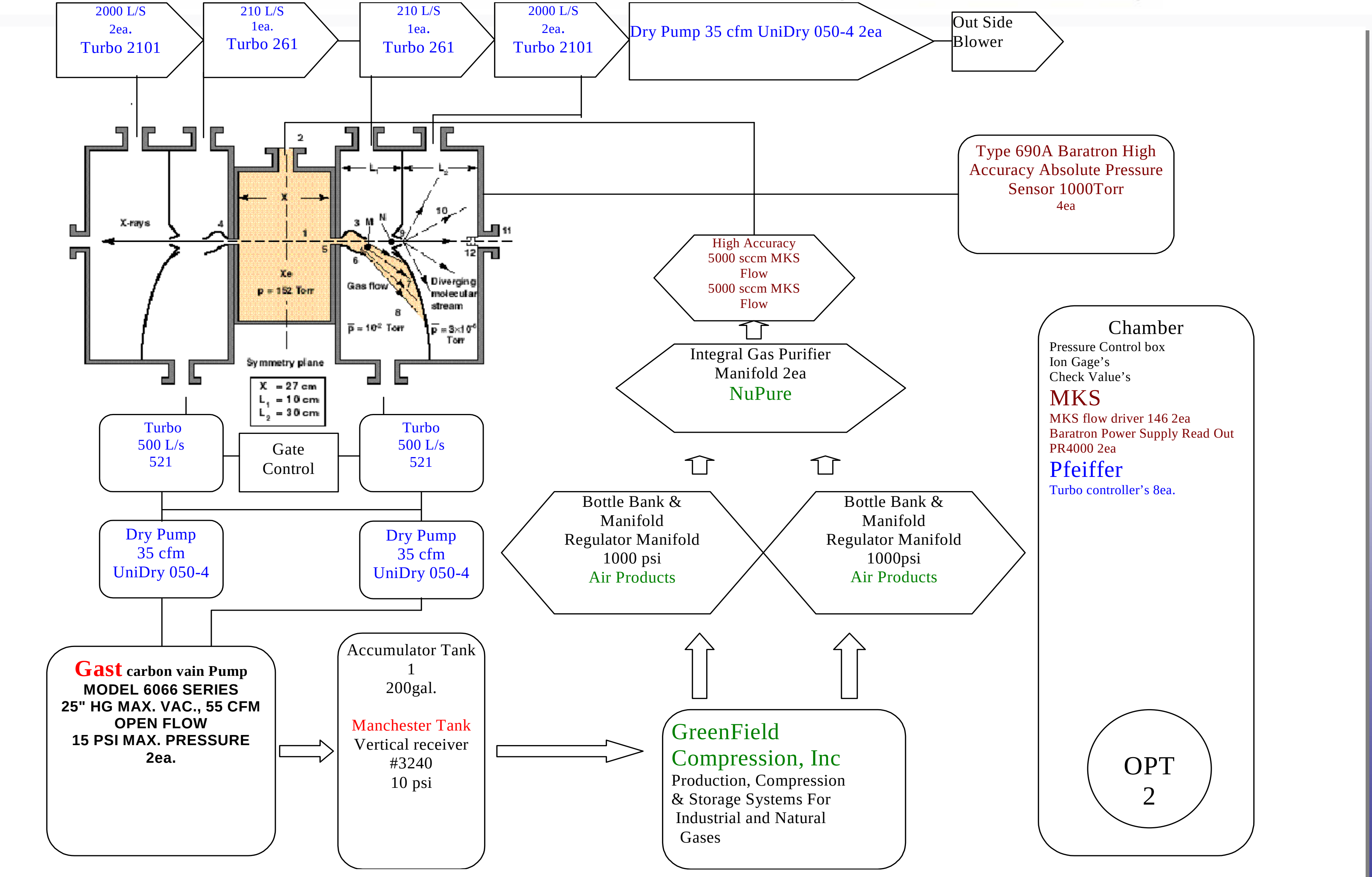
Electron Dump

Diagnostics for Commissioning



Gas Attenuator Requirements

- Physics Requirements:
  - Gas + Solid Attenuator transmission 10^{-4} at all wavelengths
- Baseline design assumes attenuators are 9m from end-of-undulator and 0.5 m long
  - Requires 150 Torr of Xe to transmit 10^{-4} at 8 keV
  - Requires shaped nozzles
  - Requires Xe re-circulation system



2000 L/S
2ea.
Turbo 2101

210 L/S
1ea.
Turbo 261

210 L/S
1ea.
Turbo 261

2000 L/S
2ea.
Turbo 2101

Dry Pump 35 cfm UniDry 050-4 2ea

Out Side
Blower

X = 27 cm
L_1 = 10 cm
L_2 = 30 cm

Type 690A Baratron High Accuracy Absolute Pressure Sensor 1000Torr
4ea

High Accuracy
5000 sccm MKS Flow
5000 sccm MKS Flow

Integral Gas Purifier
Manifold 2ea
NuPure

Chamber
Pressure Control box
Ion Gage's
Check Value's

MKS
MKS flow driver 146 2ea
Baratron Power Supply Read Out
PR4000 2ea

Pfeiffer
Turbo controller's 8ea.

Turbo
500 L/s
521

Gate
Control

Turbo
500 L/s
521

Dry Pump
35 cfm
UniDry 050-4

Dry Pump
35 cfm
UniDry 050-4

Bottle Bank &
Manifold
Regulator Manifold
1000 psi
Air Products

Bottle Bank &
Manifold
Regulator Manifold
1000psi
Air Products

Gast carbon vain Pump
MODEL 6066 SERIES
25" HG MAX. VAC., 55 CFM
OPEN FLOW
15 PSI MAX. PRESSURE
2ea.

Accumulator Tank
1
200gal.

Manchester Tank
Vertical receiver
#3240
10 psi

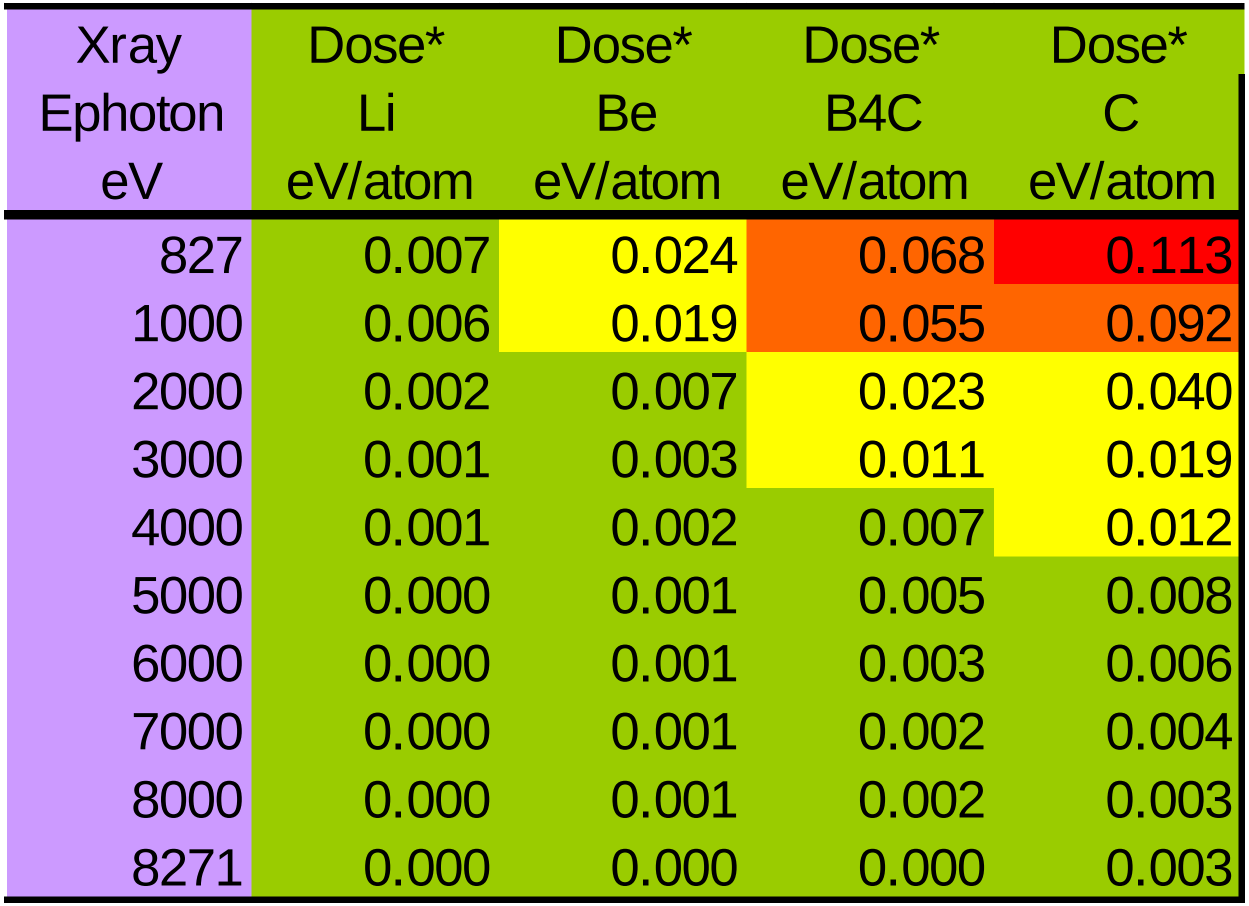
GreenField
Compression, Inc
Production, Compression & Storage Systems For Industrial and Natural Gases

OPT
2

Post Title I Attenuator Position Requires New Design

- Gas Attenuator length increased to 6 m
  - Allows lower pressures
  - Allows use of other gases
- Attenuator distance from undulator increased to 88 m
  - Allows Be attenuators to survive at lower photon energies relaxing gas attenuator required operating range
  - But FEL divergence requires a bigger opening

Solid Be likely to survive at 88 m



Xray Ephoton eV	Dose* Li eV/atom	Dose* Be eV/atom	Dose* B4C eV/atom	Dose* C eV/atom
827	0.007	0.024	0.068	0.113
1000	0.006	0.019	0.055	0.092
2000	0.002	0.007	0.023	0.040
3000	0.001	0.003	0.011	0.019
4000	0.001	0.002	0.007	0.012
5000	0.000	0.001	0.005	0.008
6000	0.000	0.001	0.003	0.006
7000	0.000	0.001	0.002	0.004
8000	0.000	0.001	0.002	0.003
8271	0.000	0.000	0.000	0.003

Be < 0.1 eV/atom for all photon energies

Pressure or thickness for 10^{-4} attenuation

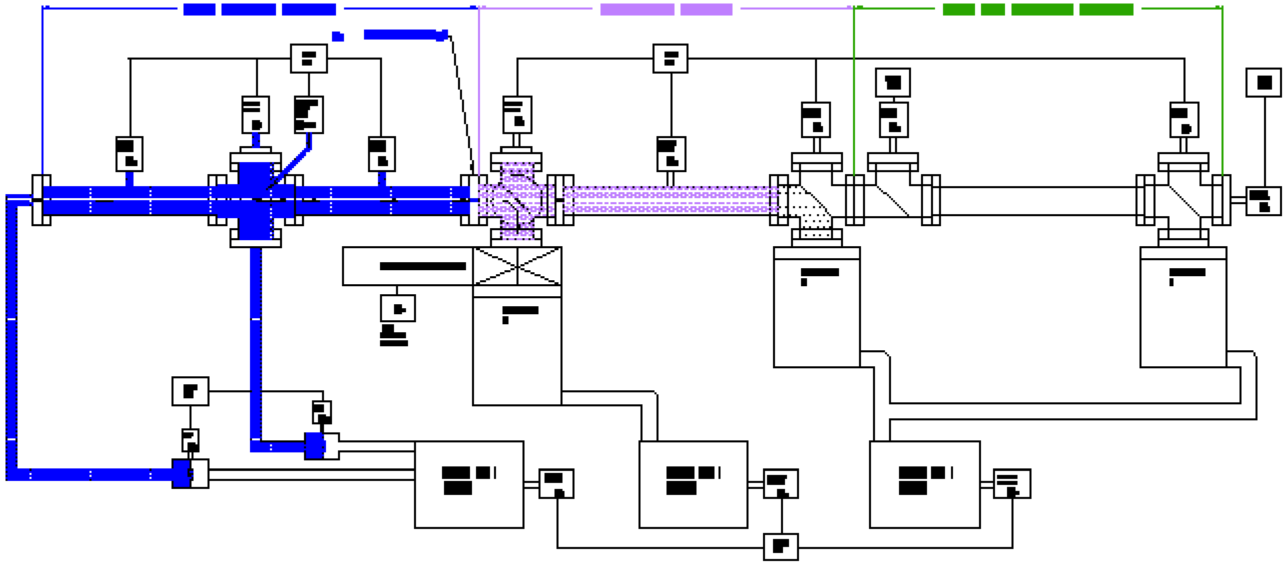
Xray Energy eV	Pressure* N2 Torr	Thickness Be t, um	Thickness B4C t, um	Hole Size Diam um
827	1.7	47	15	1378
1000	2.8	83	25	1171
2000	19.5	672	192	675
3000	64.3	2387	657	507
4000	152.5	5962	1600	422
5000	301.4	12226	3220	370
6000	527.8	22088	5735	335
7000	856.2	36525	9376	309
8000	1292.6	56579	14392	289
8271	1457.3	63641	16148	285

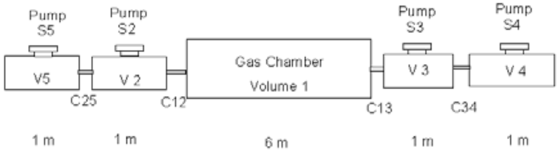
Use Gas

Use Solids

* 6 m of gas at pressure

Gas Attenuator Prototype Design and Analyses Will Validate Concepts



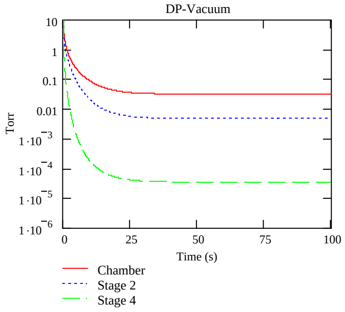


4-Port Configuration

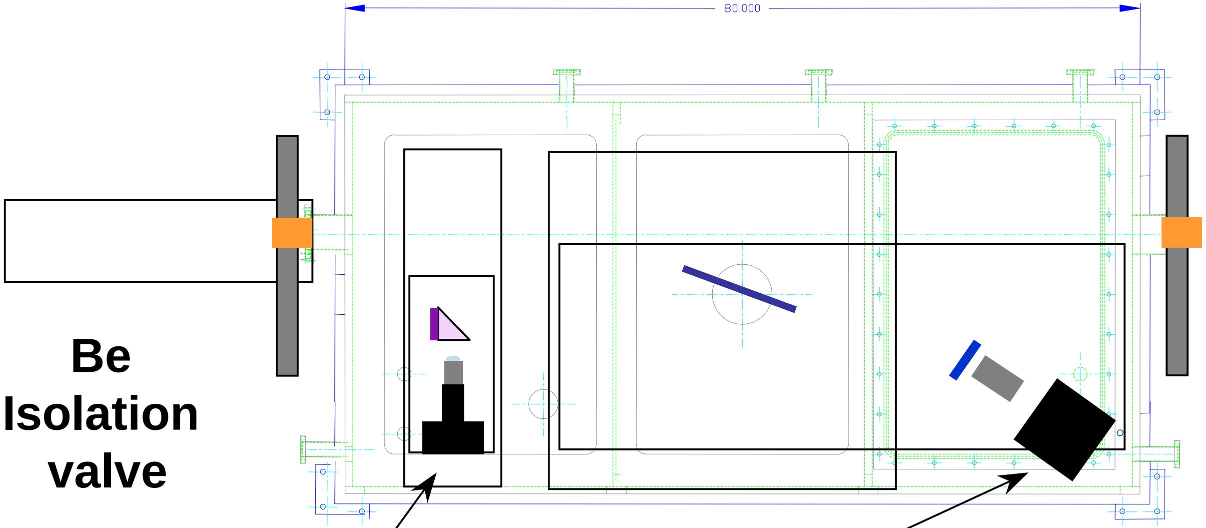
+

Conductance – Intermediate Flow Modeled

$$C_t = C_m\,(1.114\,P_{avg} d\ F_g + \frac{(1+18.958\,P_{avg}\ d\ F_g)}{(1+23.413\,P_{avg}\ d\ F_g)}$$



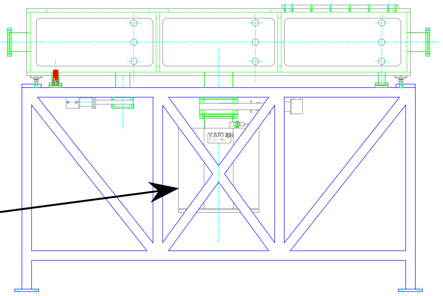
Imaging Detector Tank



Be Isolation valve

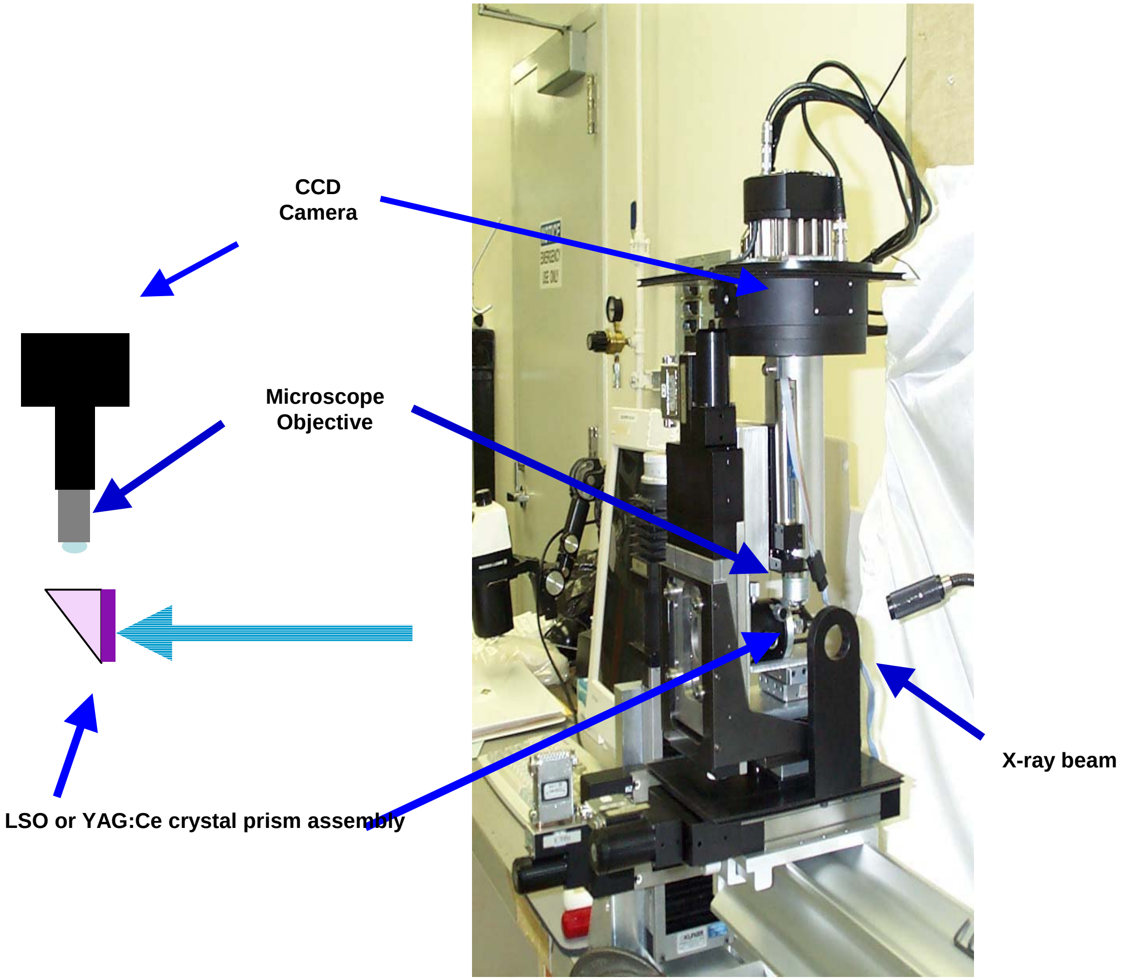
Direct Imager (Placed directly in beam)

Indirect Imager (Sees only a low intensity reflection)



Turbo pump

Imaging detector head prototype

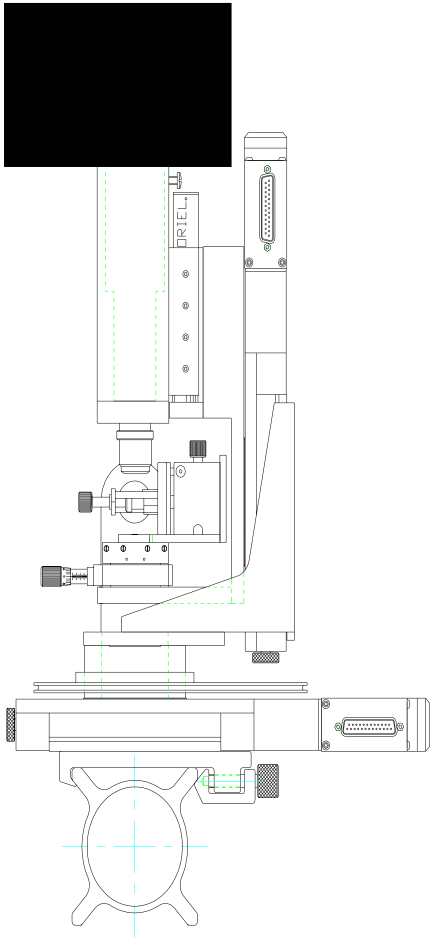


CCD Camera

Microscope Objective

X-ray beam

LSO or YAG:Ce crystal prism assembly

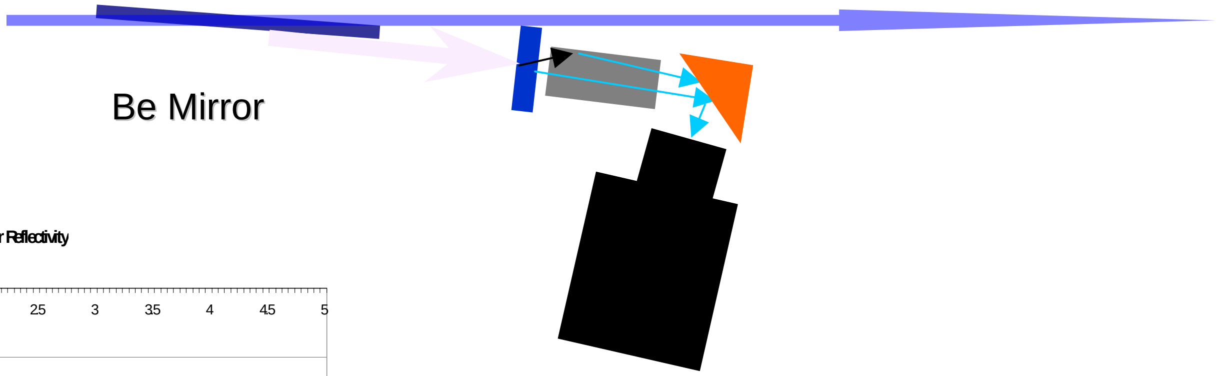


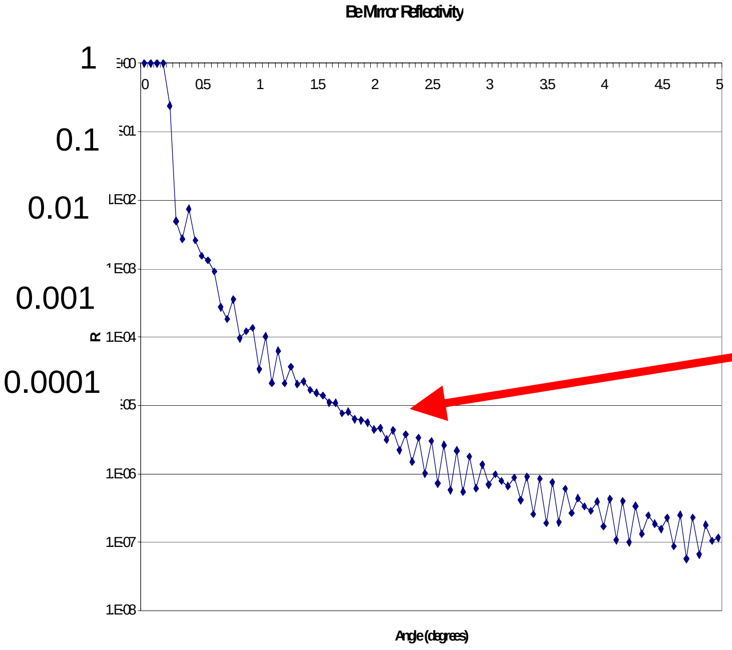
Direct imager issues

- Vacuum Operation
- Low Photon Energy Performance
- 120 Hz Readout
- Afterglow in LSO
- High Energy Spontaneous Background
- Damage threshold

Indirect Imager reflects small amount of FEL into camera, avoiding damage

Be Mirror Reflectivity at 8 KeV





Be Mirror angle provides "gain" adjustment over several orders of magnitude and discriminates against high energy spontaneous background

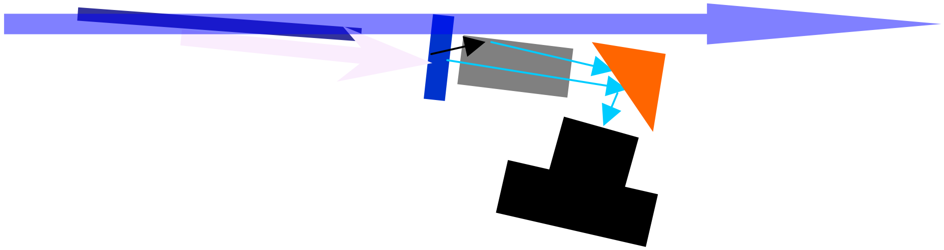
Minimum mirror reflectivity needed to fill CCD well

Objective mag	2.5 x
Solid Angle	1.088E-3
Optical efficiency	0.911
Scintillator Sensitivity	30000 γ/MeV
CCD QE	0.67

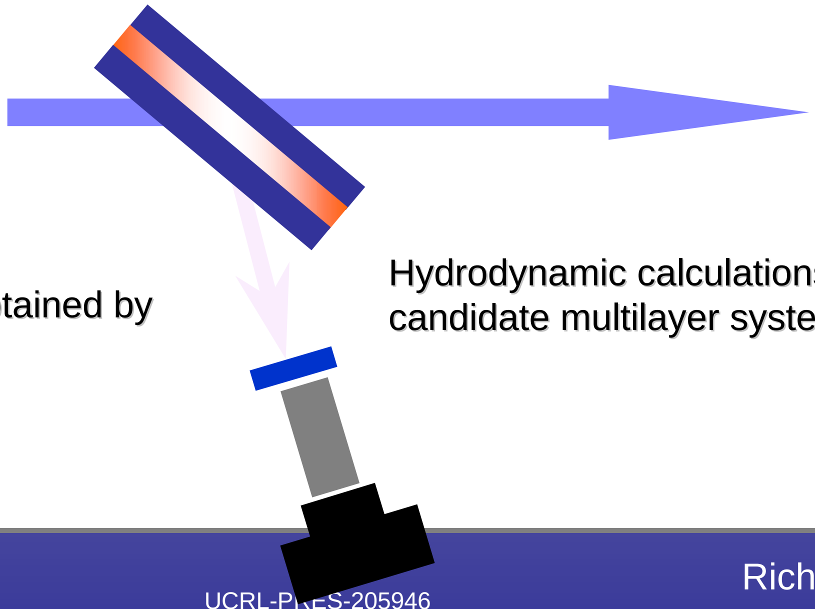
	1 keV	4 keV	8 keV
Photons / nm^2	11.6	27.1	35.0
Photoelectrons	2.0×10^7	1.9×10^8	4.7×10^8
Full Well / PE	2.5×10^{-2}	2.7×10^{-3}	1.0×10^{-3}

Multilayer allows higher angle, higher transmission and energy selection, but high z layer gets high dose

Be Mirror needs grazing incidence, camera close to beam



Single high Z layer tamped by Be may hold together



Hydrodynamic calculations needed for
candidate multilayer systems

Best performance may be obtained by
SiC / B_4C multilayer

Indirect imager issues

- Calibration
- Mirror roughness
- Tight camera geometry
- Compton background
- Vacuum θ–2θ mechanics
- Making mirror thin enough for maximum transmission
  - Ceramic multilayers?
- Use as an Imaging Monochrometer

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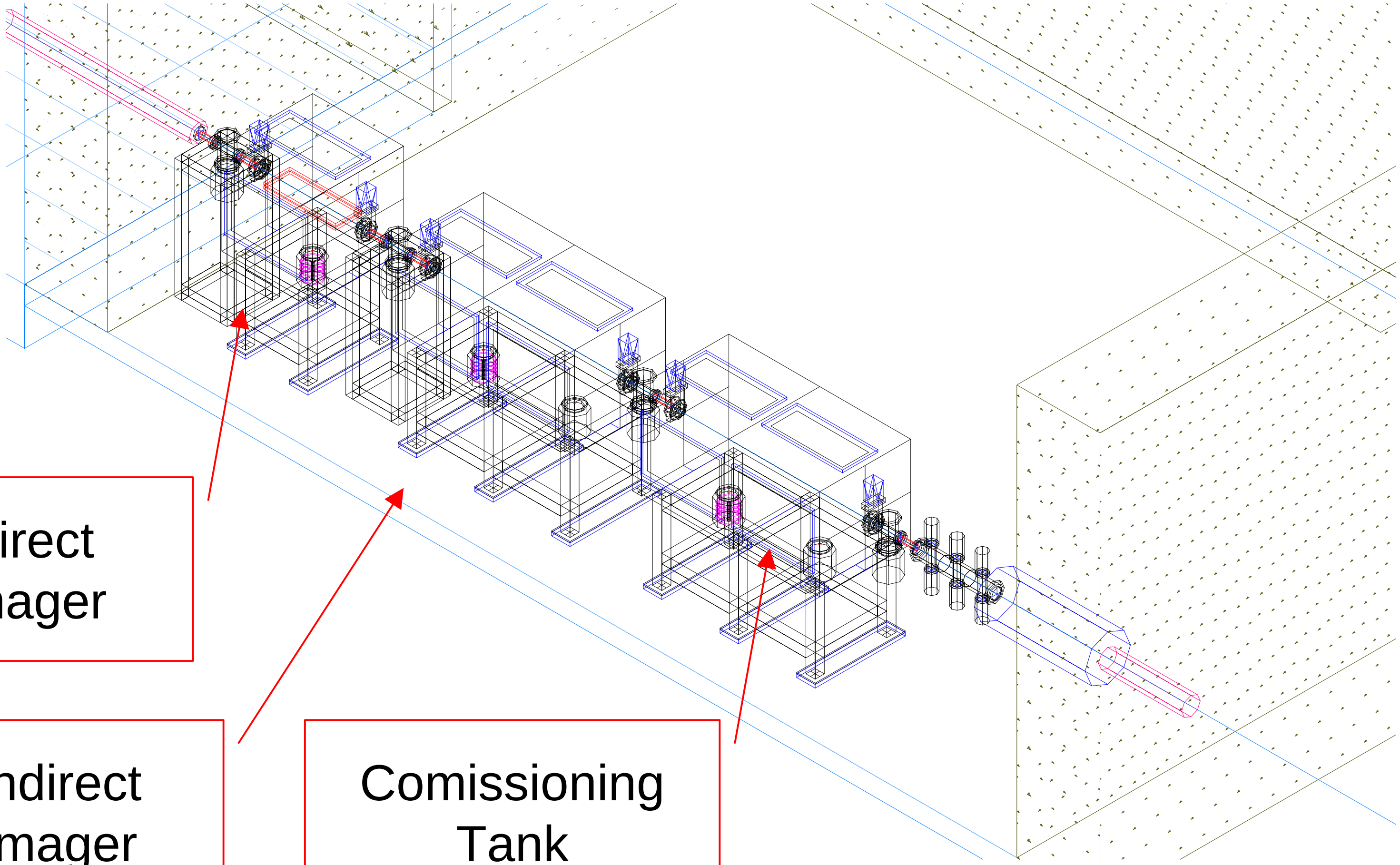
NEH Hutch 1 Diagnostic systems



Direct Imager

Indirect Imager

Comissioning Tank

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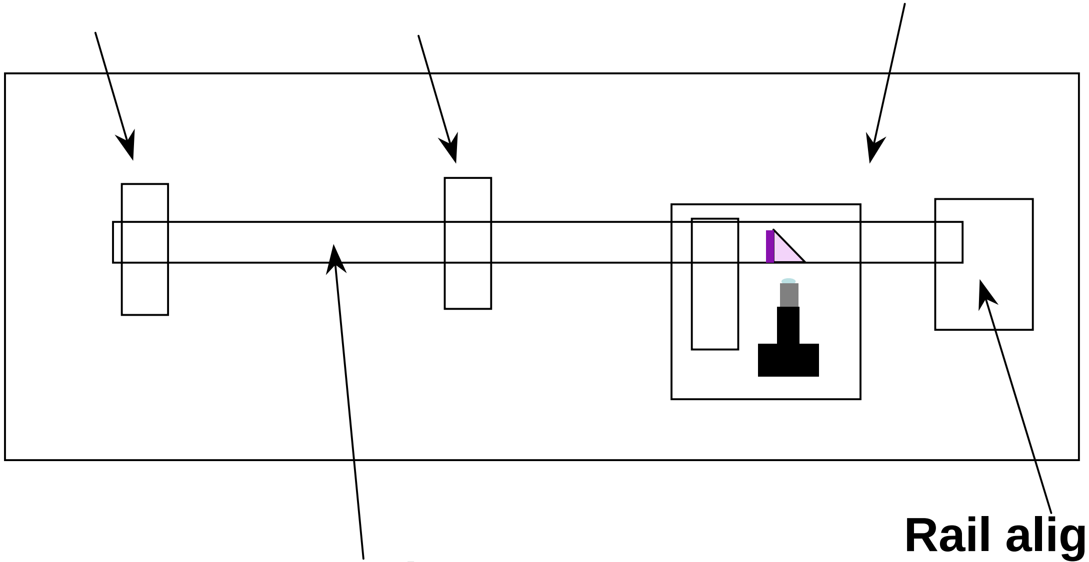
Commissioning diagnostic tank



Aperture Stage

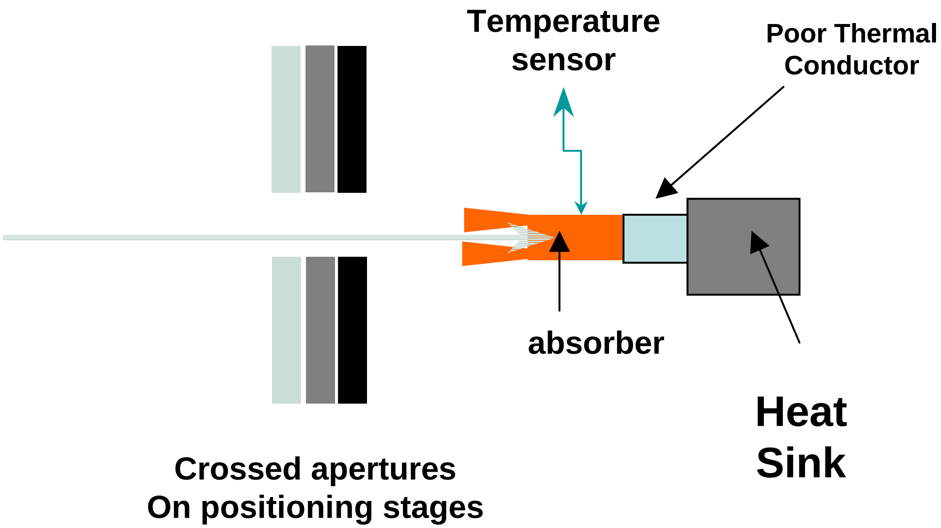
“Optic” Stage

Detector and attenuator Stage

Rail

Rail alignment Stages

Total Energy Calorimeter



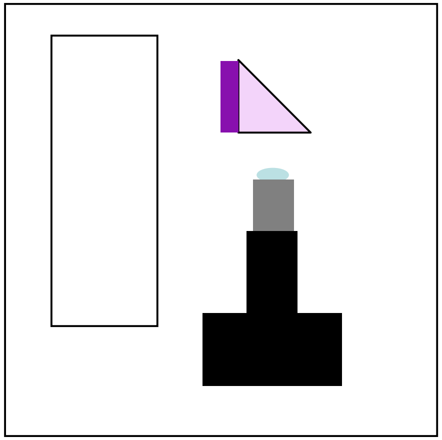
Temperature sensor

Poor Thermal Conductor

absorber

Heat Sink

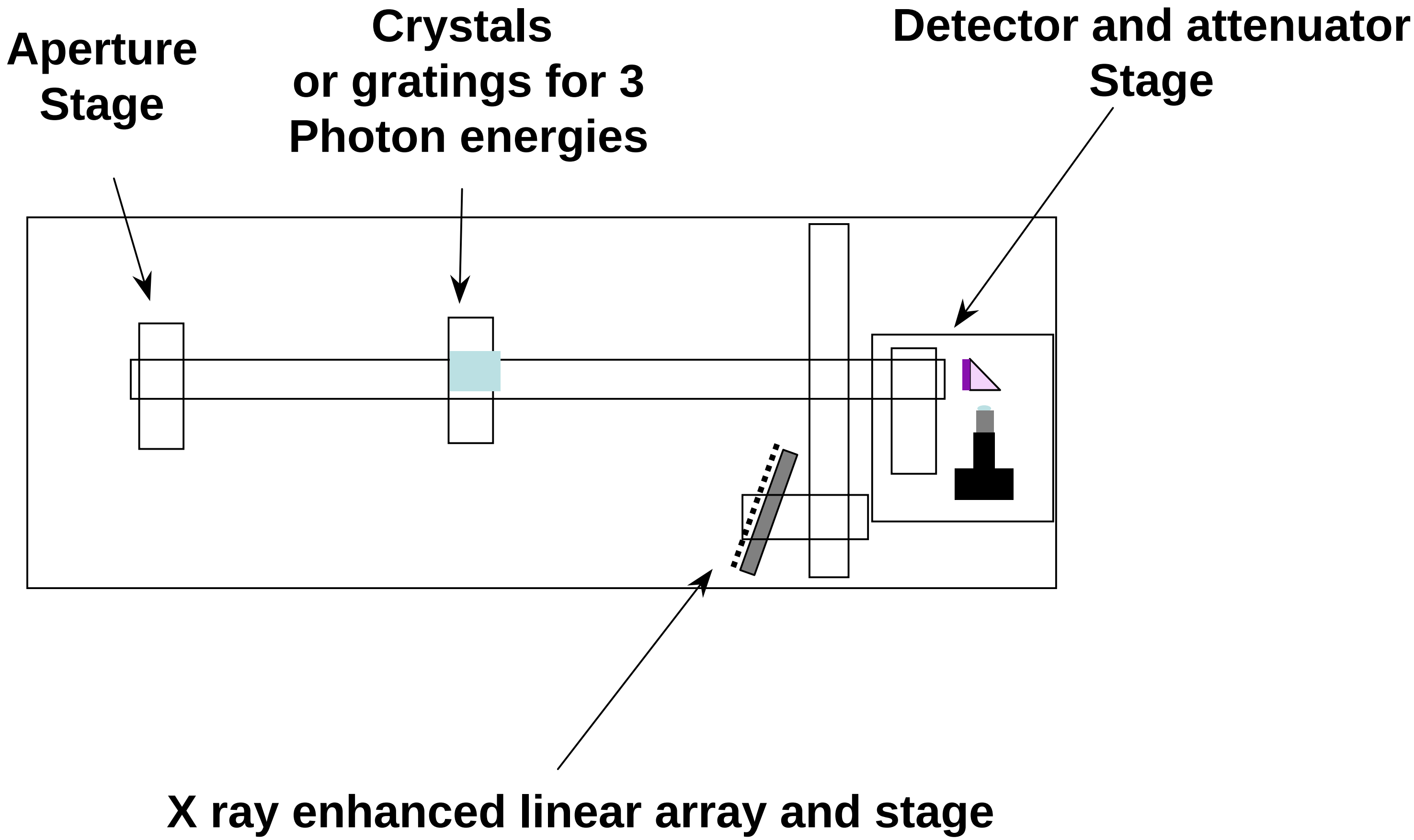
Crossed apertures
On positioning stages



Attenuator
Scintillator

	Absorber	Dose	2 x FWHM	4 x attn lngth
		eV/atom	microns	microns
0.8 KeV	Be	0.01	2628	20
0.8 KeV	Be	0.00	412	27640
0.8 KeV	Si	0.10	2628	7
8 KeV	Si	0.08	412	299

Photon Spectra Measurement



Aperture Stage

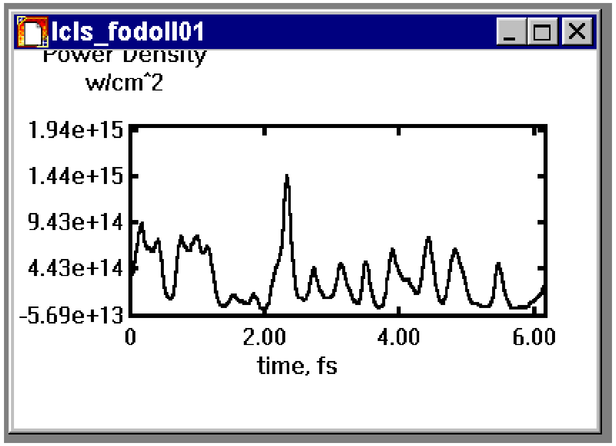
Crystals or gratings for 3 Photon energies

Detector and attenuator Stage

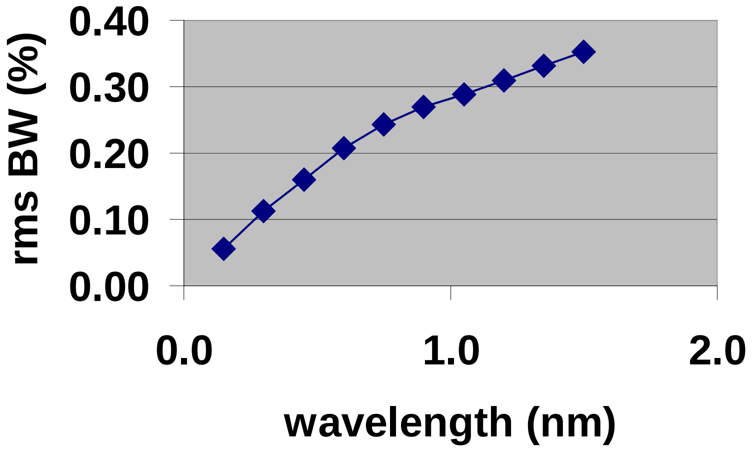
X ray enhanced linear array and stage

Expected Spectra

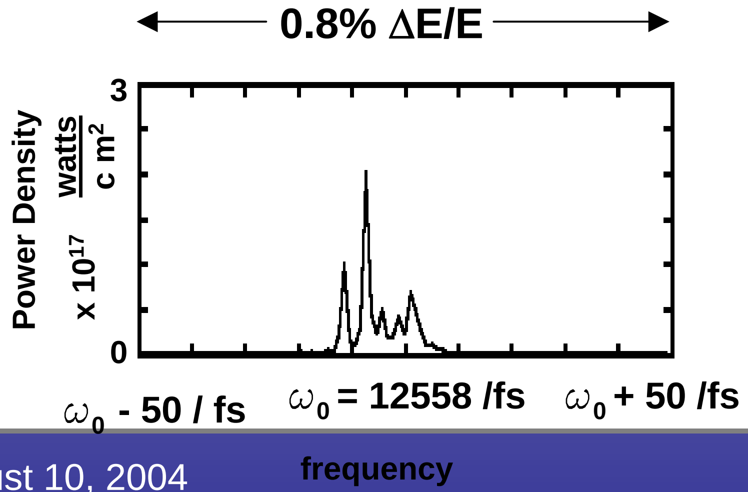
λ= 0.15 nm
Time Domain



rms BW (%) vs wavelength (nm)



λ= 0.15 nm
Frequency Domain



Spectrometer Issues

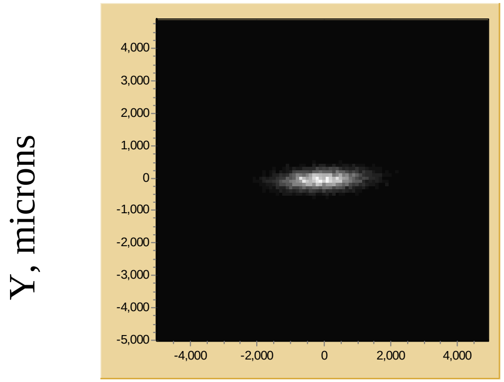
- How to achieve 10^{-4} resolution over a 0.5% bandwidth shot-to-shot?
- Dynamic range
- Designs for low divergence beam

Commissioning strategy

- Start with Low Power Spontaneous
  - Saturate Direct Imagers, measure linearity with solid attenuators
  - Raise power, Measure linearity of Calorimeter and Indirect imager. Cross calibrate
  - Test Gas Attenuator
- Raise Power, Look for FEL
  - in Direct Imager
    - Verify linearity with attenuators
  - switch to Indirect Imager if scintilator damages

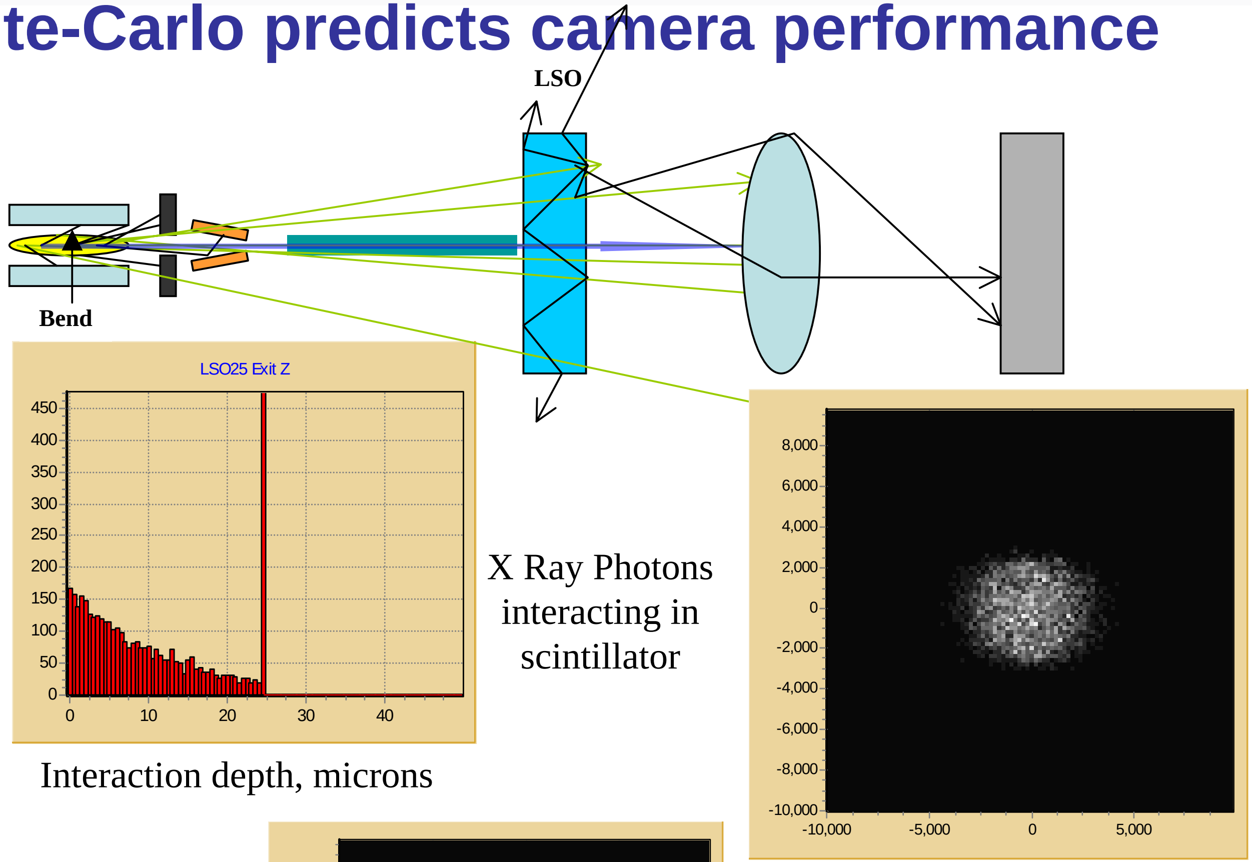
Simulation and modeling

SPEAR Monte-Carlo predicts camera performance



X, microns

SPEAR source simulation

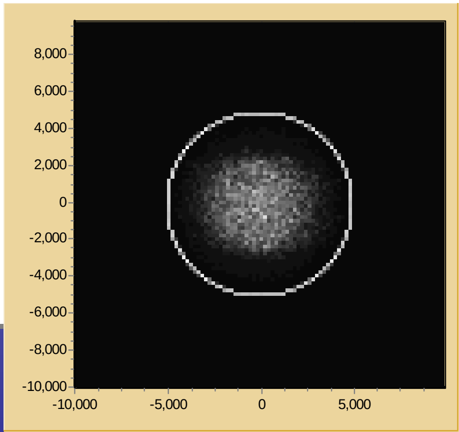


Interaction depth, microns

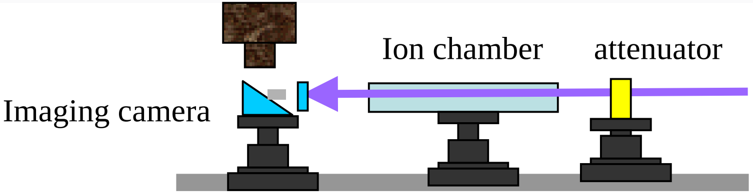
X Ray Photons interacting in scintillator

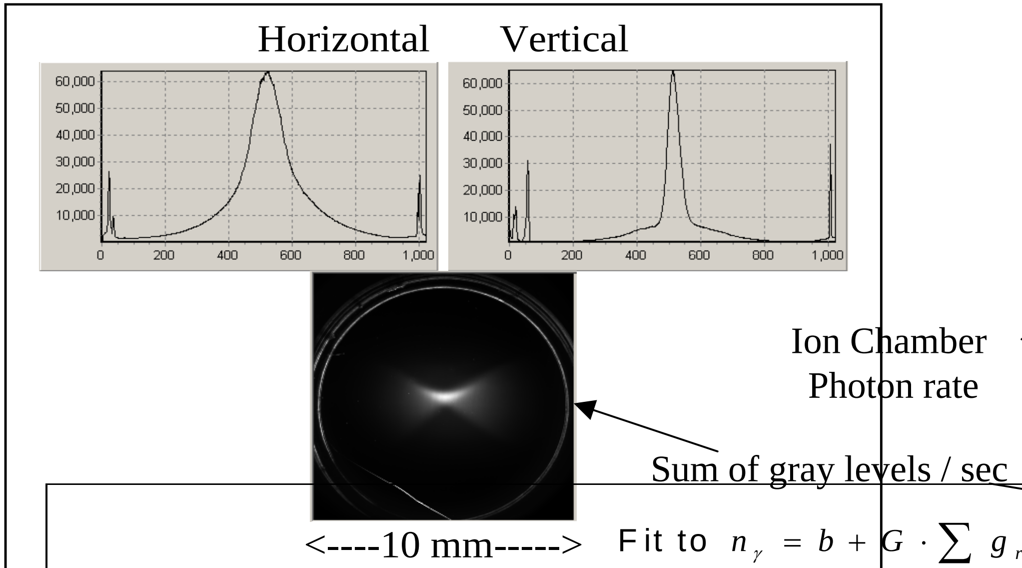
Transverse position, microns

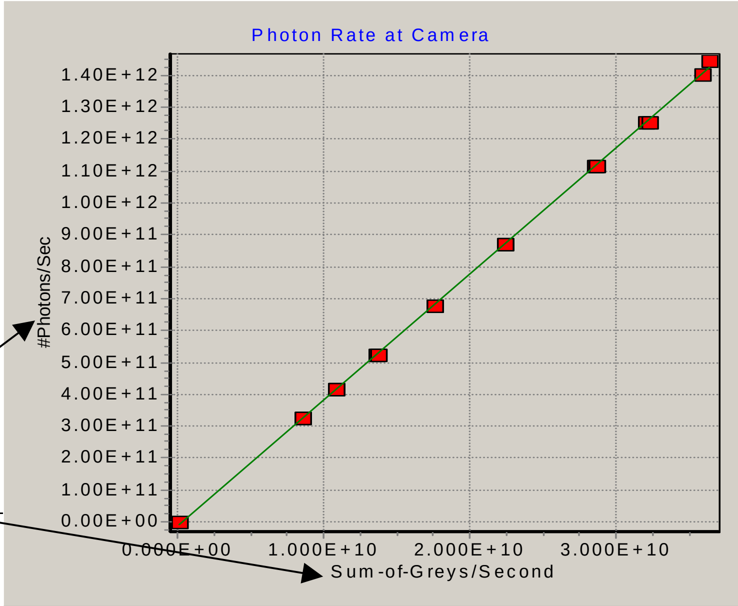
Visible photons detected by CCD



Camera Sensitivity Measurements at SPEAR 10-2







Fit to $n_\gamma = b + G \cdot \sum g_{r,c}$

In front of camera window				At scintillator			
Item	Fit	Error	Units	Item	Fit	Error	Units
G	39.4	0.1	γ/g	G	31.1	0.1	γ/g
b	-1.1×10^{10}	0.3×10^{10}	γ	b	-0.9×10^{10}	0.3×10^{10}	γ

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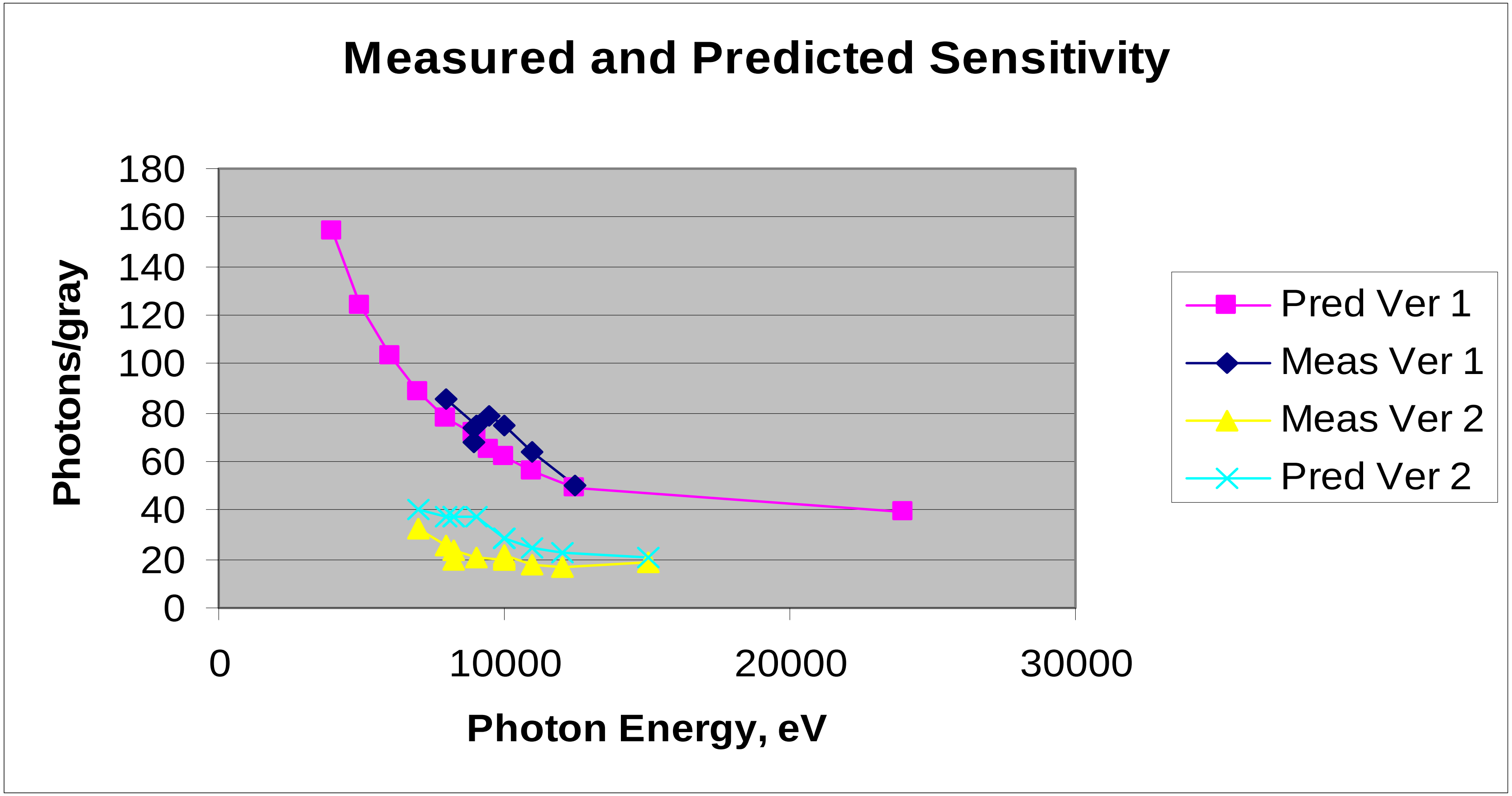
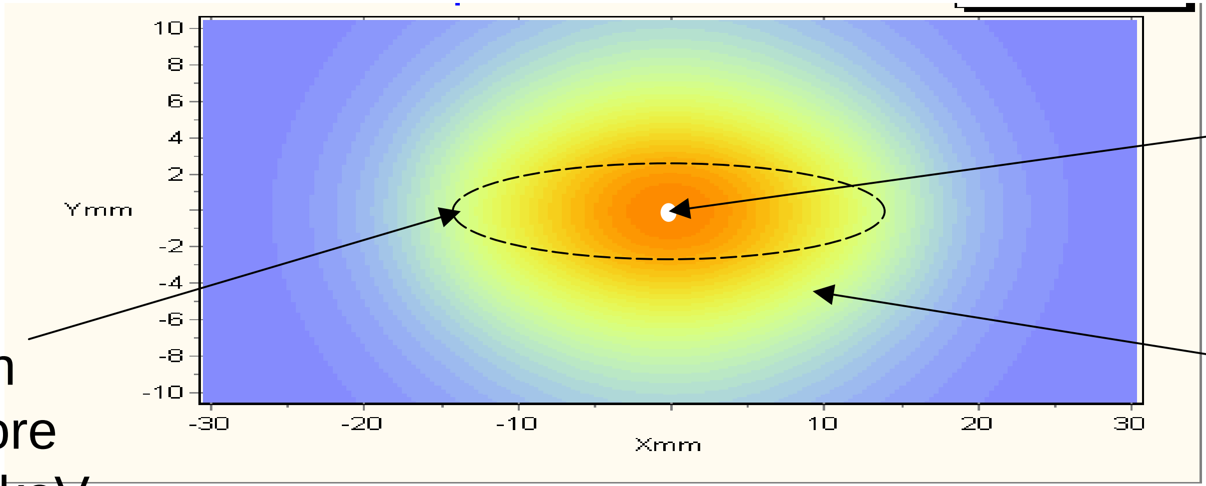
Prototype measured and predicted sensitivities in fair agreement



LCLS beam footprint

Expected LCLS beam profile contains FEL and Spontaneous halo



2-3 mJ FEL

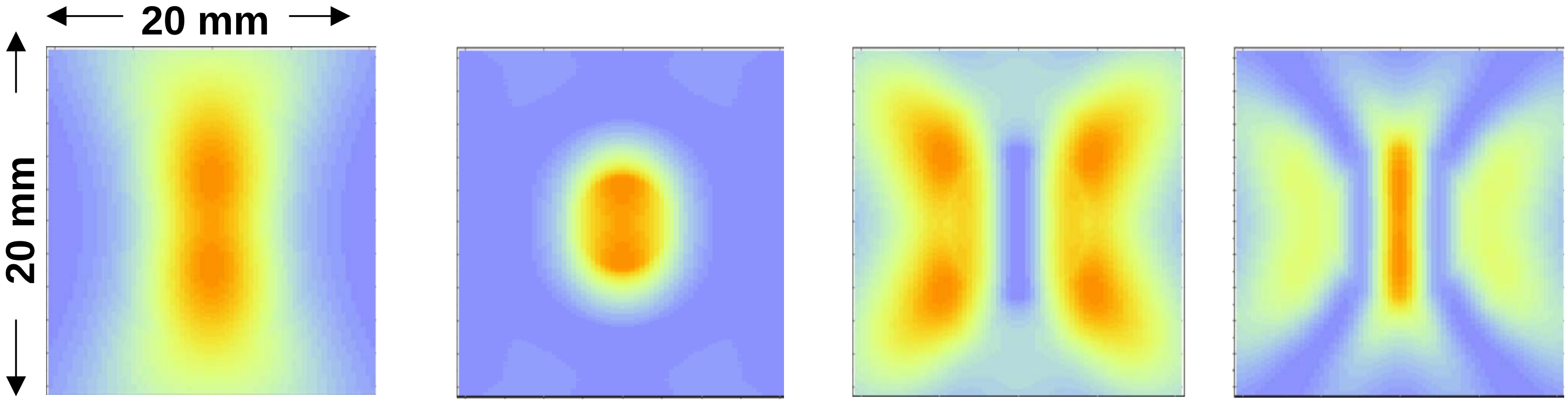
3 mJ High energy core $E\gamma > 400$ keV

20 mJ Spontaneous

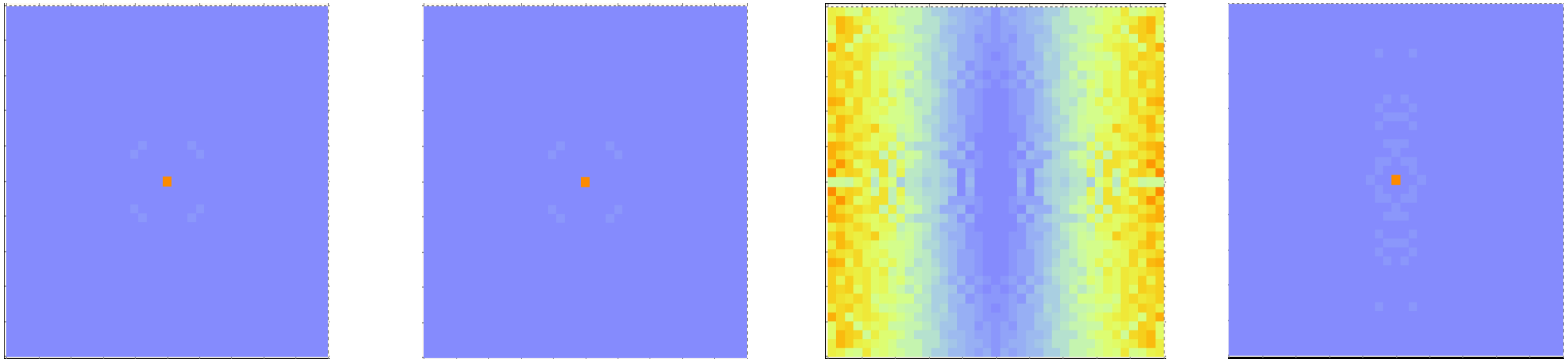
At entrance to NEH, FEL tuned to 8261 eV Fundamental

LCLS spontaneous radiation calculations

Near-Field calculation 88 m from End-of-Undulator, Sven Richie, UCLA

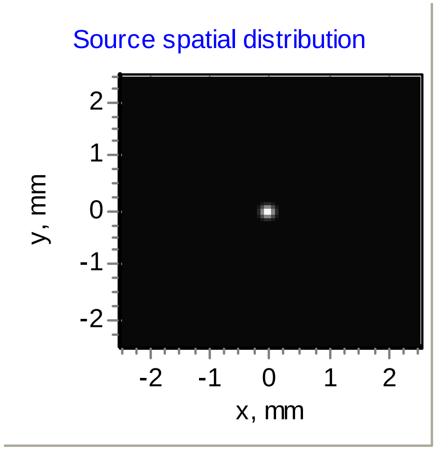


Far-Field calculation 400 m from Center-of-Undulator, Roman Tatchyn, SSRL

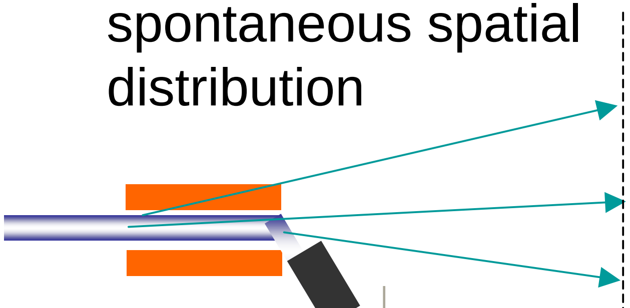


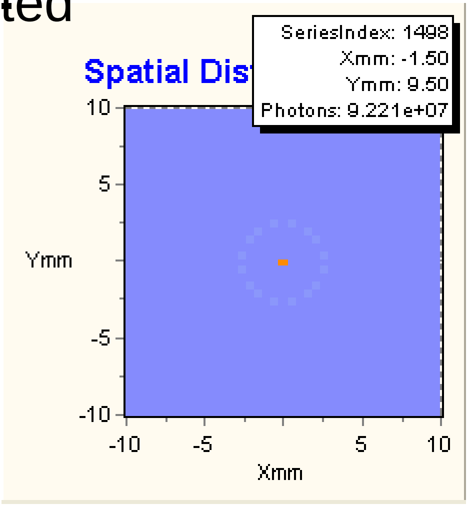
0 < E < 10 keV **7.6 < E < 9.0 keV** **10 < E < 20 keV** **20 < E < 27 keV**

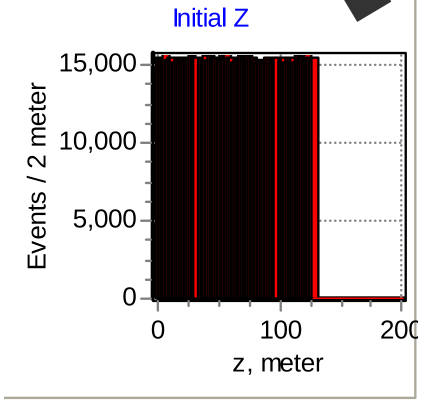
Spontaneous Monte Carlo Simulation



Photon starting angles generated to give calculated spontaneous spatial distribution

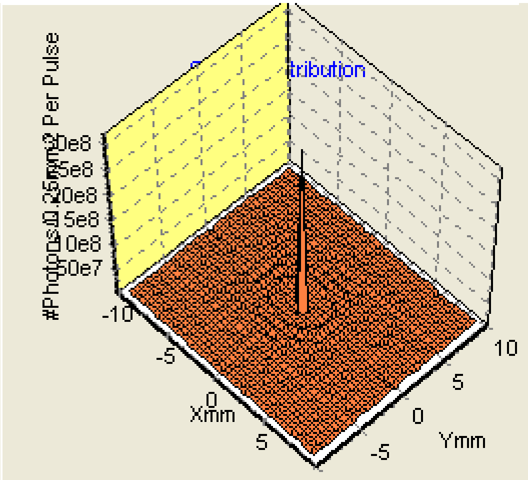




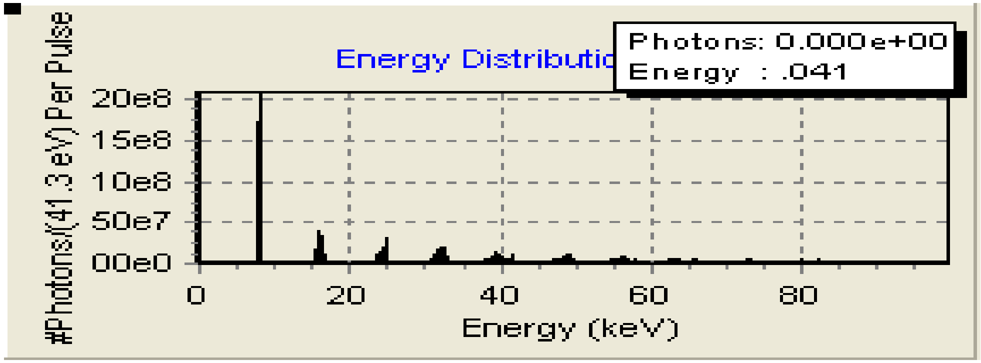


Photon starting x, y matches electron distribution, a Gaussian with σ = 30 μm

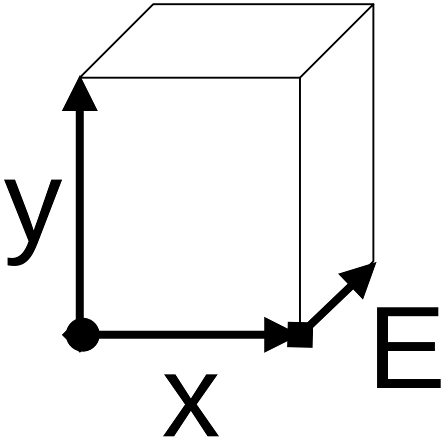
Photon starting z is uniform along undulator (from 0 < z < 130 m)

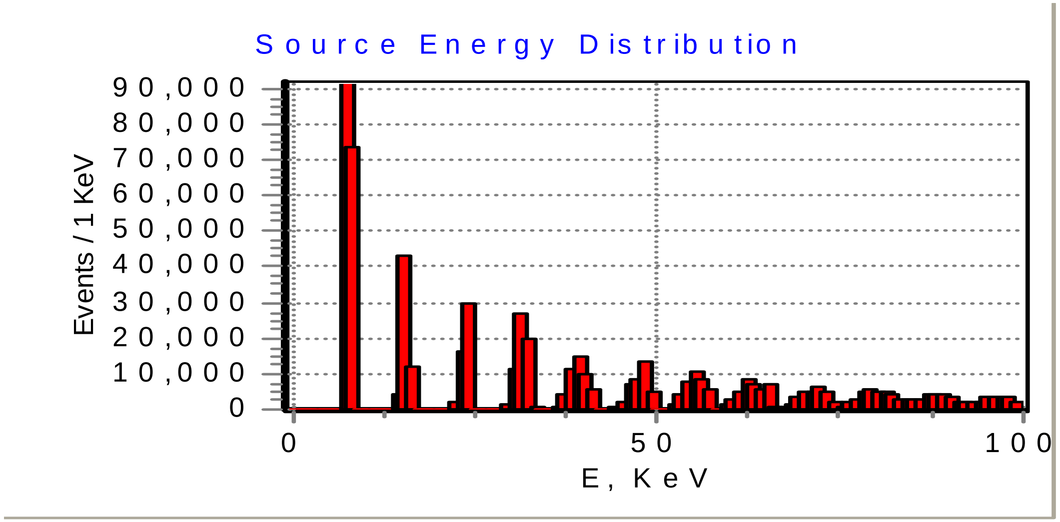


Each photon final x, y has its own cumulative energy distribution



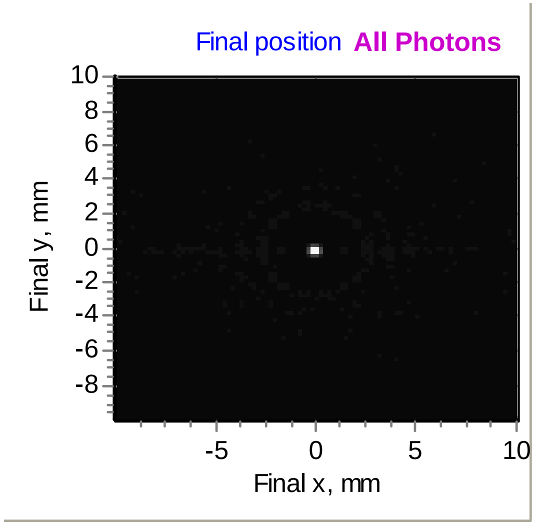
Calculated far-field energy spectrum

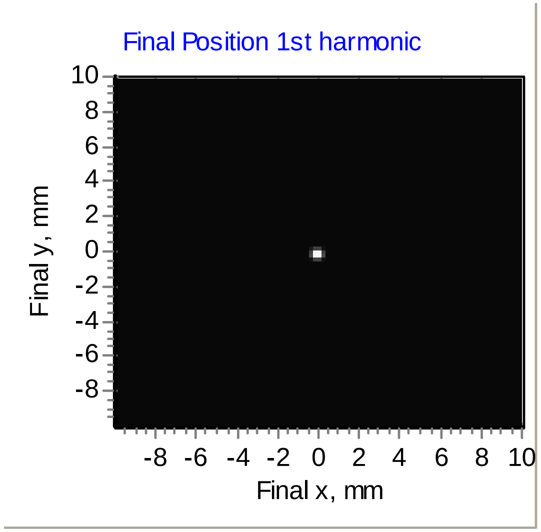




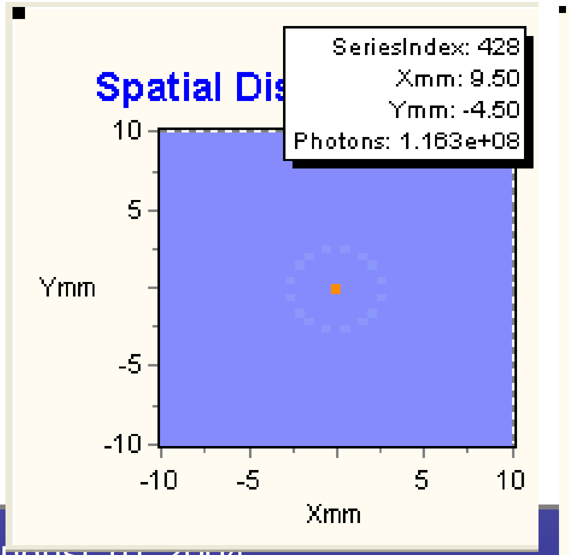
Monte Carlo Energy Distribution

Simulated spatial distributions agree with far-field calculation

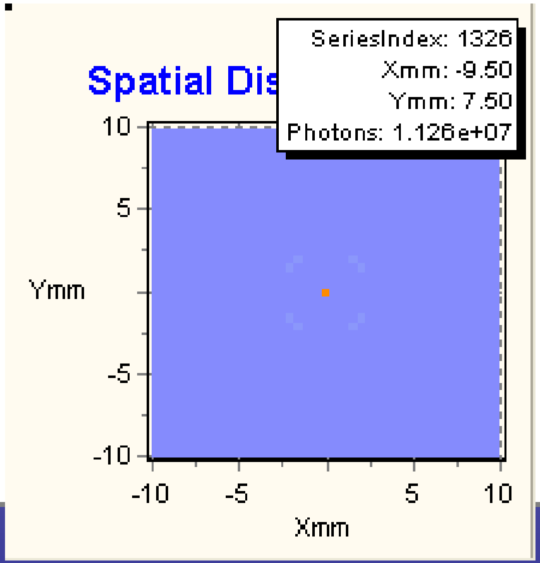




Monte Carlo 465 m from beginning of undulator



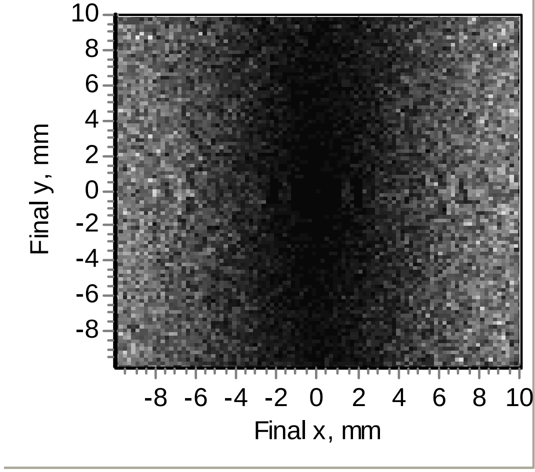
SeriesIndex: 428
Xmm: 9.50
Ymm: -4.50
Photons: 1.163e+08

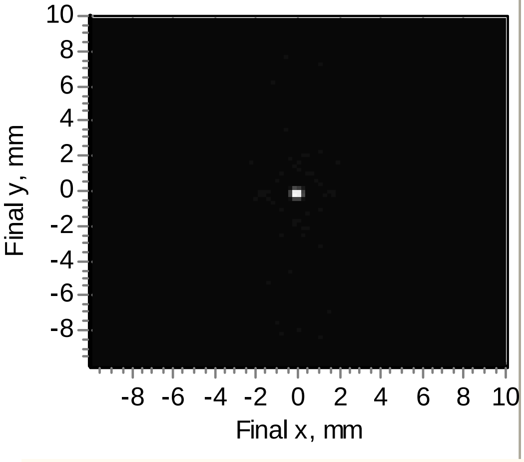


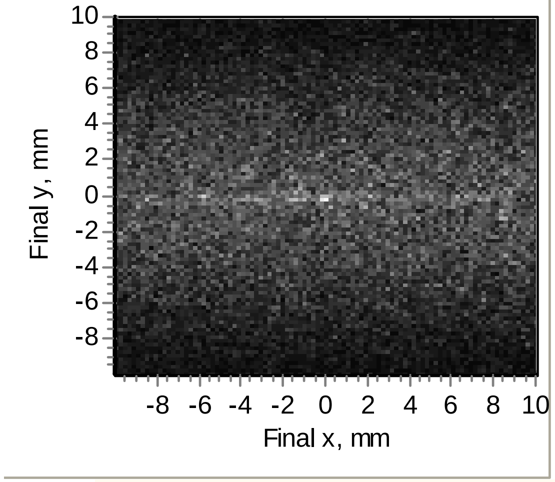
SeriesIndex: 1326
Xmm: -9.50
Ymm: 7.50
Photons: 1.126e+07

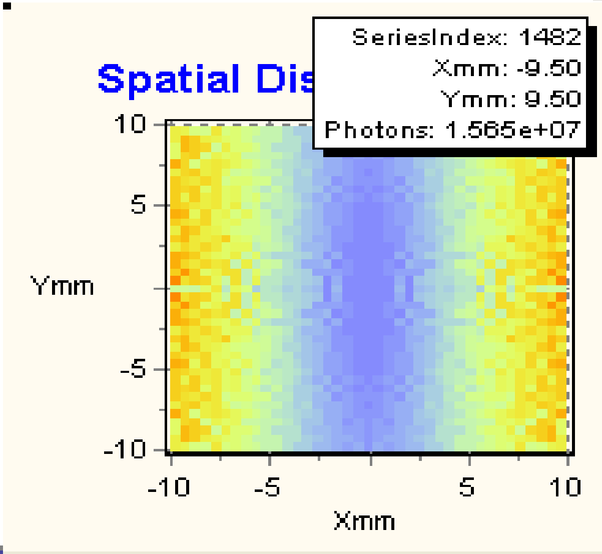
Far-Field Calculation 400 m from center of undulator

Simulated spatial distributions agree with far-field calculation – higher orders

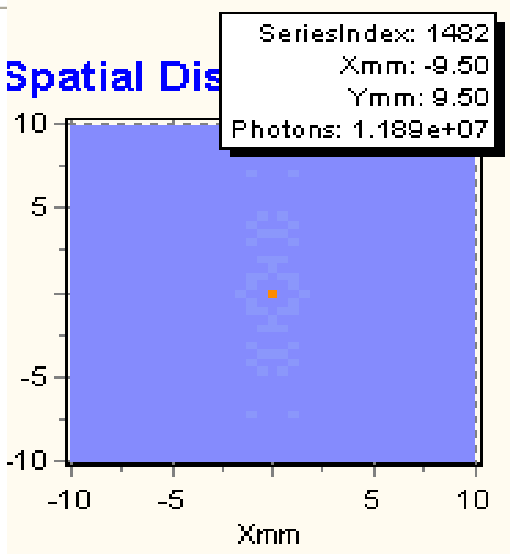

Final position, 2nd harmonic


Final Position, 3rd harmonic

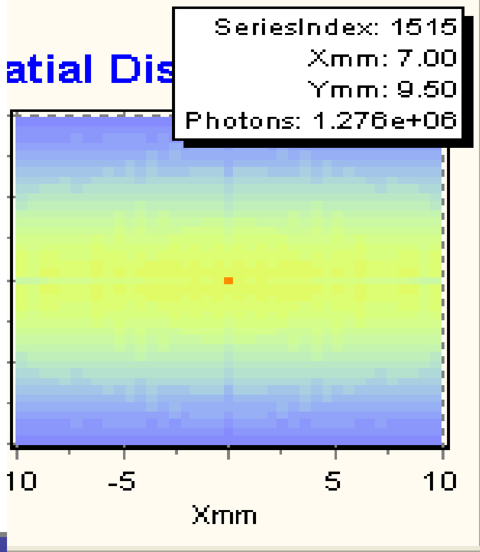

Final position, E> 400 KeV



SeriesIndex: 1482
Xmm: -9.50
Ymm: 9.50
Photons: 1.565e+07



SeriesIndex: 1482
Xmm: -9.50
Ymm: 9.50
Photons: 1.189e+07



SeriesIndex: 1515
Xmm: 7.00
Ymm: 9.50
Photons: 1.276e+06

Simulation work in progress

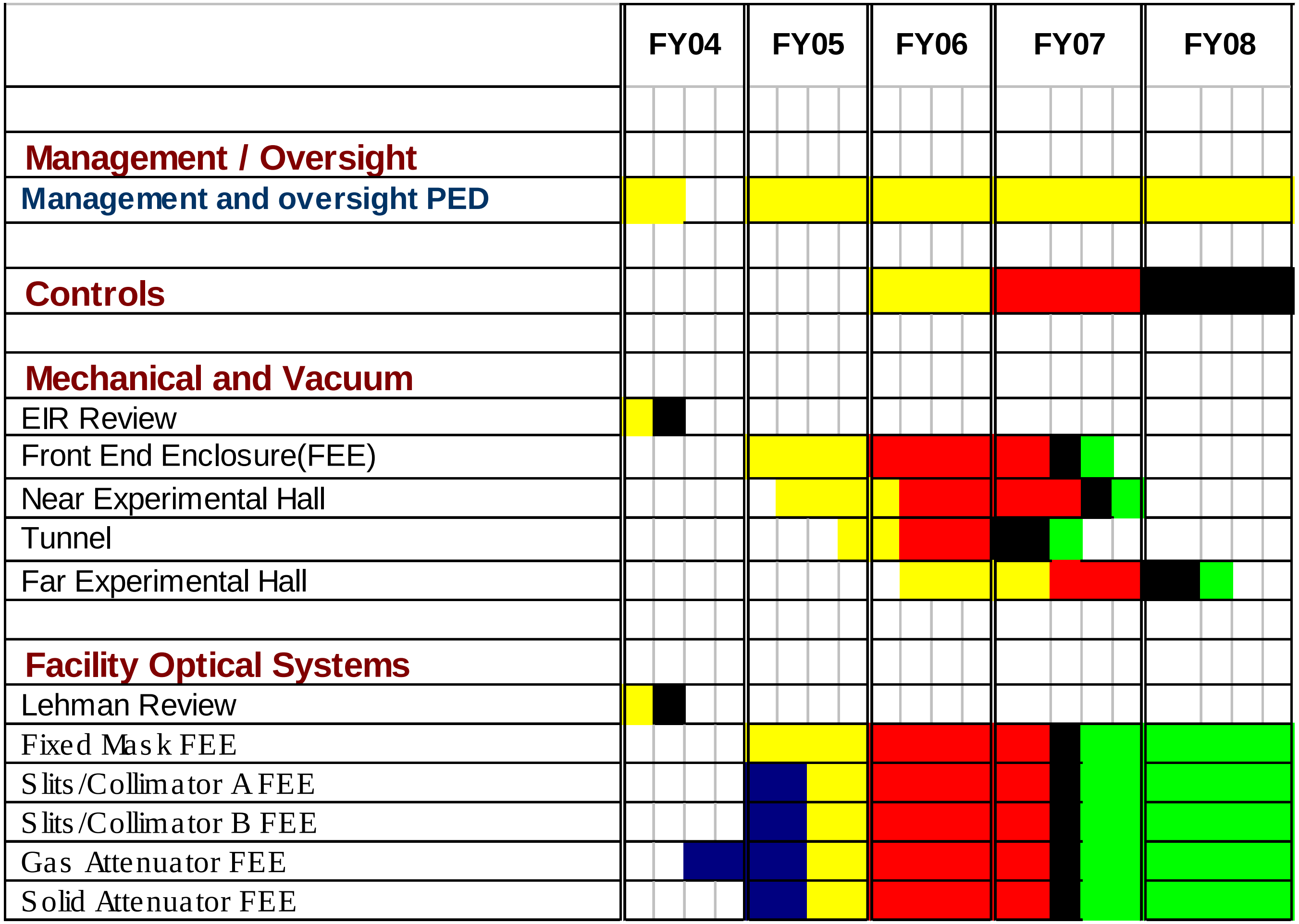
- Generate near field patterns
  - For selected energies
  - At positions of instrumentation
- Incorporate near-field into Simulation
- Run Simulations of
  - Spontaneous reflections in undulator tube
  - Backgrounds in camera from slits
  - Spontaneous + FEL in imagers

Programmatics

XTOD WBS Organized by Function

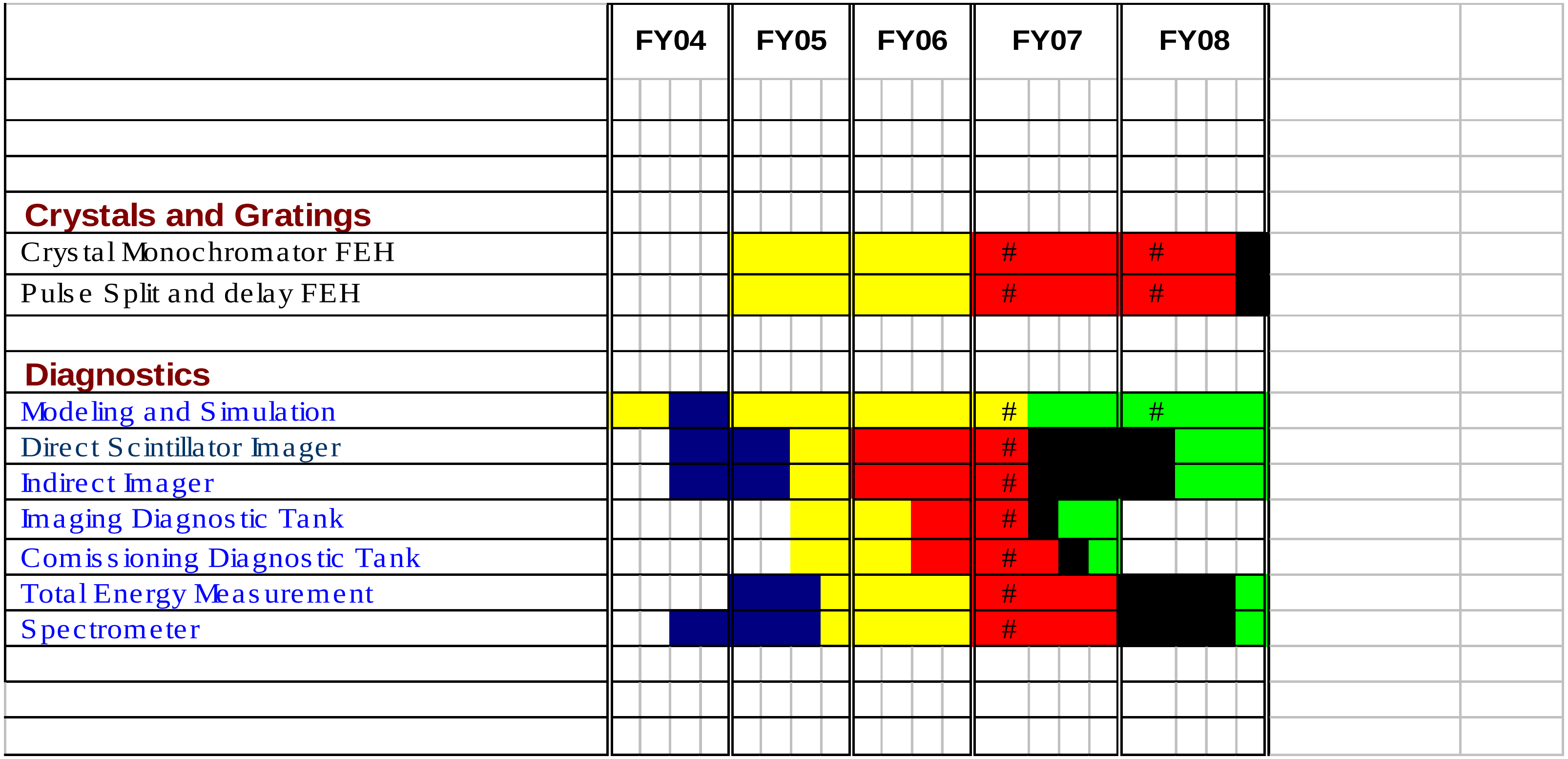
- 1.5 XTOD
  - .1 Mgmt.
  - .2 Ctrls.
    - Controls for all instruments
  - .3 Mech&Vac.
    - Pumps, pipes, and stands between instrument tanks, by room
  - .4 Optics
    - Masks
    - Slits
    - Flipper Mrr.
    - Gas Atten.
    - Solid Atten.
    - Optic Tank
    - Monochrom
    - Split & Delay
  - .5 Diagnostics
    - Simulation
    - Direct Imager
    - Indirect Imager
    - Diagnostic Tanks
    - Spectrometer
    - Calorimeter
    - Coherence
    - Shape
  - .6 Install
    - Installation of all vacuum and instruments

Schedule



	FY04				FY05				FY06				FY07				FY08			
Management / Oversight																				
Management and oversight PED	🟨	🟨			🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨
Controls									🟨	🟨	🟨	🟨	🟥	🟥	🟥	🟥	⬛	⬛	⬛	⬛
Mechanical and Vacuum																				
EIR Review	🟨	⬛																		
Front End Enclosure(FEE)					🟨	🟨	🟨	🟨	🟥	🟥	🟥	🟥	🟥	⬛	🟩					
Near Experimental Hall						🟨	🟨	🟨	🟨	🟥	🟥	🟥	🟥	🟥	⬛	🟩				
Tunnel								🟨	🟨	🟥	🟥	🟥	⬛	🟩						
Far Experimental Hall										🟨	🟨	🟨	🟨	🟥	🟥	🟥	⬛	🟩		
Facility Optical Systems																				
Lehman Review	🟨	⬛																		
Fixed Mask FEE					🟨	🟨	🟨	🟨	🟥	🟥	🟥	🟥	🟥	⬛	🟩	🟩	🟩	🟩	🟩	🟩
Slits/Collimator A FEE					🟦	🟦	🟨	🟨	🟥	🟥	🟥	🟥	🟥	⬛	🟩	🟩	🟩	🟩	🟩	🟩
Slits/Collimator B FEE					🟦	🟦	🟨	🟨	🟥	🟥	🟥	🟥	🟥	⬛	🟩	🟩	🟩	🟩	🟩	🟩
Gas Attenuator FEE			🟦	🟦	🟦	🟦	🟨	🟨	🟥	🟥	🟥	🟥	🟥	⬛	🟩	🟩	🟩	🟩	🟩	🟩
Solid Attenuator FEE					🟦	🟦	🟨	🟨	🟥	🟥	🟥	🟥	🟥	⬛	🟩	🟩	🟩	🟩	🟩	🟩

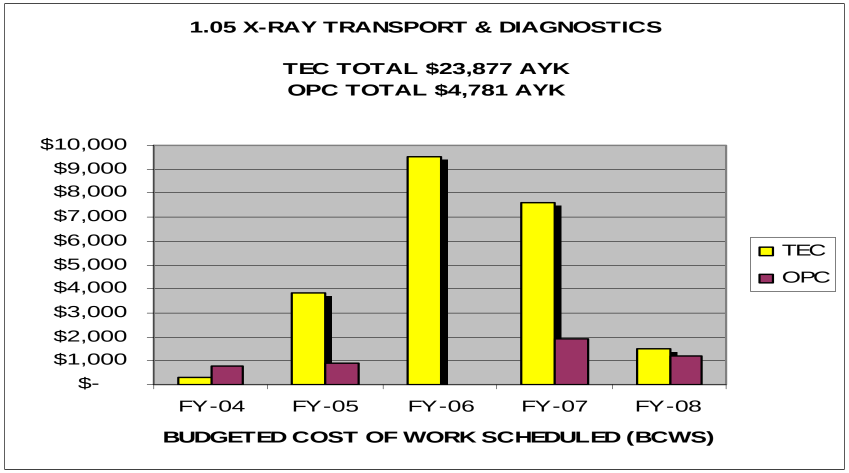
Schedule (cont.)

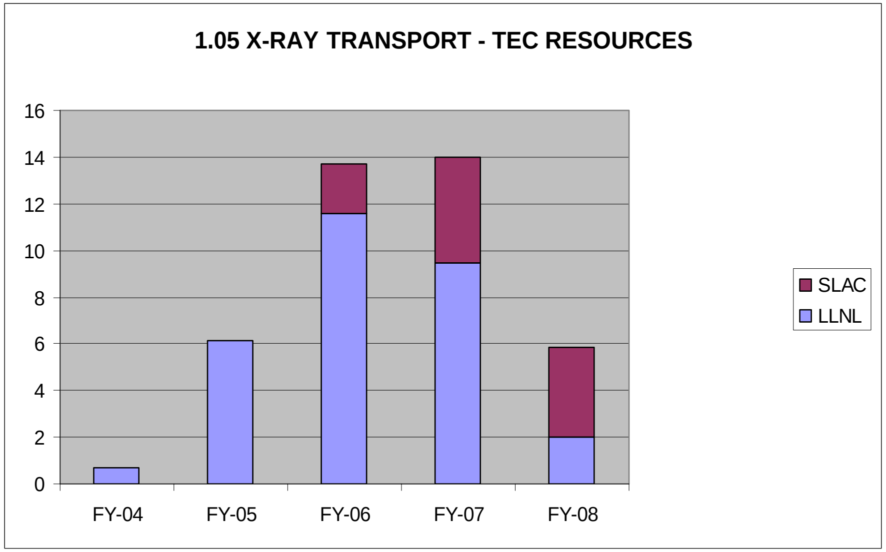


	FY04				FY05				FY06				FY07				FY08			
Crystals and Gratings																				
Crystal Monochromator FEH					🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟥 #	🟥	🟥	🟥	🟥 #	🟥	🟥	⬛
Pulse Split and delay FEH					🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟥 #	🟥	🟥	🟥	🟥 #	🟥	🟥	⬛
Diagnostics																				
Modeling and Simulation	🟨	🟨	🟦	🟦	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨 #	🟩	🟩	🟩	🟩 #	🟩	🟩	🟩
Direct Scintillator Imager			🟦	🟦	🟦	🟦	🟨	🟨	🟥	🟥	🟥	🟥	🟥 #	⬛	⬛	⬛	⬛	🟩	🟩	🟩
Indirect Imager			🟦	🟦	🟦	🟦	🟨	🟨	🟥	🟥	🟥	🟥	🟥 #	⬛	⬛	⬛	⬛	🟩	🟩	🟩
Imaging Diagnostic Tank							🟨	🟨	🟨	🟨	🟥	🟥	🟥 #	⬛	🟩	🟩				
Comissioning Diagnostic Tank							🟨	🟨	🟨	🟨	🟥	🟥	🟥 #	🟥	⬛	🟩				
Total Energy Measurement					🟦	🟦	🟦	🟨	🟨	🟨	🟨	🟨	🟥 #	🟥	🟥	🟥	⬛	⬛	⬛	🟩
Spectrometer			🟦	🟦	🟦	🟦	🟦	🟨	🟨	🟨	🟨	🟨	🟥 #	🟥	🟥	🟥	⬛	⬛	⬛	🟩

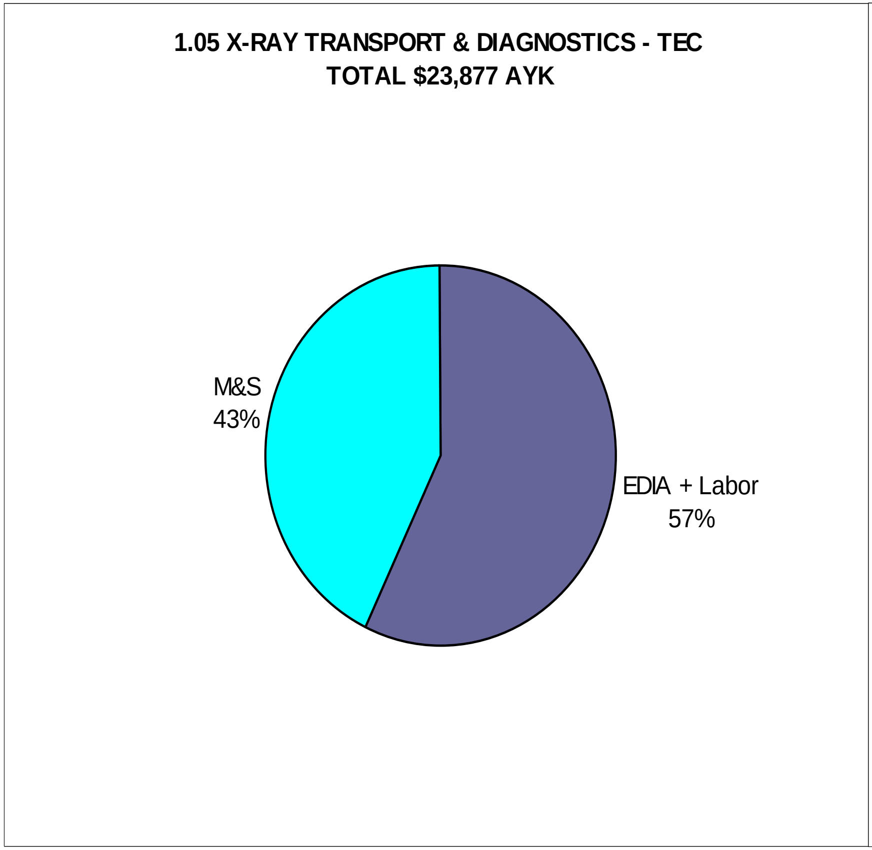
Resources

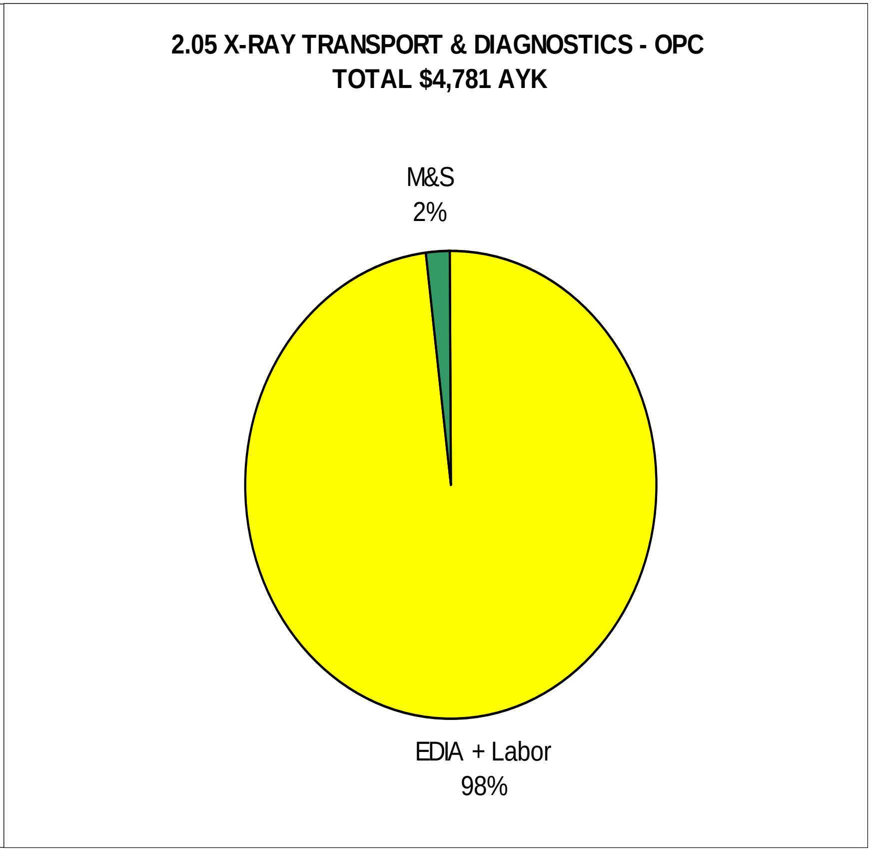
	$K
Management	**5993**
Controls	**1119**
Mech & Vac	**2724**
Fixed Mask	**338**
Slit A & B	**1954**
Flipper Mirror	**769**
Gas Attenuator	**2044**
Solid Attenuator	**233**
Optics Tanks	**684**
Monochrometer	**338**
Pulse Split and Delay	**275**
Modeling and Simulation	**864**
Direct Imager	**820**
Indirect Imager	**689**
Diagnostic tanks	**573**
Total energy	**806**
Spectral Measurement	**739**
Coherence Measurement	**383**
Centroid and Divergence	**94**
Installation	**2461**
R&D	**2491**
Total	**26391**



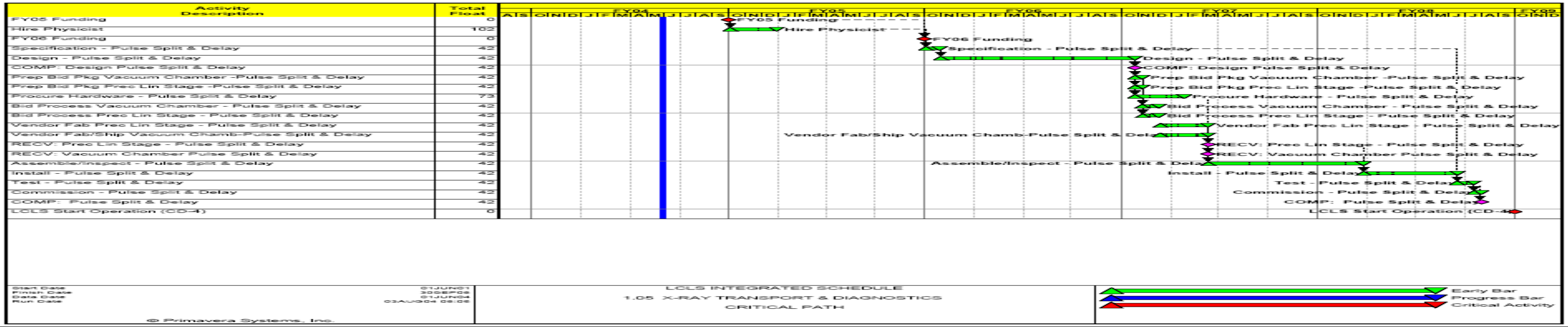


Labor vs. M&S


1.05 X-RAY TRANSPORT & DIAGNOSTICS - TEC
TOTAL $23,877 AYK
M&S
43%
EDIA + Labor
57%


2.05 X-RAY TRANSPORT & DIAGNOSTICS - OPC
TOTAL $4,781 AYK
M&S
2%
EDIA + Labor
98%

Critical Path



Activity Description	Total Float
FY05 Funding	0
Hire Physicist	102
FY06 Funding	0
Specification - Pulse Split & Delay	42
Design - Pulse Split & Delay	42
COMP: Design Pulse Split & Delay	42
Prep Bid Pkg Vacuum Chamber -Pulse Split & Delay	42
Prep Bid Pkg Prec Lin Stage -Pulse Split & Delay	42
Procure Hardware - Pulse Split & Delay	73
Bid Process Vacuum Chamber - Pulse Split & Delay	42
Bid Process Prec Lin Stage - Pulse Split & Delay	42
Vendor Fab Prec Lin Stage - Pulse Split & Delay	42
Vendor Fab/Ship Vacuum Chamb-Pulse Split & Delay	42
RECV: Prec Lin Stage - Pulse Split & Delay	42
RECV: Vacuum Chamber Pulse Split & Delay	42
Assemble/Inspect - Pulse Split & Delay	42
Install - Pulse Split & Delay	42
Test - Pulse Split & Delay	42
Commission - Pulse Split & Delay	42
COMP: Pulse Split & Delay	42
LCLS Start Operation (CD-4)	0

Start Date 01JUN01
Finish Date 30SEP08
Data Date 01JUN04
Run Date 03AUG04 08:06

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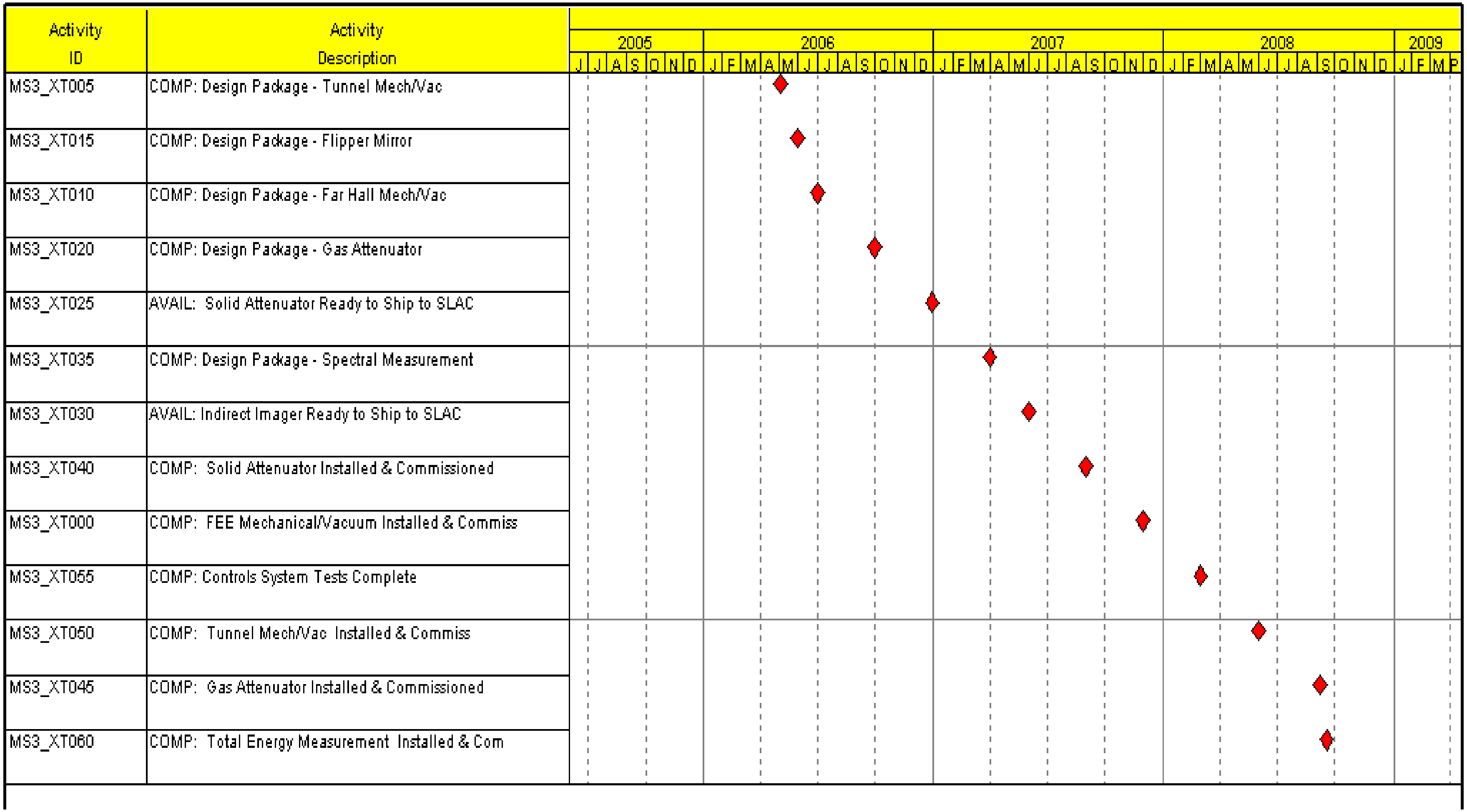
LCLS INTEGRATED SCHEDULE
1.05 X-RAY TRANSPORT & DIAGNOSTICS
CRITICAL PATH

First 7 items on critical path are not needed for commissioning or CD4. First "truly critical item", gas attenuator is number 8

Level 3 Milestones



Activity ID	Activity Description
MS3_XT005	COMP: Design Package - Tunnel Mech/Vac
MS3_XT015	COMP: Design Package - Flipper Mirror
MS3_XT010	COMP: Design Package - Far Hall Mech/Vac
MS3_XT020	COMP: Design Package - Gas Attenuator
MS3_XT025	AVAIL: Solid Attenuator Ready to Ship to SLAC
MS3_XT035	COMP: Design Package - Spectral Measurement
MS3_XT030	AVAIL: Indirect Imager Ready to Ship to SLAC
MS3_XT040	COMP: Solid Attenuator Installed & Commissioned
MS3_XT000	COMP: FEE Mechanical/Vacuum Installed & Commiss
MS3_XT055	COMP: Controls System Tests Complete
MS3_XT050	COMP: Tunnel Mech/Vac Installed & Commiss
MS3_XT045	COMP: Gas Attenuator Installed & Commissioned
MS3_XT060	COMP: Total Energy Measurement Installed & Com

Future work and conclusions

Near term activities planned

- Mechanical & Vacuum
  - Gas Attenuator Calculations and Prototype
  - Beam Line Layout / Standardization / Detailed Specifications
- Modeling and Simulation
  - Spontaneous / FEL simulation
  - Calculate Beam sizes at Gas Attenuator, Cameras, etc
  - Simulations of Camera response to mix of Spontaneous and FEL
- Component R&D
  - Spectrometer
  - Total Energy
  - Damage

Technical Activities in FY05

- Detailed Design in preparation for construction in FY06
  - Mech. & Vac. through Near Hall
  - Slit
  - Gas attenuator
  - Direct Imager
- R&D & Prototype
  - Total Energy
  - Spectrometer
  - Indirect Imager

Summary

- No XTOD Long-Lead Procurements
- XTOD Risks identified
- XTOD Baseline Set
- XTOD Ready for serious R&D and Engineering effort to begin in FY05 in preparation for procurement and fabrication in FY06