LUXE Inverse Compton Source Considerations

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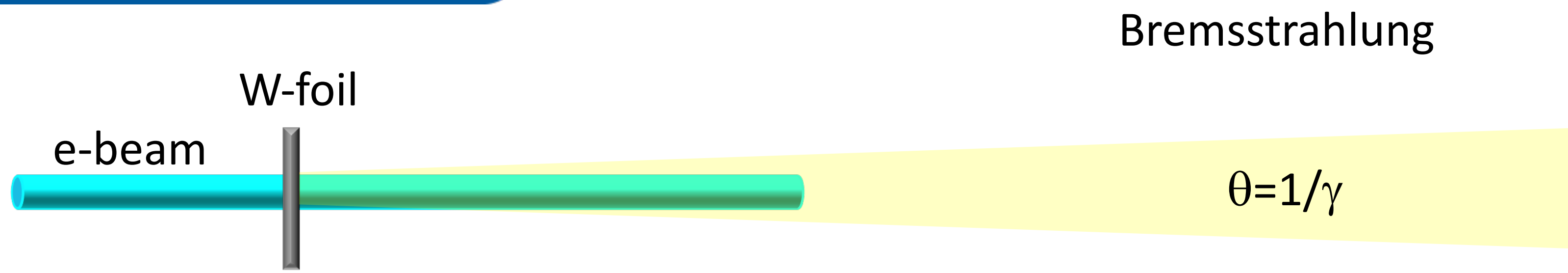
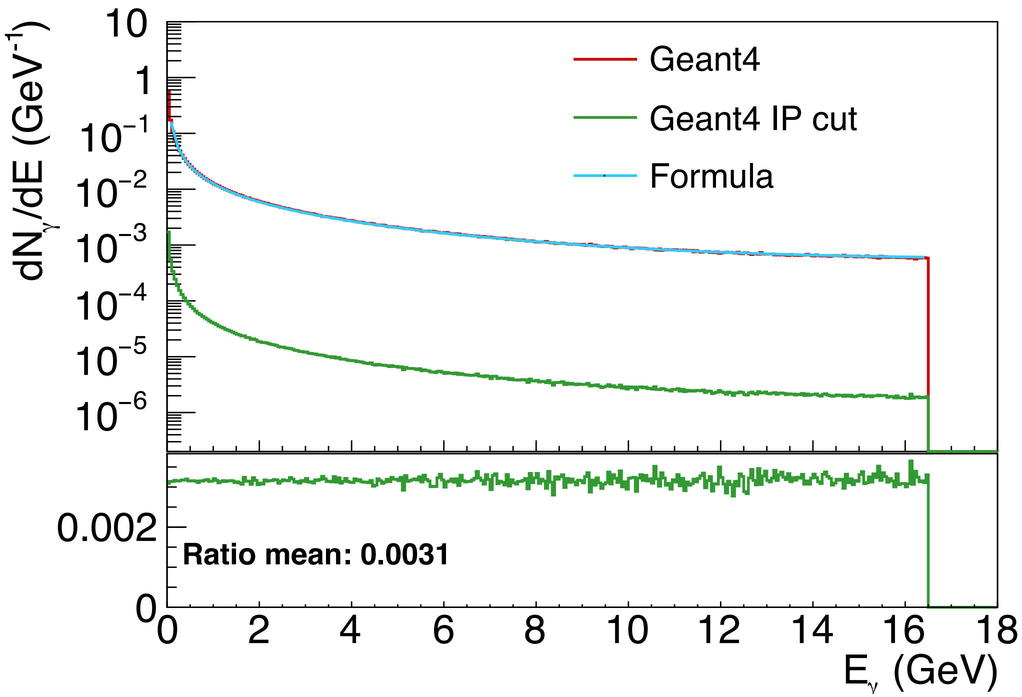
Bremstrahlung





- Efficiency ~ 10^{-3}
  - at $>0.9E_{max}$
- Scales with converter thickness
- Simple to implement
- $1/\gamma$ cone angle

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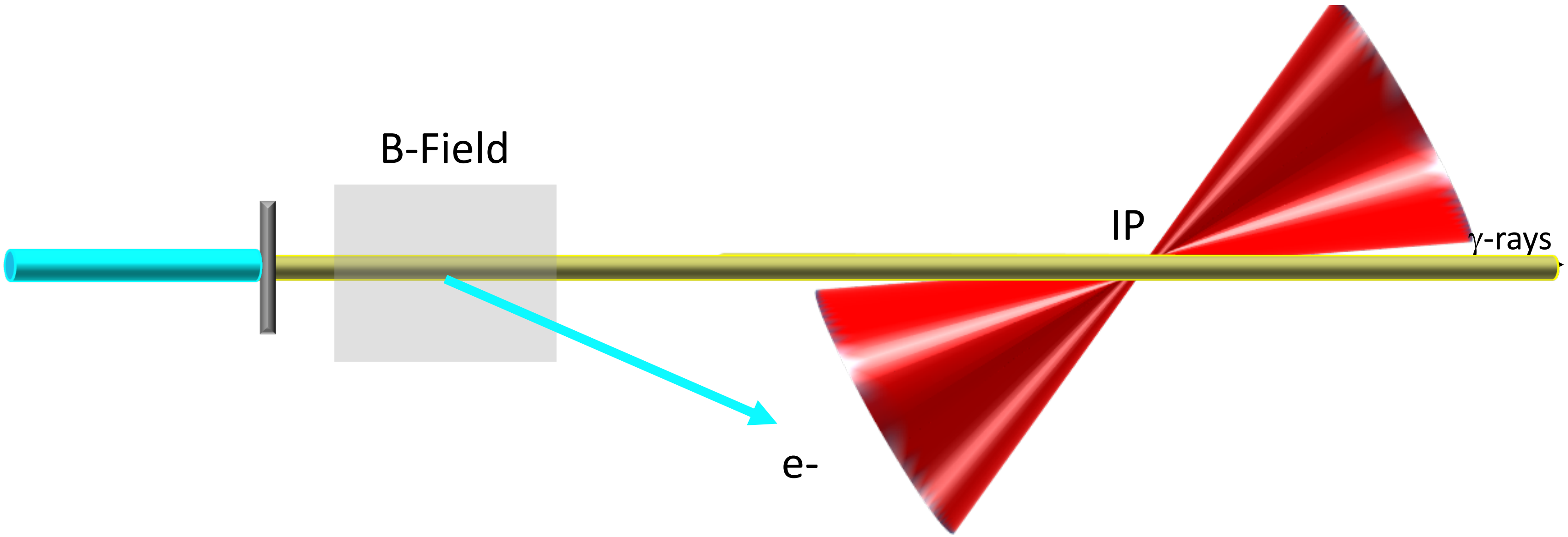
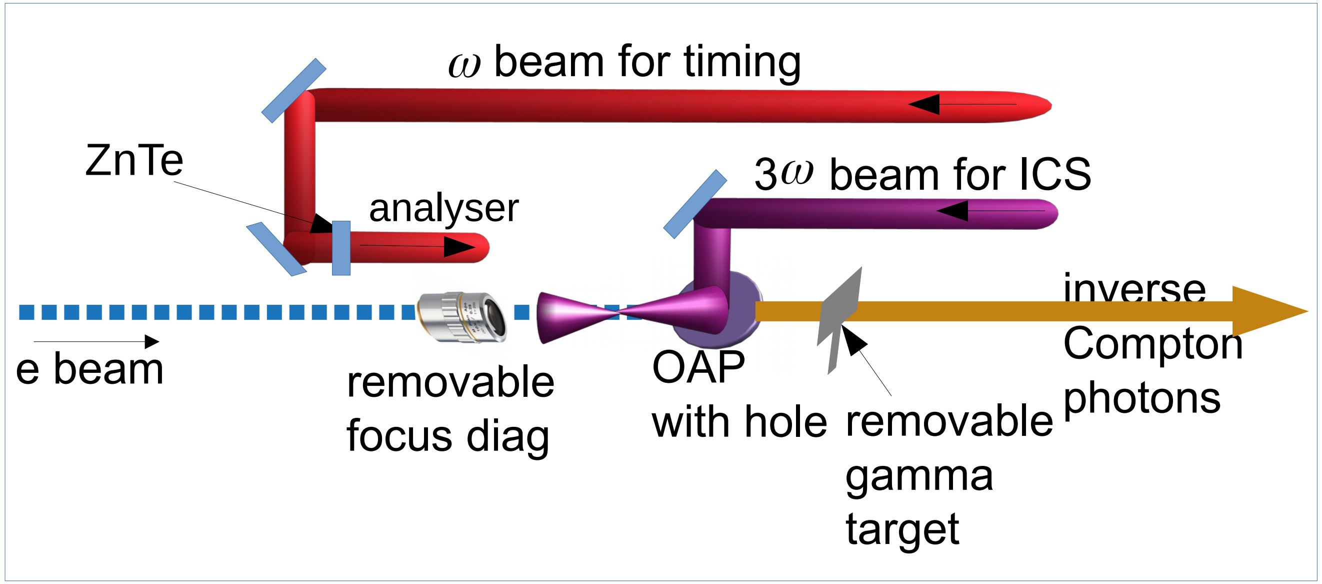
Bremstrahlung layout



- Pure photon/photon interaction at high $\chi > 1$
- Breit-Wheeler Pair production
  - $h\nu_{\gamma}\,\mathrm{N}h\nu_{laser} > m_e c^2(1\text{-}\cos(\alpha))$
- Magnet to separate out leptons from IP

Inverse Compton Alternative



- Replace Bremsstrahlung Target with ICS
  - Photon energy ~ $\omega' = 4\gamma^2\omega$ (ignoring recoil)
  - Normal incidence (OAP with hole) for max ω'
- Approximate conditions a0<0.3
  - $N_{gamma\_photons} \sim a0^2/137$ per optical cycle
- **5µm focus => Focus OF E-beam needs to be ICS source**
  - Match electron beam focus for best efficiency!

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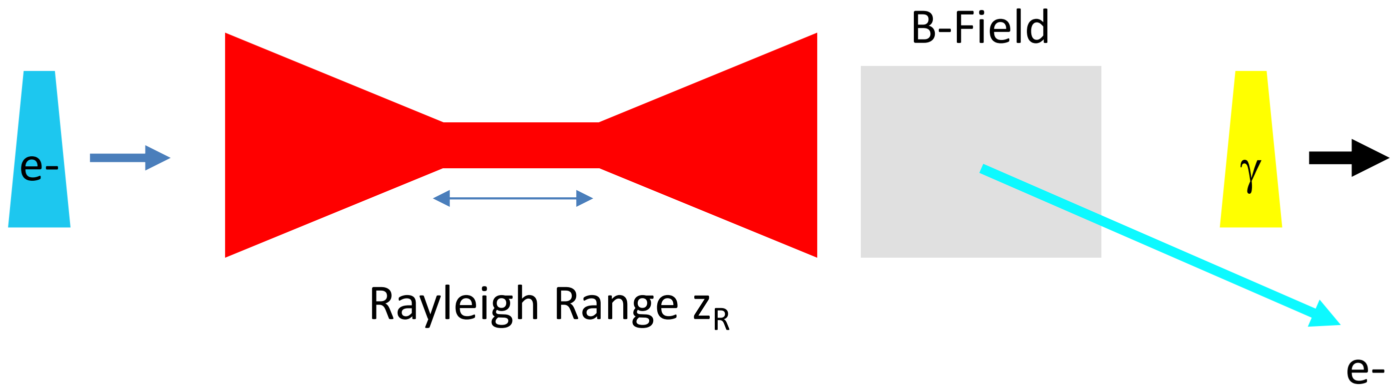
Pulseduration can be longer



- Interaction time set by Rayleigh Range, electron pulse duration
- G-pulse duration set by electron pulse duration
  - γ^2 compression in time due to relativistic effects
- For z_R~300µm => $t_{pulse\_max} = z_R\,c$~1ps
  - Pulse durations up to 1ps don‘t affect γ pulse duration
  - For E_{laser}=const, $t_{pulse} < z_R\,c$ => $N_{gamma\_photons}$~const
    => don‘t need very short pulse!

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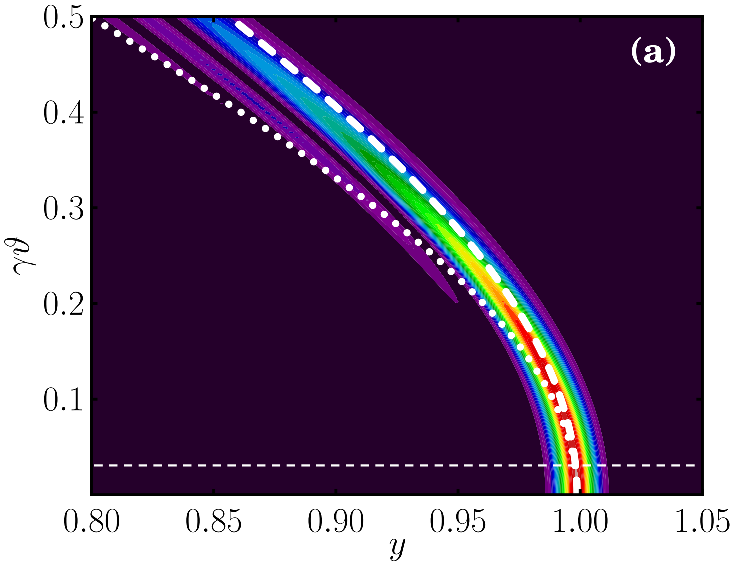
ICS at low a0



from Seipt et al.

- ICS at low a0<<1
- Frequency around $\omega' = 4\gamma^2\ \omega$
- angle dependent
- $\theta = 1/\gamma$
- Narrowband
  - Well defined interaction
  - Full reconstruction of reaction kinematics

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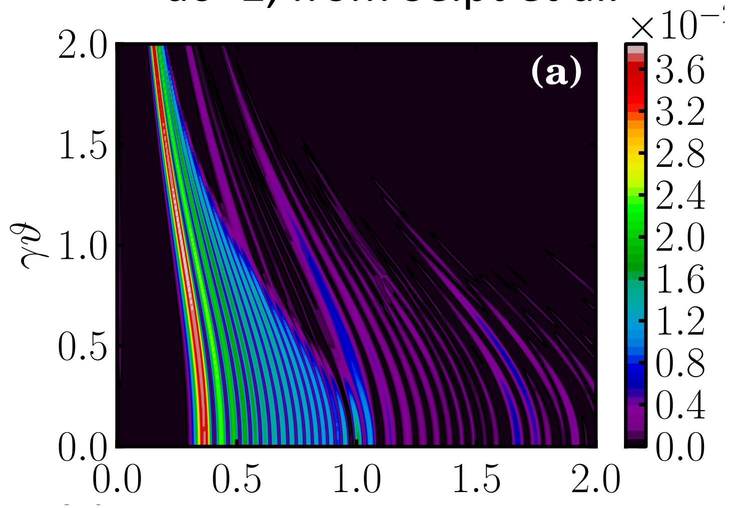
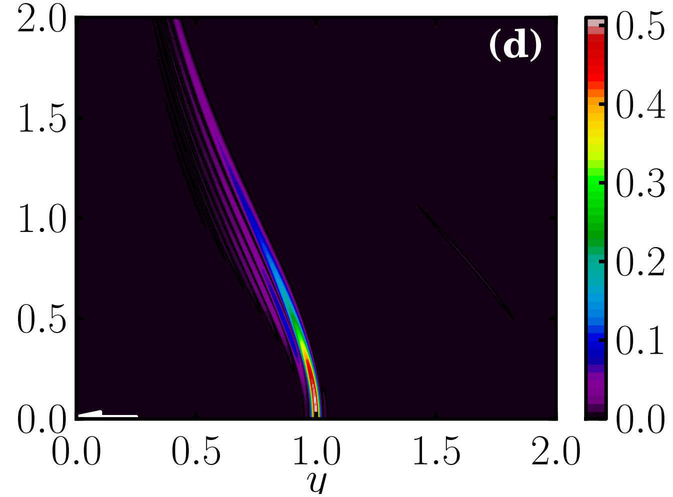
ICS at high a0

a0=2, from Seipt et al.



a0=2

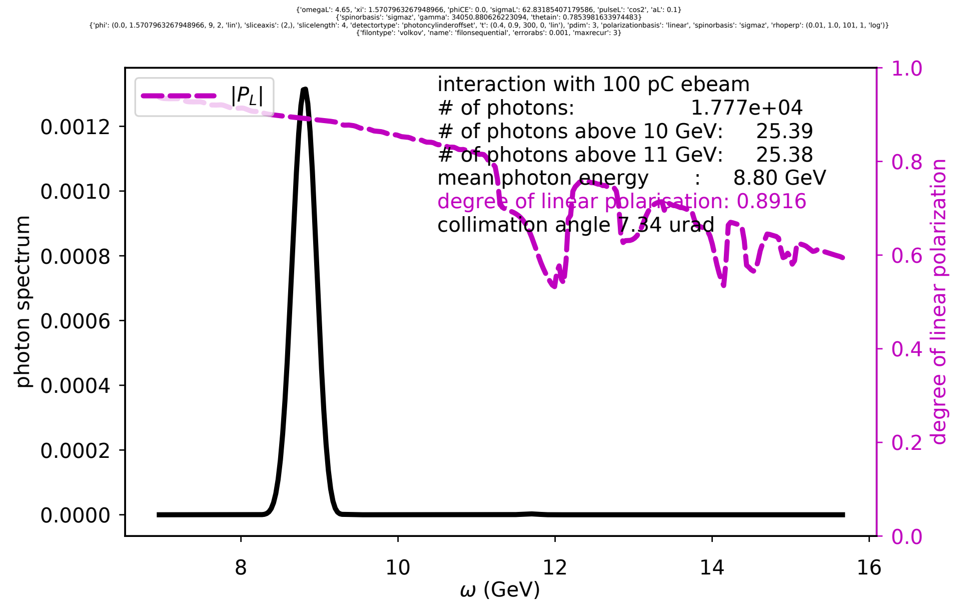
Chirp compensated relativistic mass increase



- Photon number ~ a0^2/137
  - More photons at high a0
- Harmonics for a0 >~1
  - Loose monochromaticity
- Redshift from $\omega'=4\gamma^2\,\omega$ due to
  - Relativistic Mass increase for a0>1
  - Photon recoil

Polarised gamma-source

3ω ICS, 45° collision angle



- Polarised gamma source => see Daniel‘s talks
- Would require channeling crystal for polarised bremsstrahlung

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Advantages of ICS source

- Lower background on detectors
  - better defined angular distribution
- Better defined input into reaction
  - Better reaction reconstruction
  - Note: Dressed states mean we don‘t know pair energy in rest frame!
- Polarised
- Added complication of secondary IP
- Need to do some laser development

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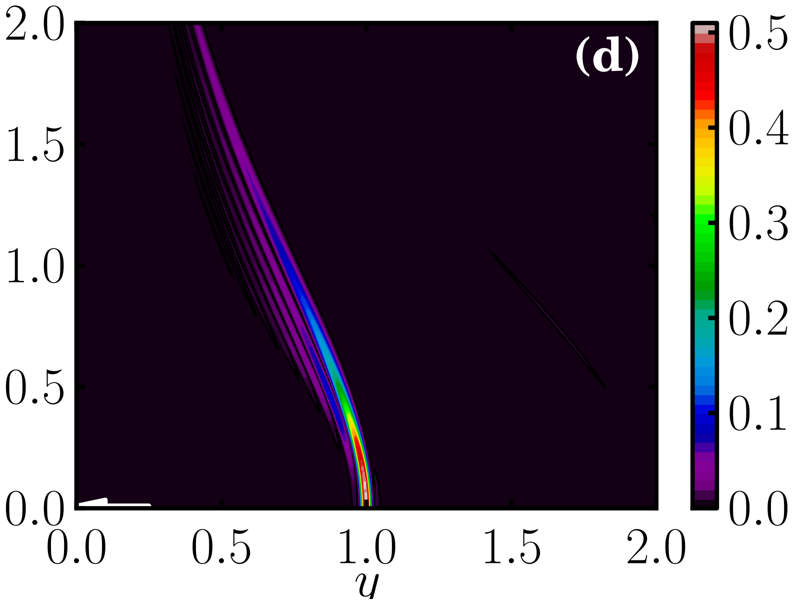
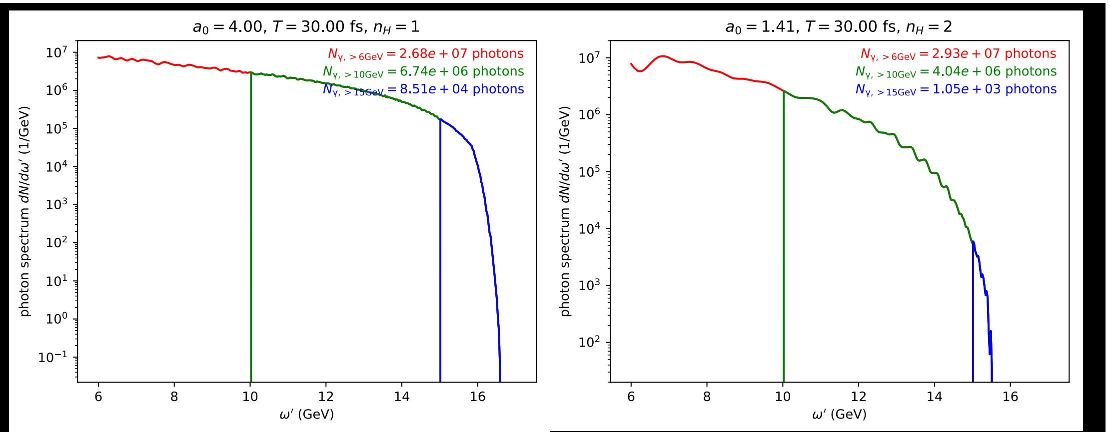
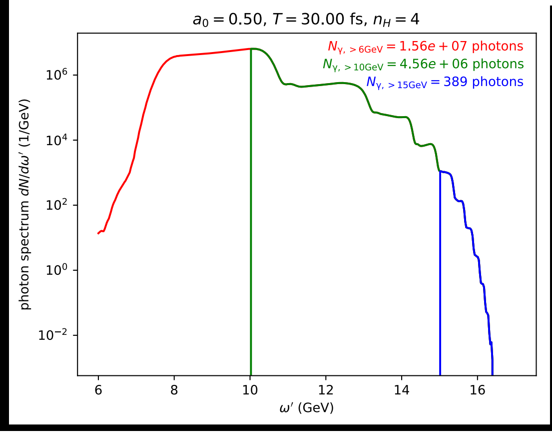
What wavelength do we need?



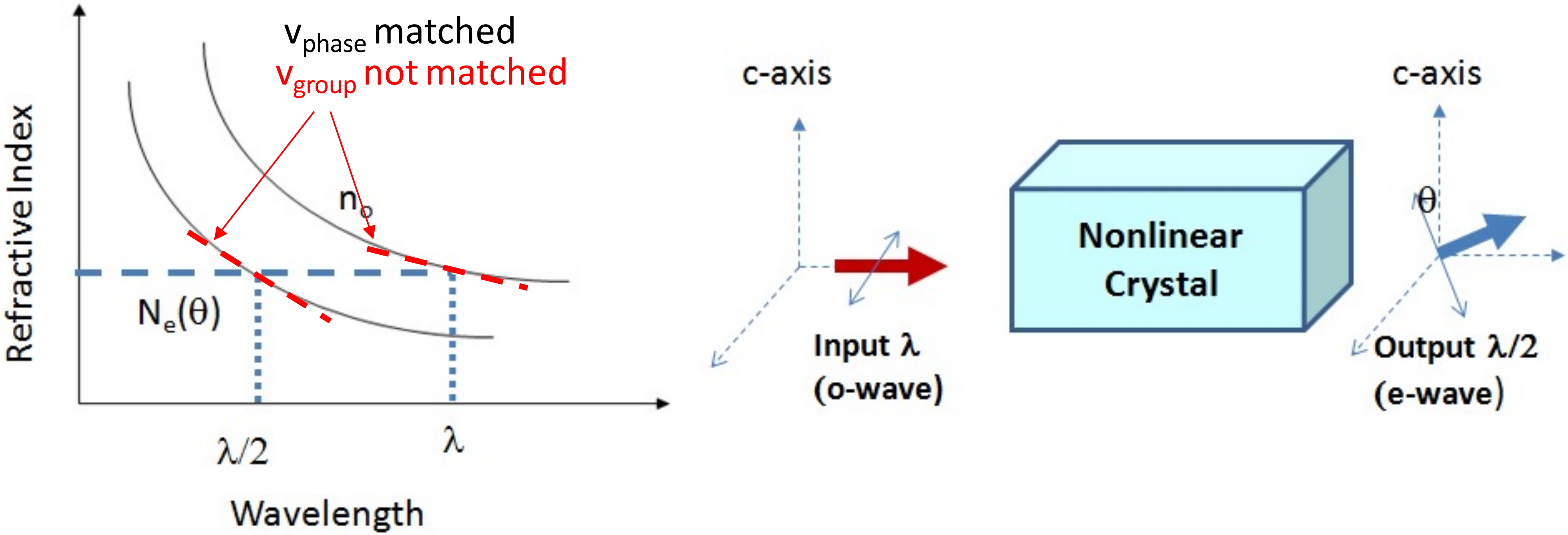




laser harmonic	a0	>10 GeV	>15 GeV
1	**4**	6.7E+06	8.5E+04
2	1.4	**4E+07**	2011
4	0.5	4.5E+06	389

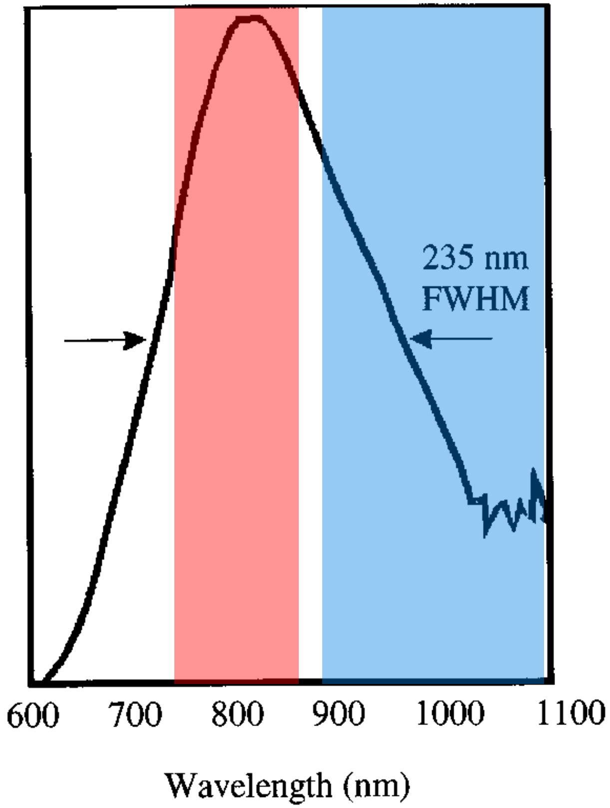
- Ideally as short as possible
  - High energy fundamental
- Perfectly co-timed
- a0 <~1 for narrow band interaction
- a0>1 for maximum hard photon flux

Real world limitations



- Tripling can be very efficient (90%@1054nm), Quadrupling can reach ~25% **BUT…**
- Phase matching achieved in bi-refringent X-tal
  - No (good) solution for very short wavelengths (800nm/4=200nm, 800m/3=266nm
- Group Velocity $v_g=d\omega/dk$ walkoff
  - Short pulses increasingly inefficient at short wavelengths
- **Tripling 800nm won‘t work!**

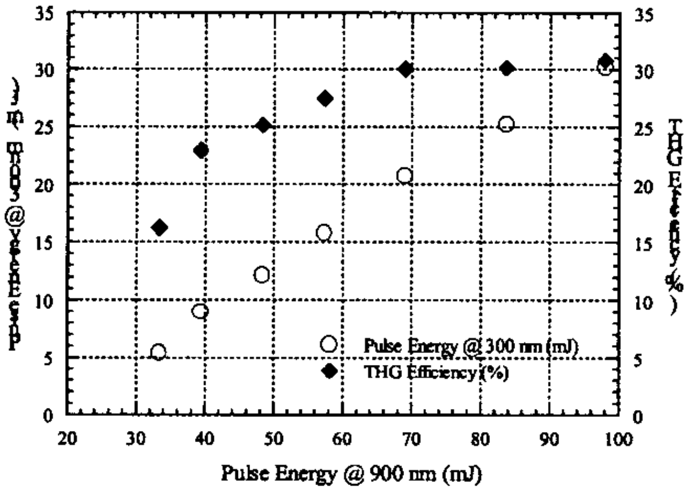
Ti:Sapphire Spectrum



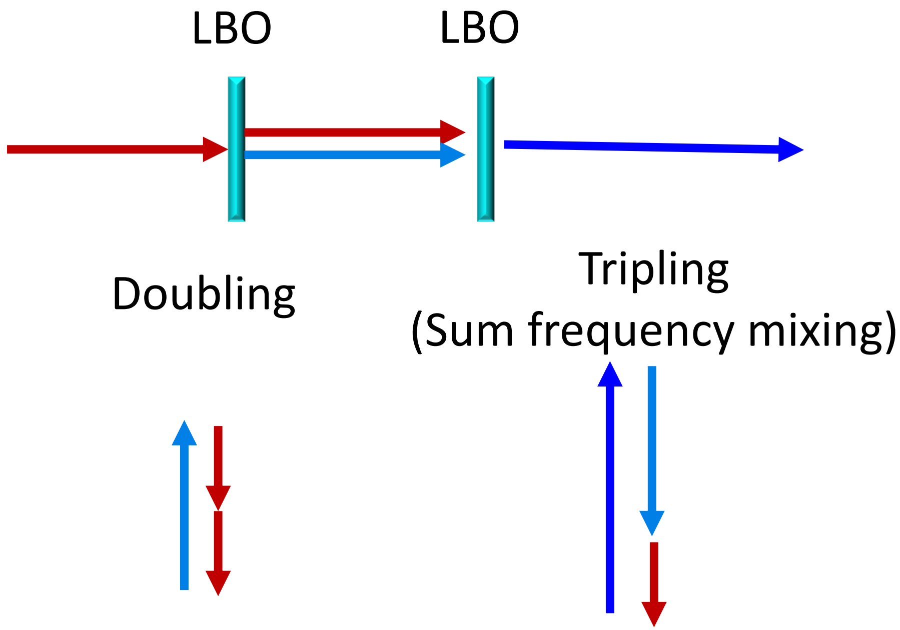
3ω range: 290-366nm
4.3 - 3 eV

- Ti:Sapphire has a broad spectrum
- Only small fraction around 800nm is used for high intensity pulse
- Ti:S Spectrum covers region for efficient tripling

Tripling Ti:Sapphire at 900nm



CThP6 **Fig. 3.** Output pulse energy and energy conversion efficiency at 300 nm as a function of the input pulse energy of the Ti:Sapphire laser at 900 nm



- Ti: Sapphire can amplify 1060nm-700nm
- Tripling at 900nm shown to be 30% efficient
- LBO crystals are available @large aperture

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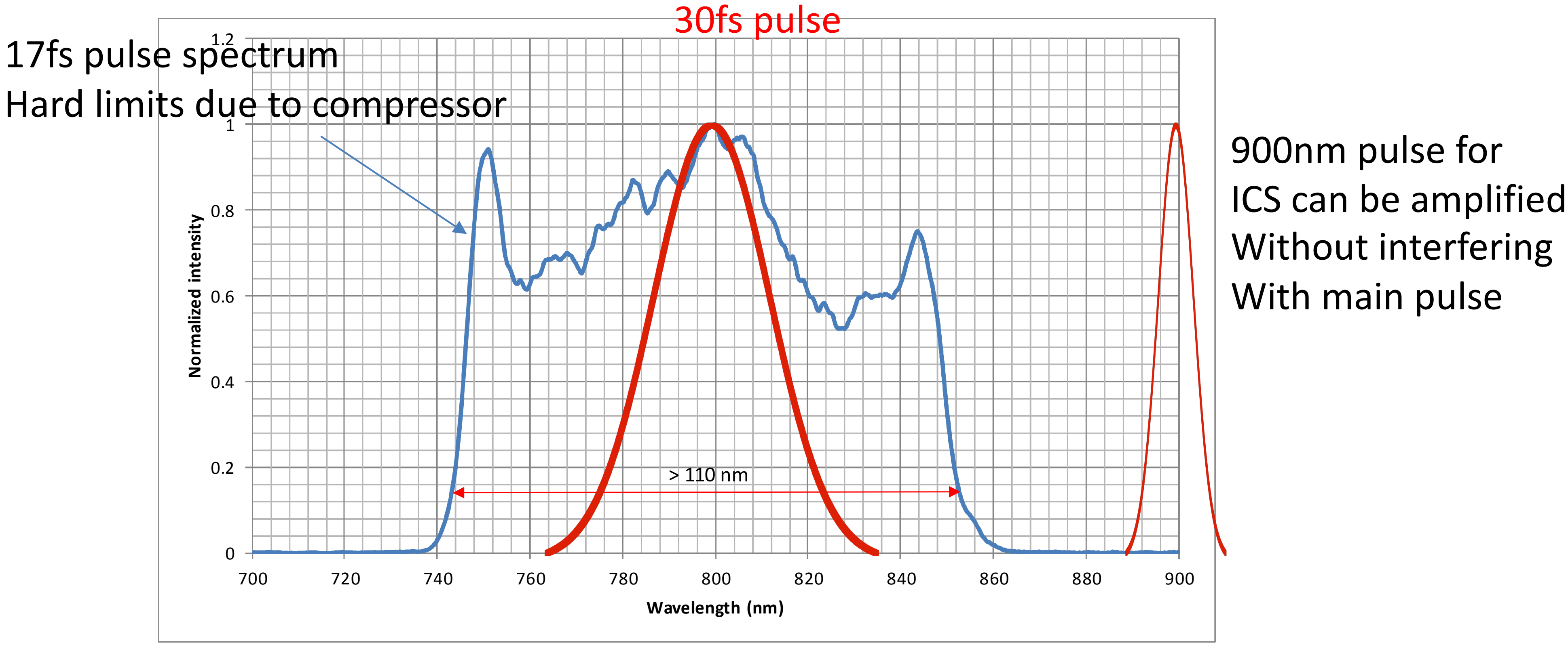
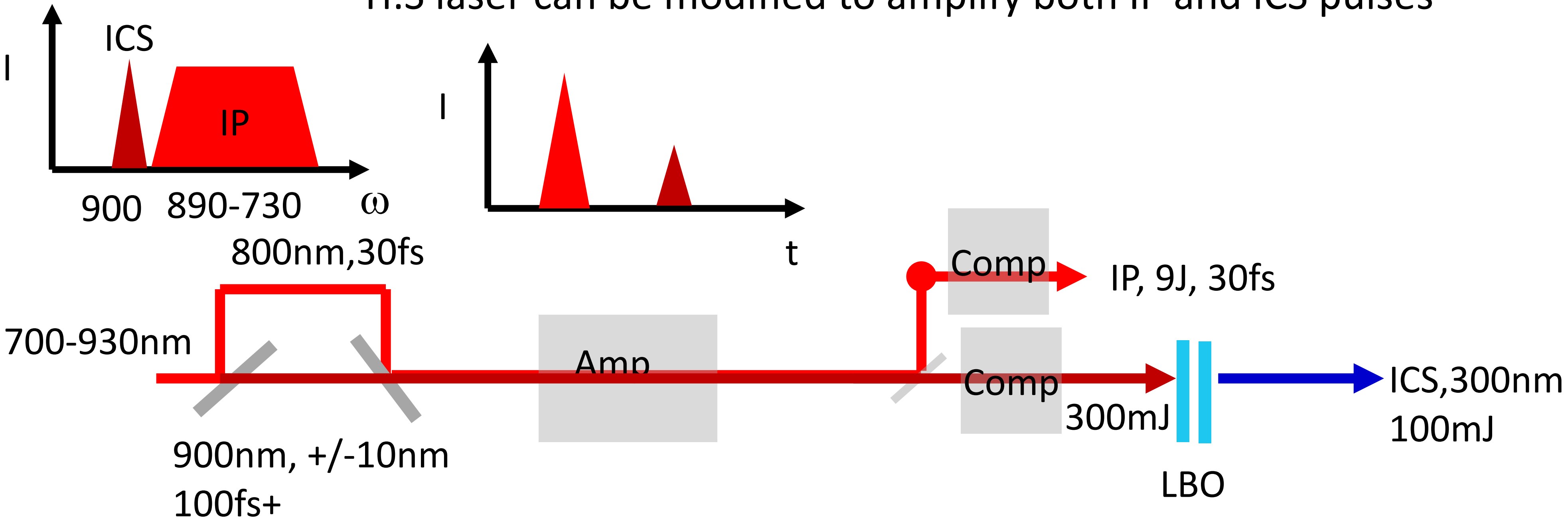
JETI spectrum



- Spectrally we can separate a 900nm pulse
  - Required bandwidth ~1-10nm for 1ps-100fs
- ~30nm for 30fs pulse at 800nm

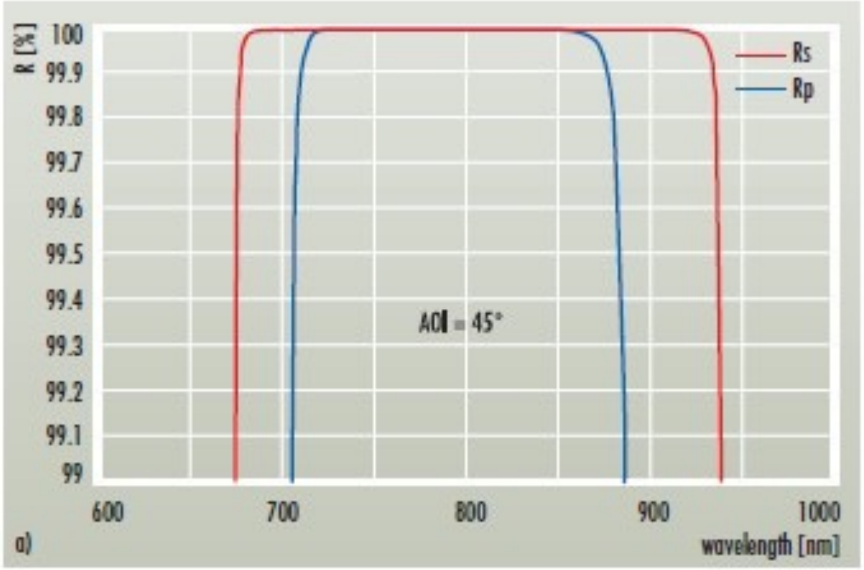
Laser Modifications

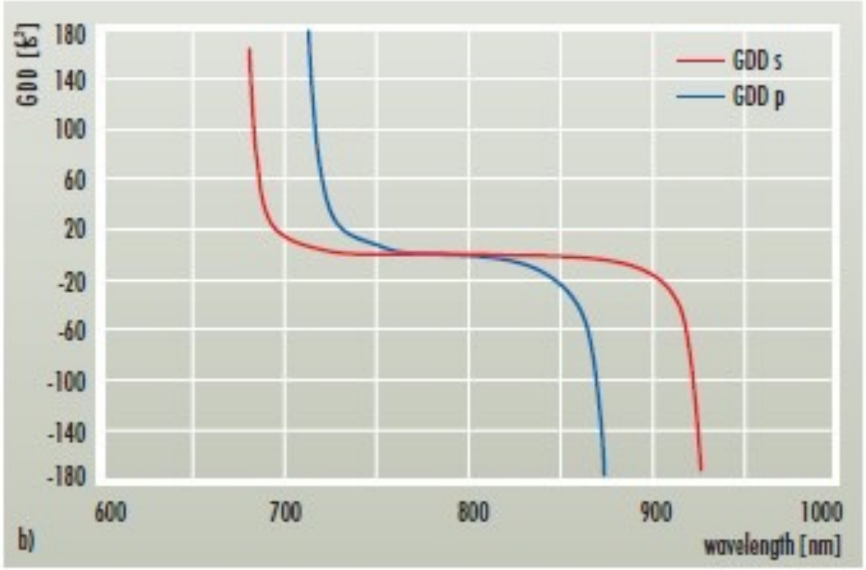
Ti:S laser can be modified to amplify both IP and ICS pulses



- 900nm pulse amplified to 300mJ
  - 3% of total energy (would be 25% of JETI40)
  - Negligible impact on IP
- Frequency tripling to~300nm (4.1 eV)

Coatings





- Sufficiently broad coatings are standard
  - But some 800nm coatings do not cover 900nm
  - Needs to be specified at order
  - GDD mirror dispersion also needs to be accounted for
    - 900nm pulse is >100fs, not very sensitive

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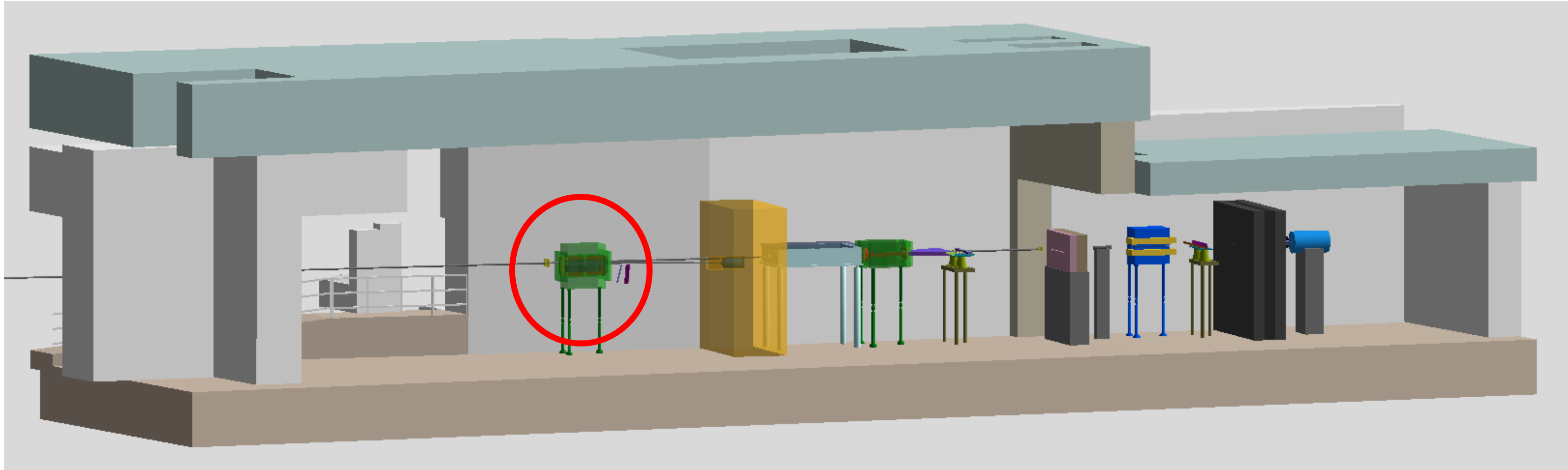
Overall Layout



- ICS generation can be accomodated in Bremsstrahlung chamber

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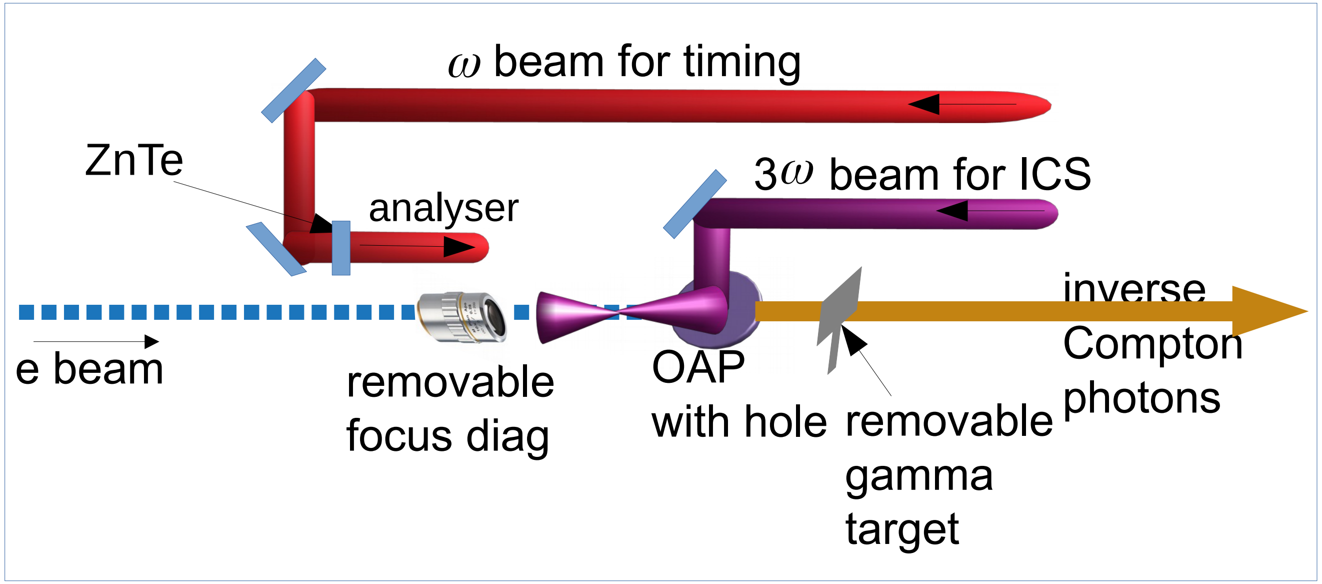
Layout



- Similar layout to main IP
- Use zero degree OAP (with hole) for highest gamma energy

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Summary

- Laser modifications
  - Front end to produce 900nm+broadband pulse
    - 3% of total energy in 900nm
  - Second compressor + Beamline
  - High flux of ~10 GeV photons
  - Narrowband possible
- Laser Development required
  - Based on literature high chance of success

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