

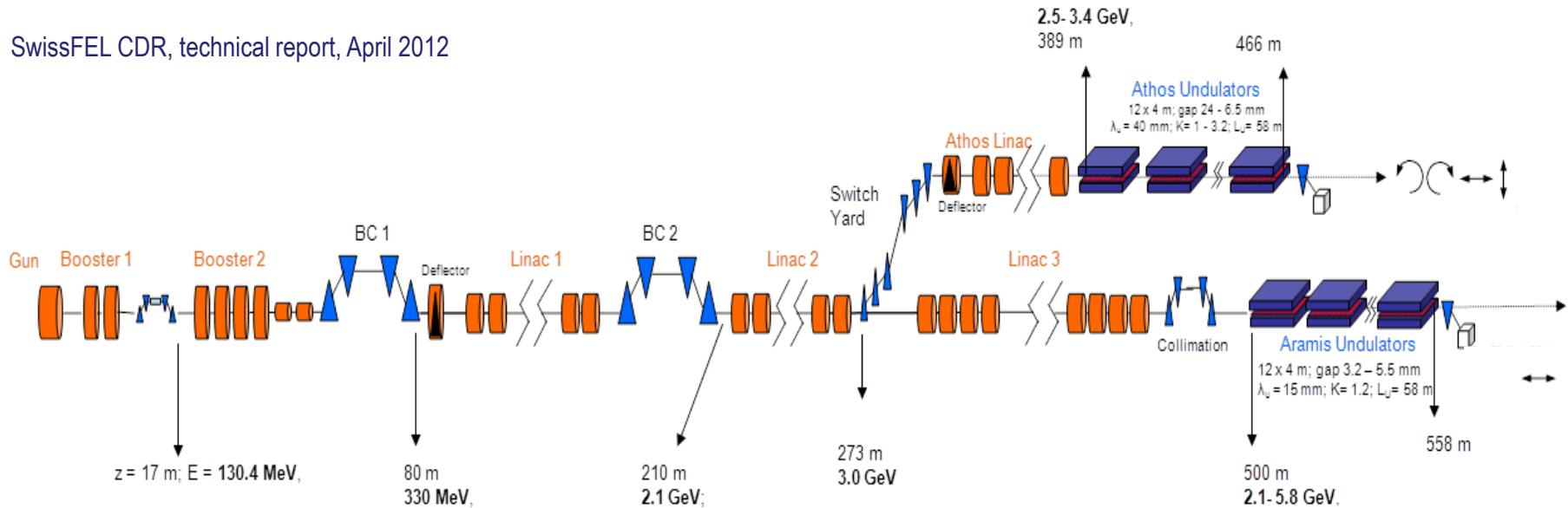
Wir schaffen Wissen – heute für morgen

# The new design of the THz streak camera at PSI

Ishkhan Gorgisyan

- **SwissFEL at PSI**
- **Our setup using THz streaking**
- **First measurements at SACLA**
- **Next generation setup**
- **Summary**

SwissFEL CDR, technical report, April 2012



## Requirements for photon diagnostics

FEL pulse length measurements

FEL vs experimental laser arrival time measurements

Non invasive measurements

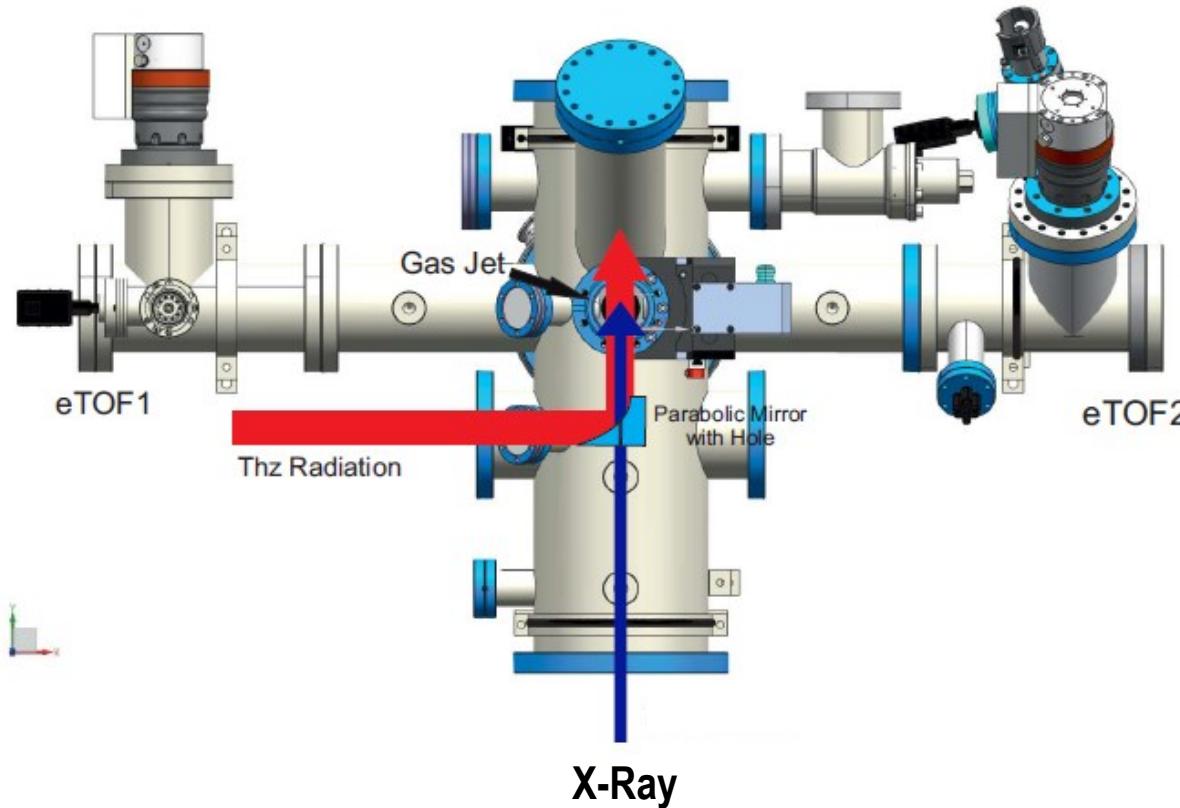
Online measurements on single-shot basis

## Goals for the SwissFEL photon pulses:

Operating Mode	X-Ray Pulse length	Arrival Time Stability	
Standard	20 fs rms	20 fs rms	Standard mode
Short-Pulse	2 fs rms	5 fs rms	
Attosecond	60 as rms	5 fs rms	Upgrade mode
Wide Bandwidth	15 fs rms	20 fs rms	

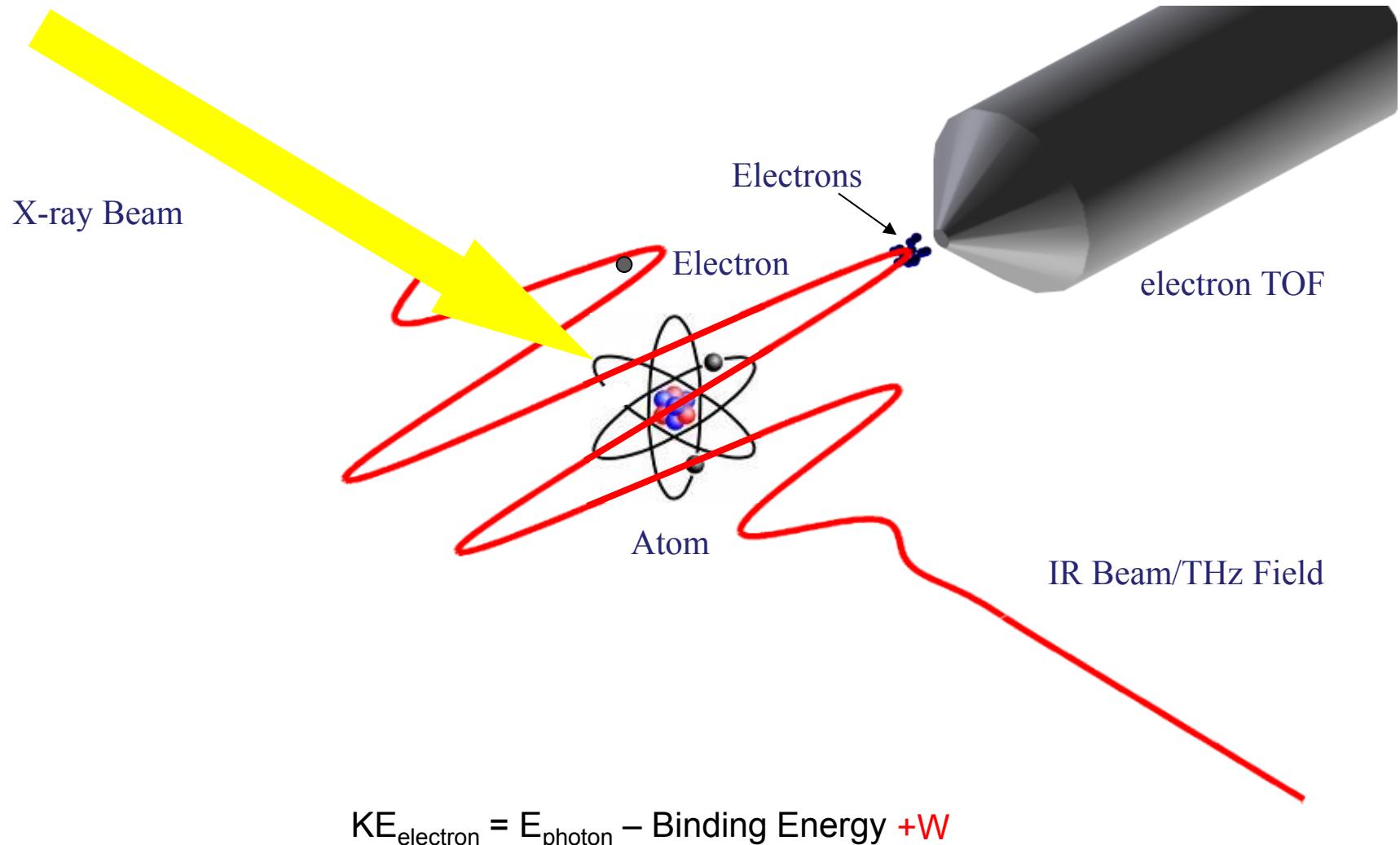
Wavelength 1 Å - 7 Å

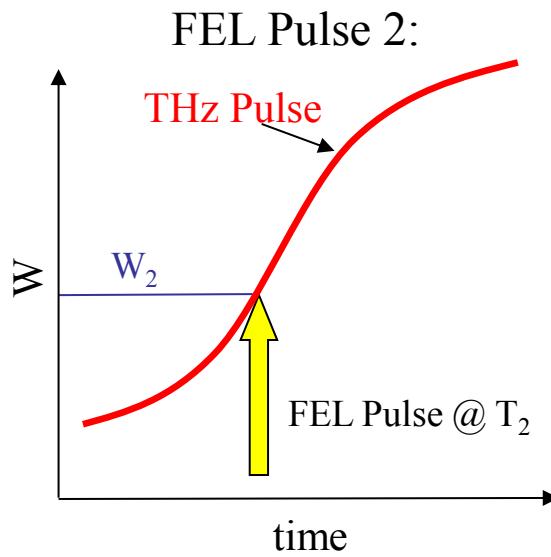
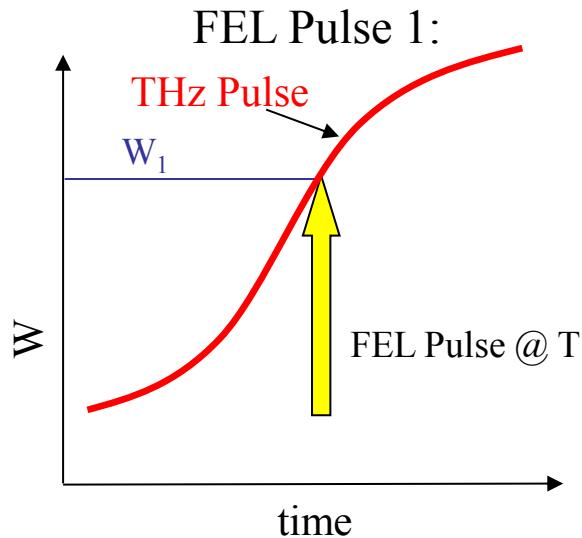
## Pulse Arrival and Length Monitor (PALM)



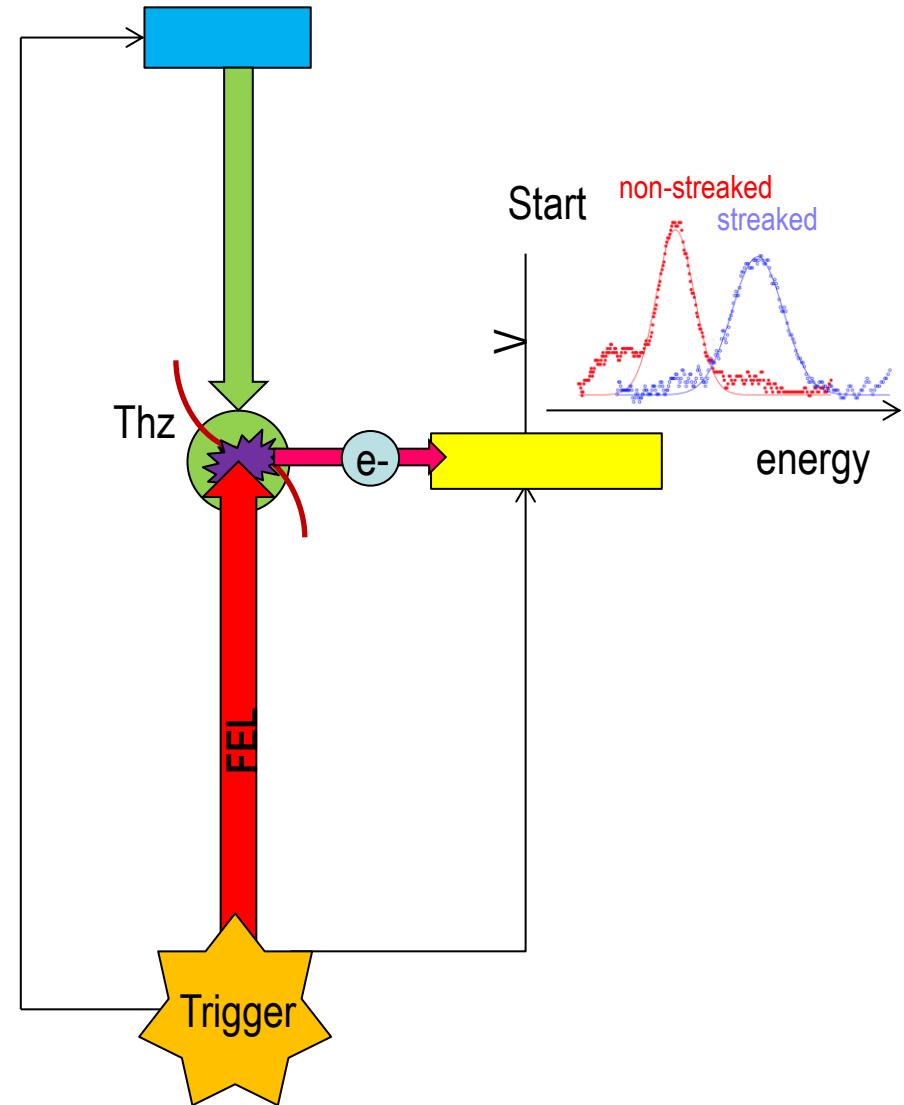
Photon pulse and relative arrival time measurement using THz streaking  
Electron time-of-flight spectrometers measuring the electron spectra  
THz generation using  $\text{LiNbO}_3$  crystal  
Pulsed Xe gas jet delivered by a piezovalve

THz streak camera concept to measure the arrival time and length of the photon pulse





$$W_2 - W_1 \rightarrow T_2 - T_1$$



## Team Members:

### PSI:

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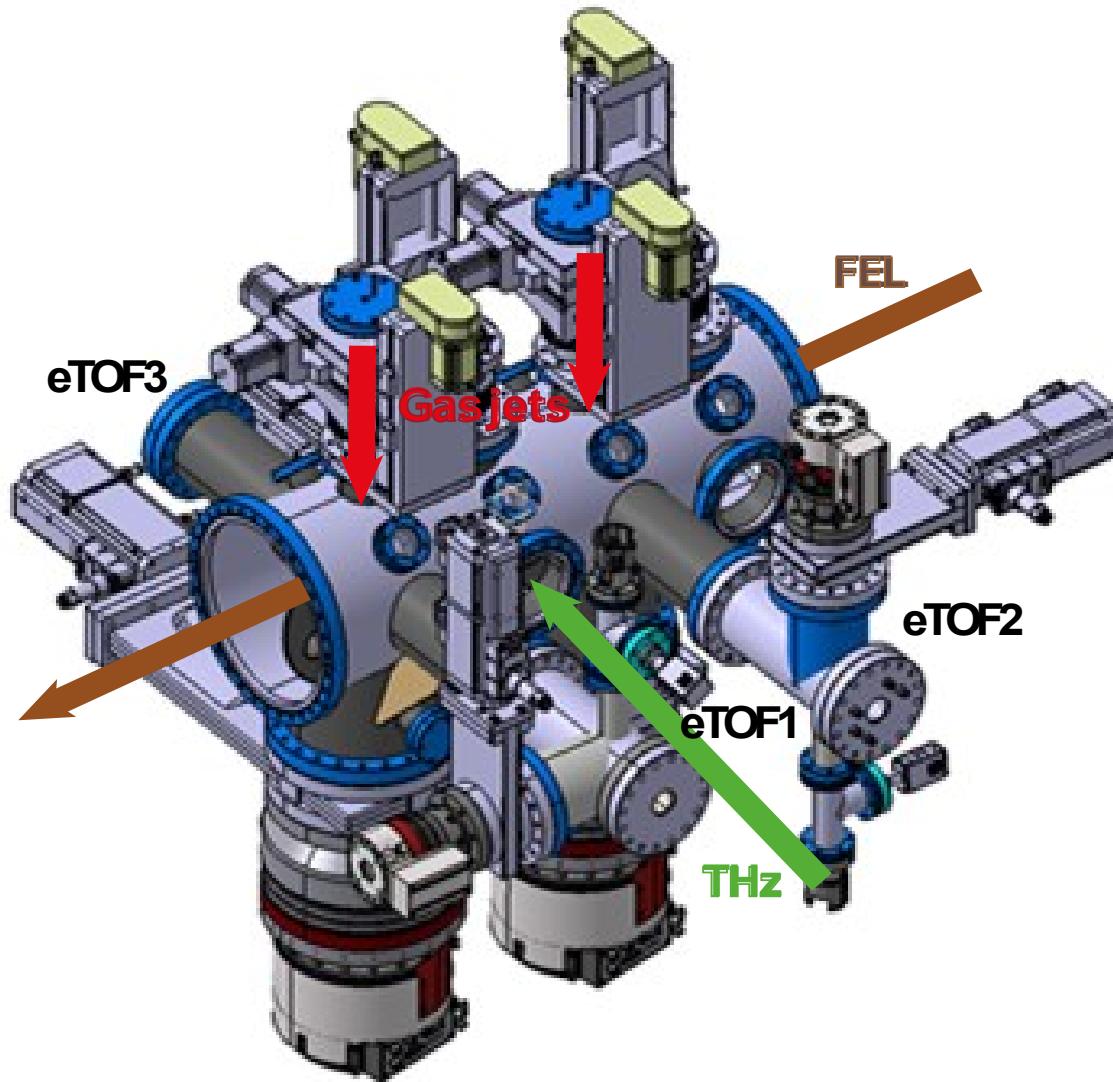
## Measurements with prototype PALM at SACLA hard X-ray FEL

- Used 5 keV, 6 keV, 7 keV, 8 keV, 9 keV, 10 keV 12.4 keV photon energies
- At most of the energies we measured with and without monochromator
- Experimental laser: 800 nm, ~7 mJ, 3-5% intensity jitter
- THz generated using LiNbO<sub>3</sub> crystal
- Frequency 0.52 THz, field strength 5MV/m
- Xenon pulses used for high photoionization cross-section

## Issues to address

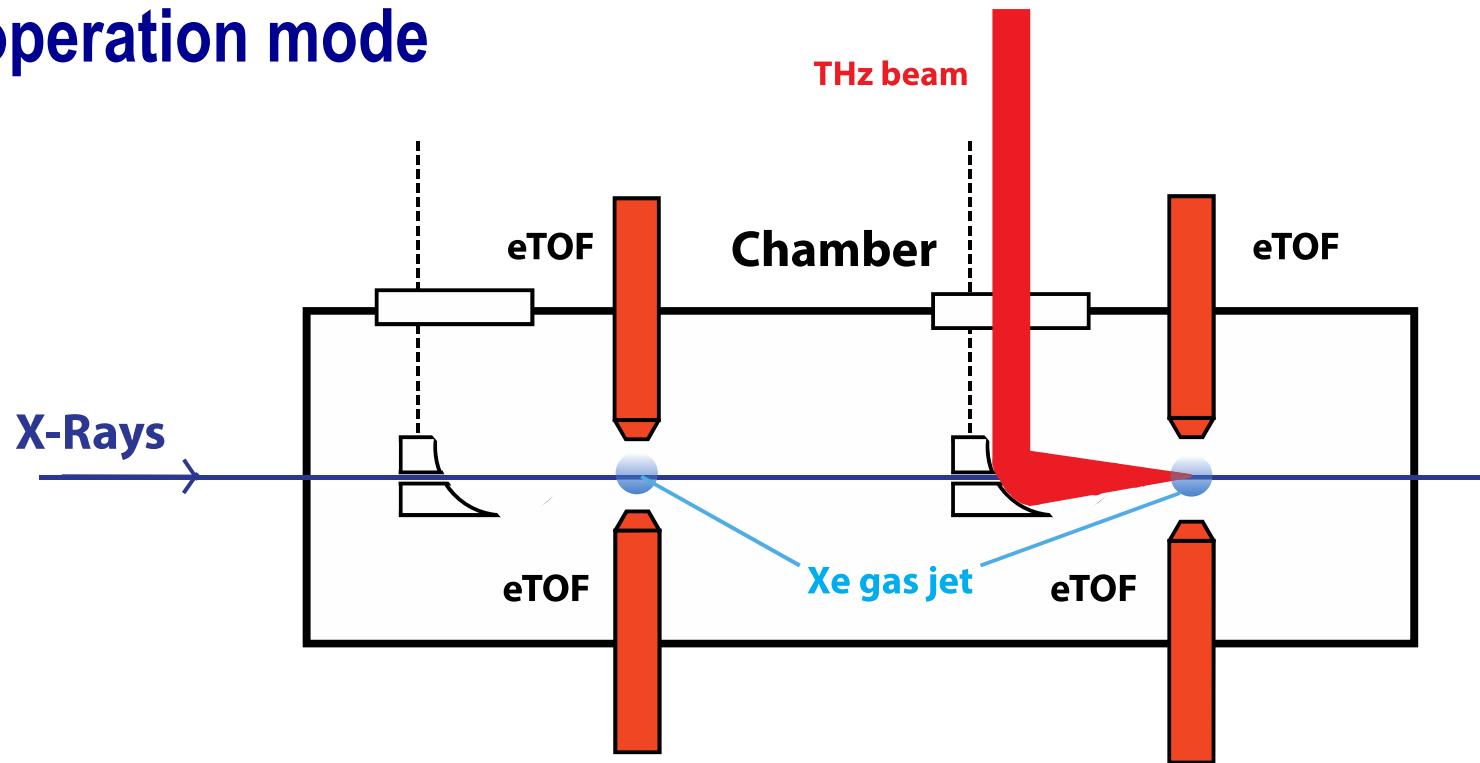
- Uncertainty caused by the shot-to-shot spectral width jitter of the photon pulses
- Improvement of stability of the generated THz beam
- Achieving higher efficiency of THz generation
- Estimation for Gouy phase shift effect in focused THz beam
- Handling large FEL arrival time jitter relative to the experimental laser
- Improving the measurement accuracy

# Next generation PALM



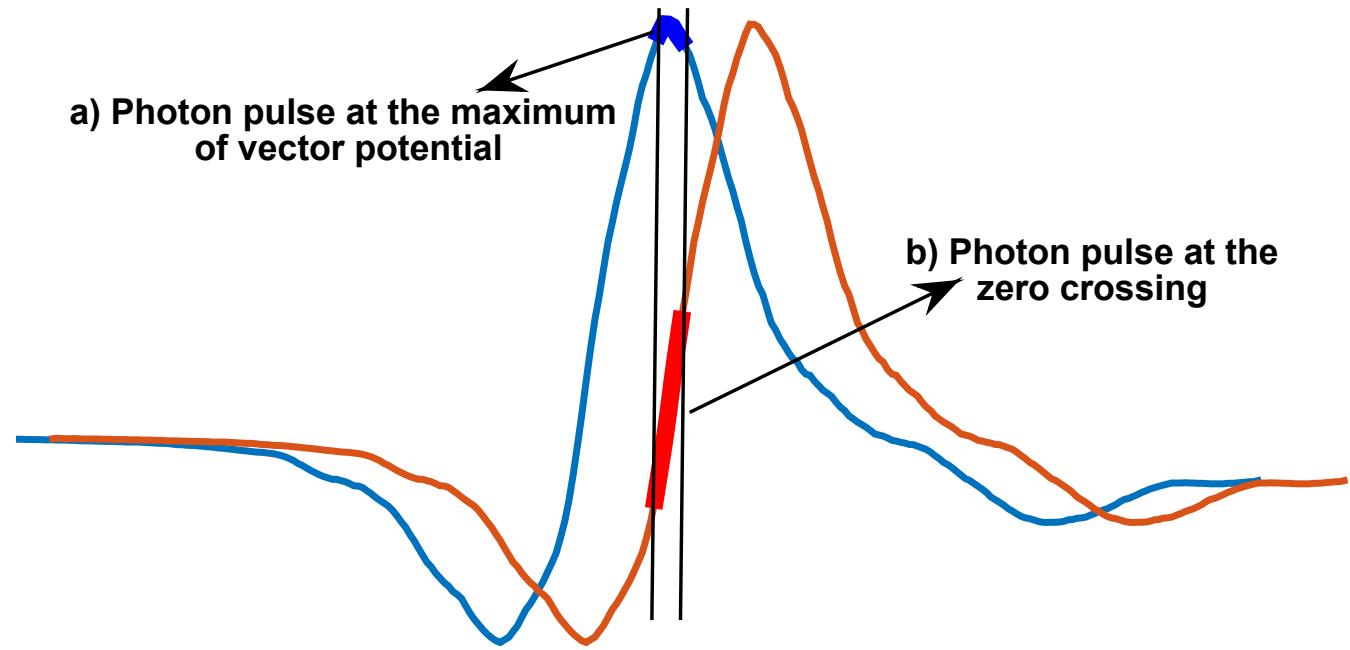
The new design allows more flexibility and measurements with improved accuracy

## Standard operation mode



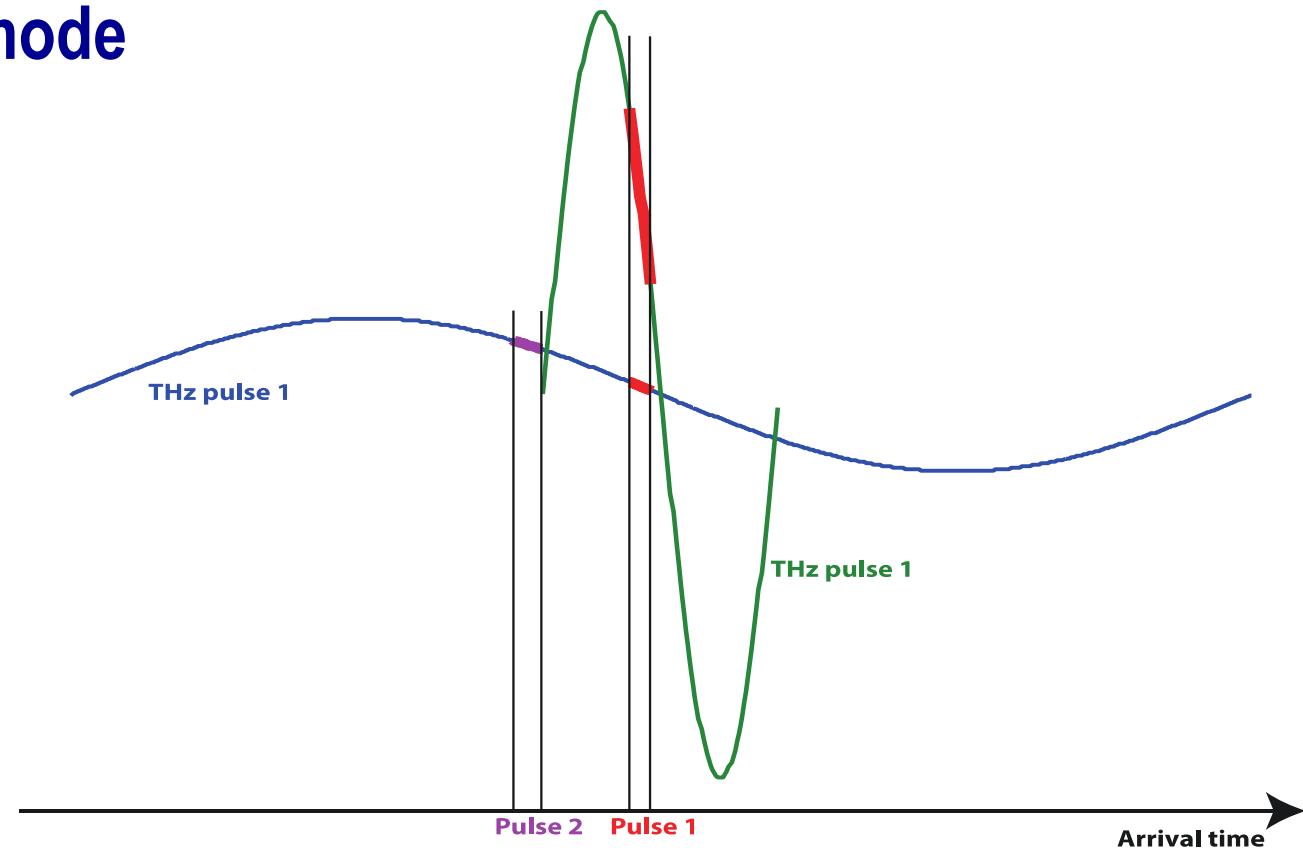
- The two interaction regions give the streaked and unstreaked electron spectra from the same FEL pulse
- This excludes the uncertainty induced by the spectral width jitter
- Measurements performed on single-shot basis

## Large dynamic range mode



- For FEL measurements with large arrival time jitter
- Two THz pulses are phase-shifted by  $90^\circ$  with respect to each other
- At least at one of the interaction regions the FEL is measured with high accuracy
- Third interaction region is required or for the single-shot measurements

## High resolution mode



- Low-frequency weak-field THz pulse gives the rough arrival time of FEL
- FEL pulses arriving at the linear part of high-frequency strong-field THz pulse are measured with high resolution
- Not all FEL pulses can be measured in this mode

- **PALM developed at PSI for FEL pulse measurements**
- **Prototype setup is tested at SACLÀ with hard X-ray FEL**
- **Successful measurements already proved the concept**
- **Next generation PALM is designed based on the first results**
- **Higher resolution is expected with the new design**
- **Flexible design allows different measurement modes**

# Acknowledgments

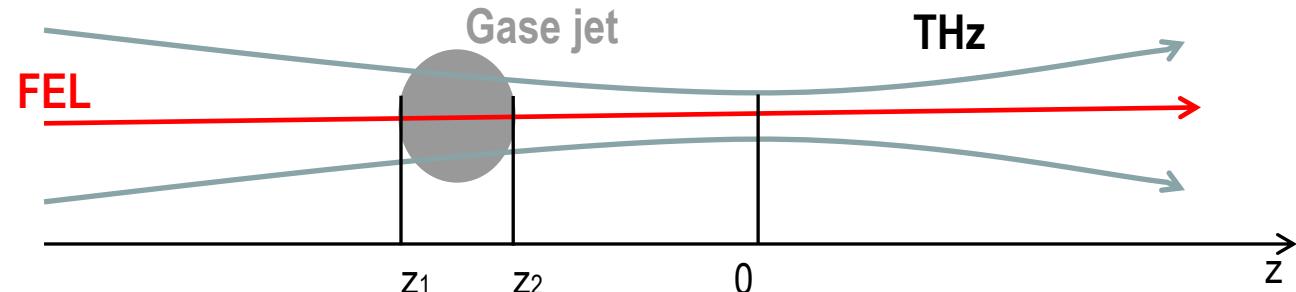
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Rosen Ivanov  
Jia Liu  
Rafael Abela  
Leonid Rivkin



Thank you for  
attention

## Gouy phase shift

$$\varphi_G = - \tan^{-1} \frac{z}{z_R}$$



$z_R$  Rayleigh length

Gouy phase shift effect on the FEL pulse length measurement

$$\tau_{FEL,G}^2 = \tau_{FEL}^2 + \sigma_{g,t}^2$$

Here  $\sigma_{g,t}$  is the gas jet rms duration

The gas jet transverse size  $G(z) = \exp\left(-\frac{(z-z_0)^2}{2\sigma_{g,z}^2}\right)$

Phase shift along the gas  $\Delta\varphi_G = - \tan^{-1} \frac{z_2 - z_1}{z_R}$  const  $\sigma_{g,z}$

Contribution to the pulse length  $\sigma_{g,t} = \Delta\varphi_G / \omega_{THz}$  where  $\omega_{THz}$  is THz frequency