

## Pulsed DC acceleration

***Citation for published version (APA):***

Brussaard, G. J. H. (2006). *Pulsed DC acceleration*. conference; Waldur Symposium 2006 'Pulsed Power'; 2006-05-30; 2006-05-30.

***Document status and date:***

Published: 01/01/2006

***Document Version:***

Publisher's PDF, also known as Version of Record (includes final page, issue and volume numbers)

***Please check the document version of this publication:***

- A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
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# Pulsed DC Acceleration

Seth Brussaard

Waldur Symposium 2006 'Pulsed Power'

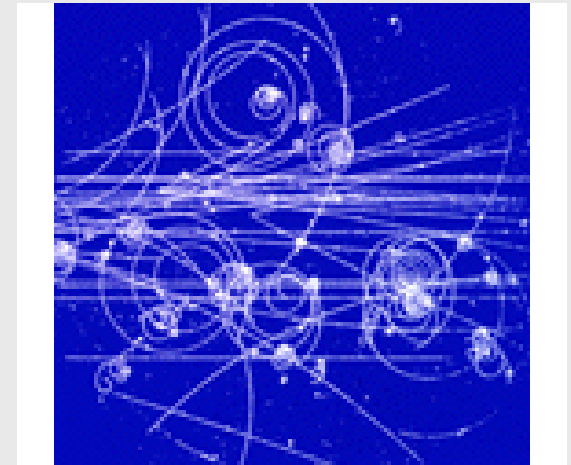
# Outline

Accelerators

The Future of Accelerators

Pulsed DC Acceleration

## CERN

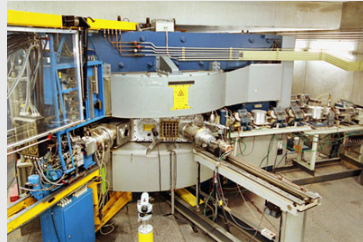


## Accelerators



CRT

10 keV



Cyclotron

10 MeV

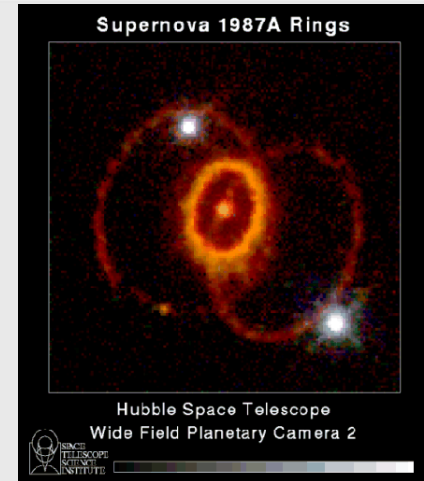


Synchrotron

10 GeV

Collider

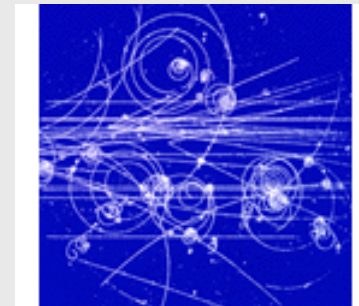
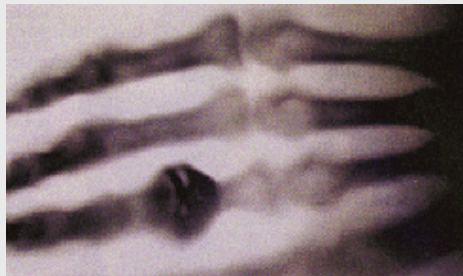
10 TeV



Supernova 1987A Rings

Hubble Space Telescope  
Wide Field Planetary Camera 2

Supernova



## Future Accelerators

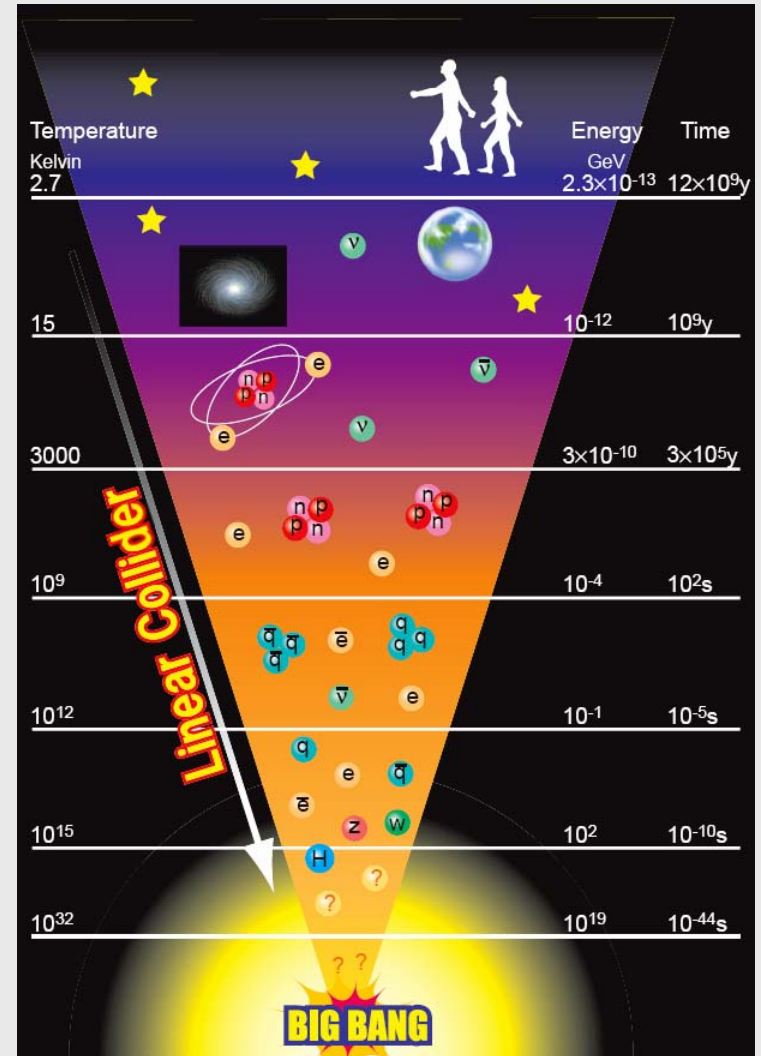
ILC: International Linear Collider

XFEL: X-ray Free Electron Laser

## ILC: International Linear Collider

P.Grannis, Michigan State

ILC →



## ILC: International Linear Collider

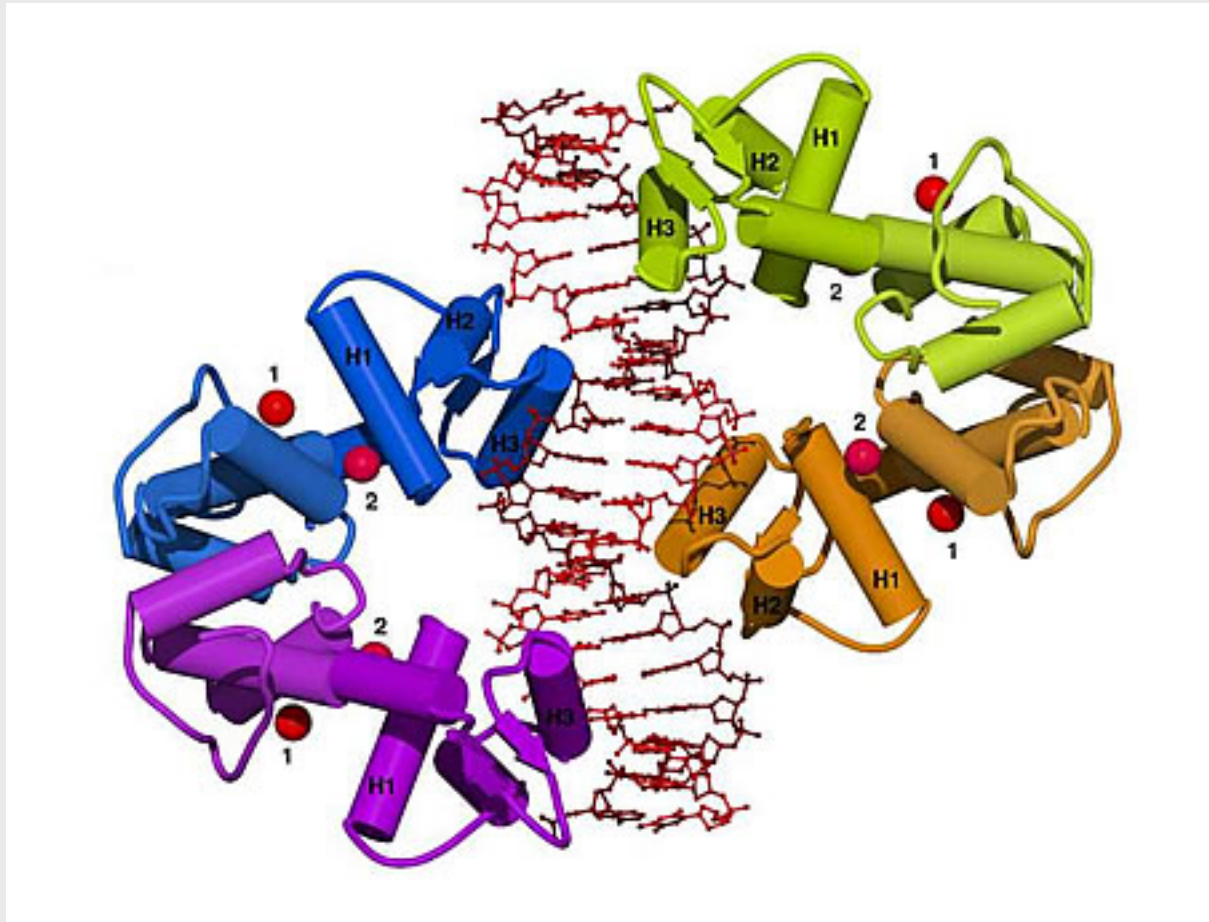
## Superconducting RF Cavities



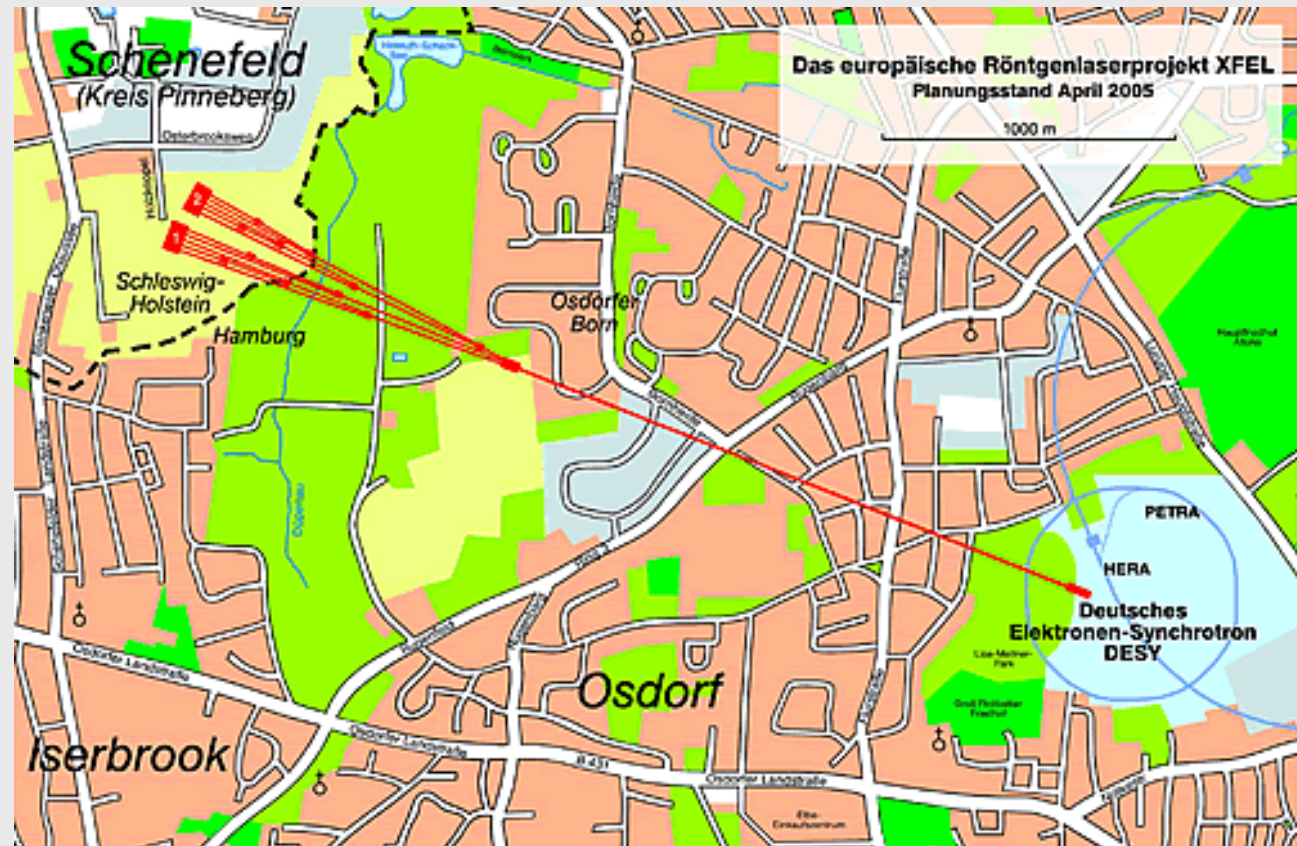
**High Gradient Accelerator  
35 MV/meter -- 40 km linear collider**



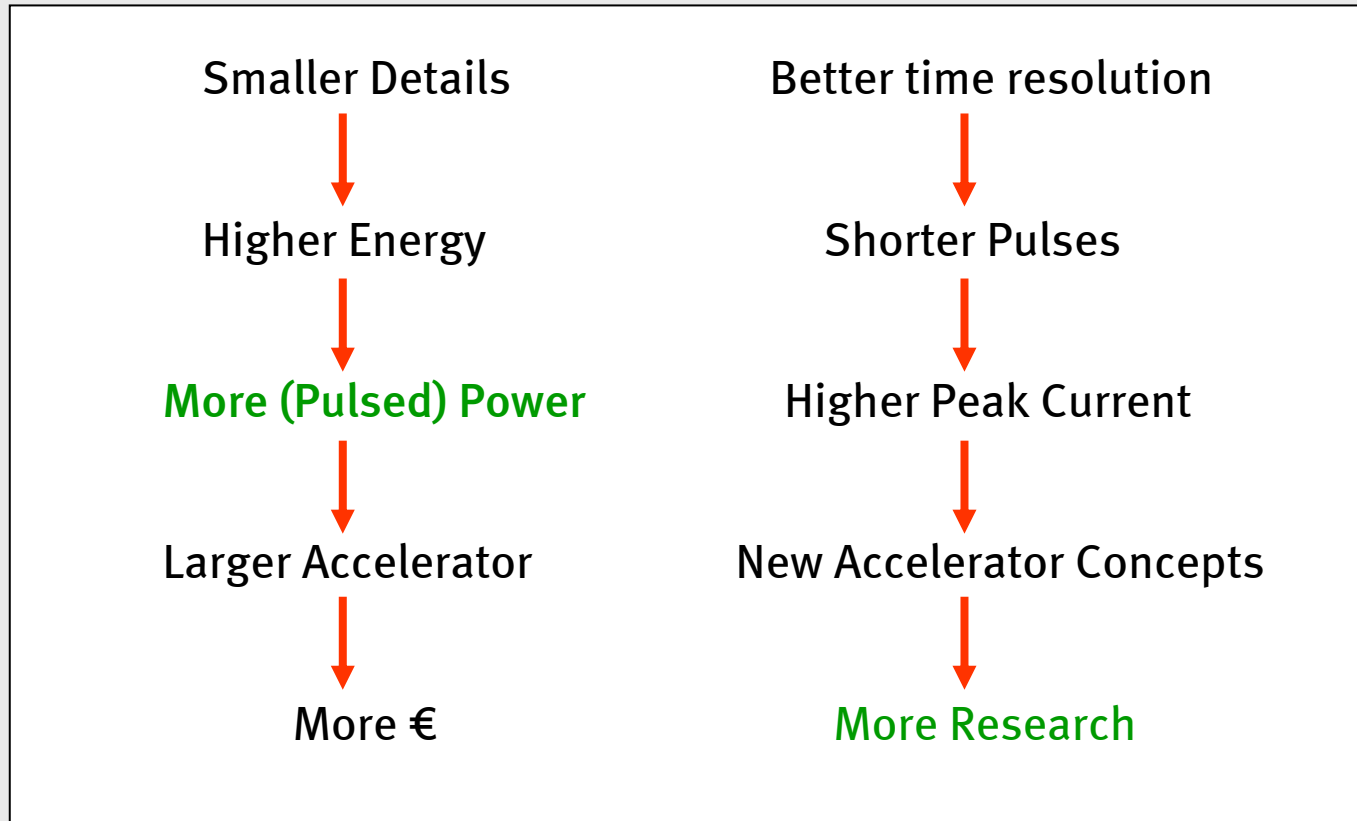
## XFEL: X-Ray Laser



## XFEL: X-Ray Laser



## Scaling Laws



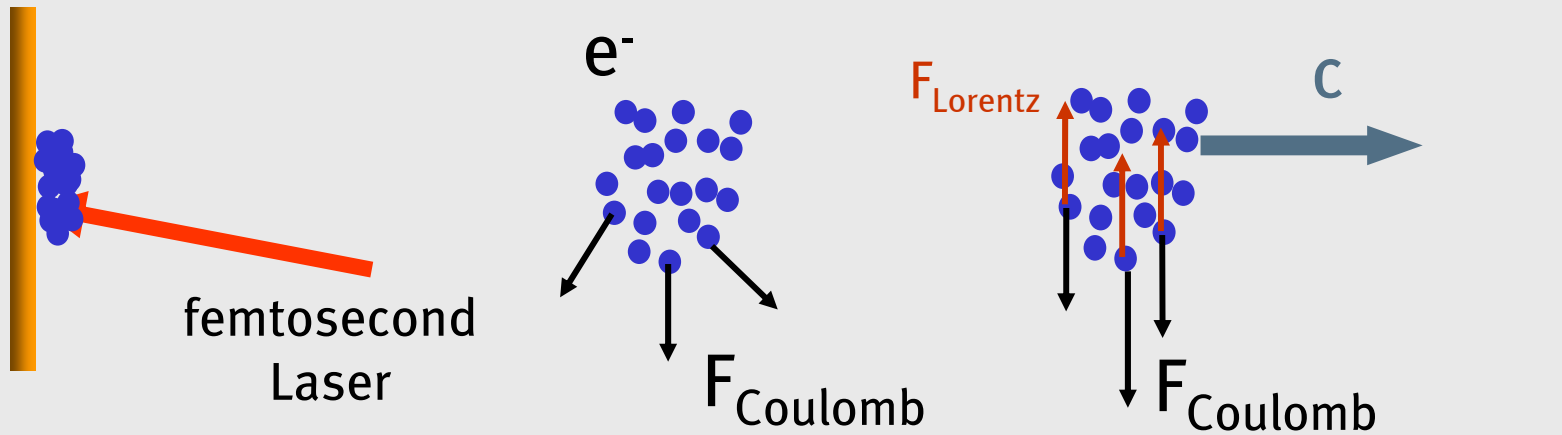
## Challenges for Future Accelerators

Shorter Bunches

with

More Electrons

## Brightness



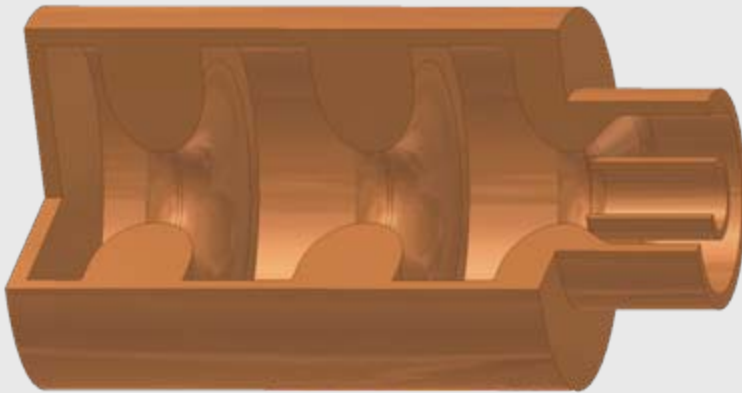
## Getting to the speed of light fast

Electron Rest Mass: 0.511 MeV

Accelerate to a few MeV

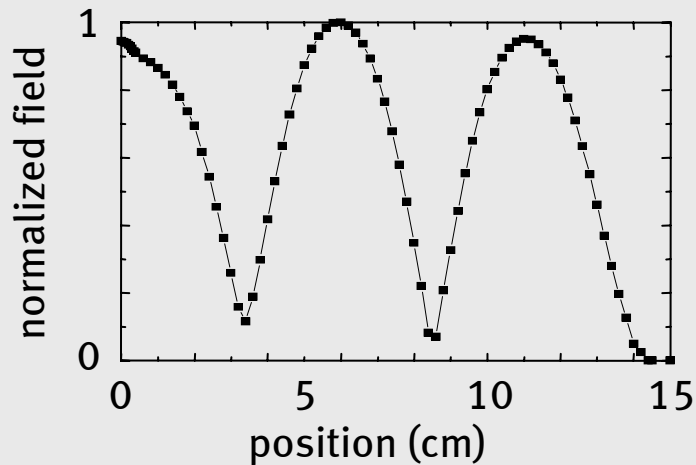
over a short distance

## TU/e Photoinjector



Total power	10 MW
Frequency	2998 MHz
Q	(2×) 7200

Maximum output energy: 6.9 MeV  
Cathode field at max energy: <100 MV/m  
Launch phase:  $-50^\circ$



## Getting to the speed of light fast

Electron Rest Mass: 0.511 MeV

Accelerate to a few MeV

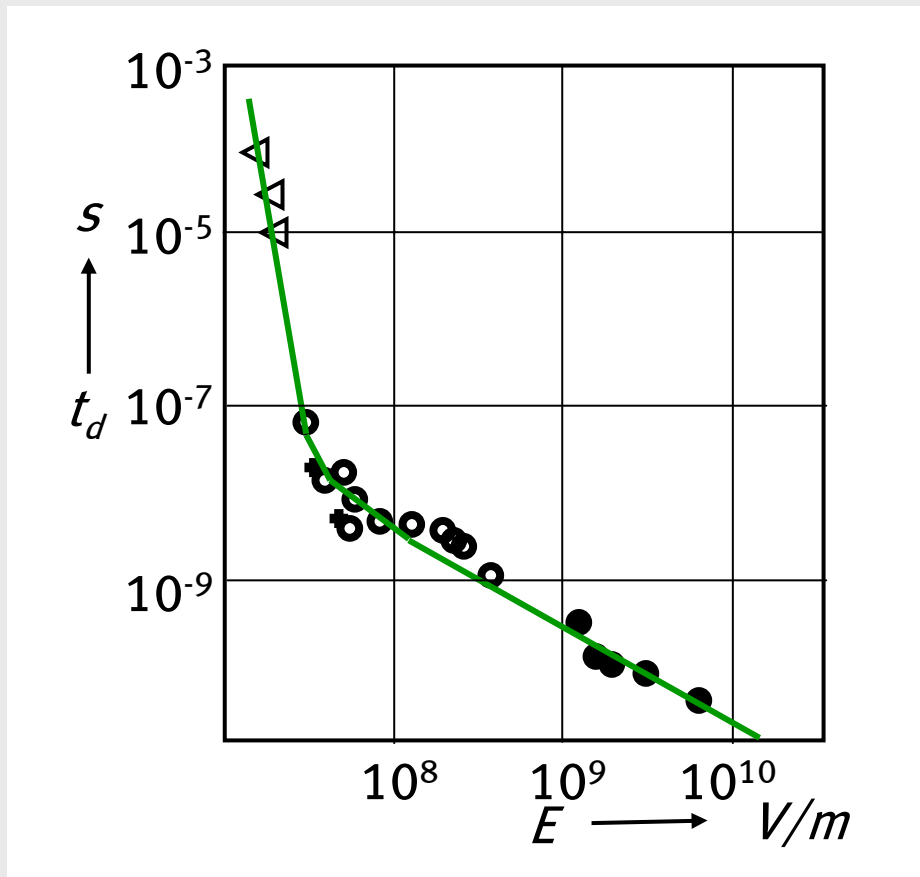
over a **shorter** distance



## Breakdown



## Breakdown needs time



A. Emelyanov

## Pulsed DC Acceleration

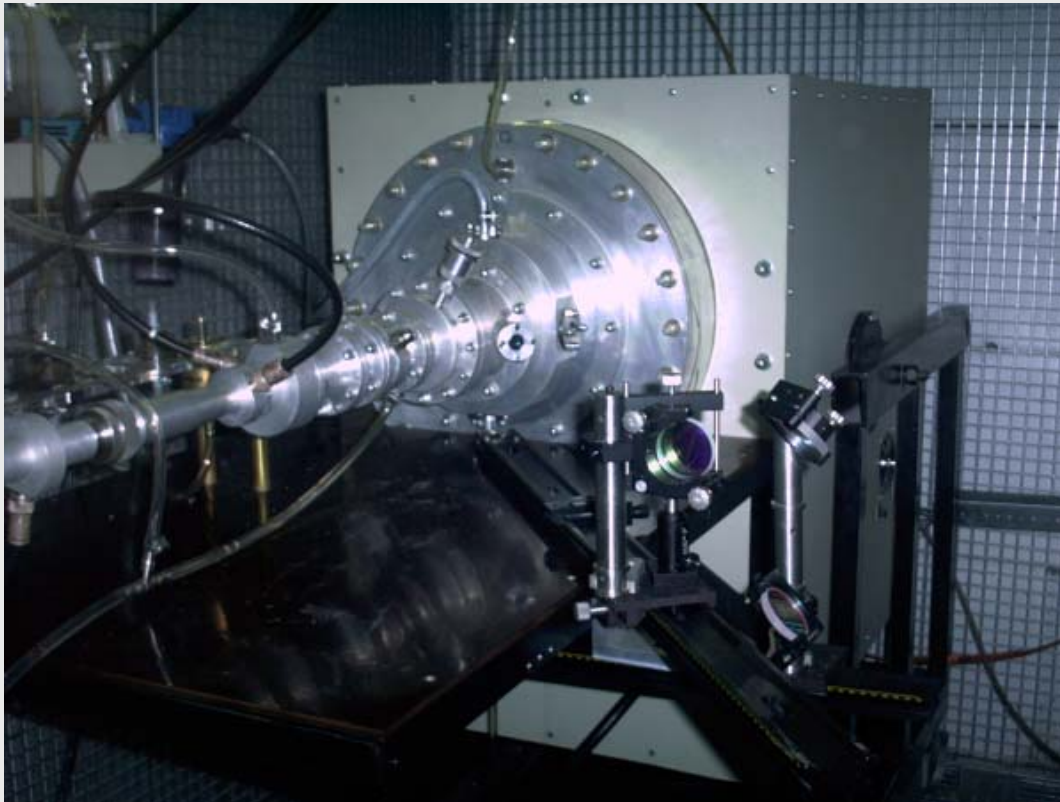
Make MegaVolt pulses

that are shorter than 1 nanosecond

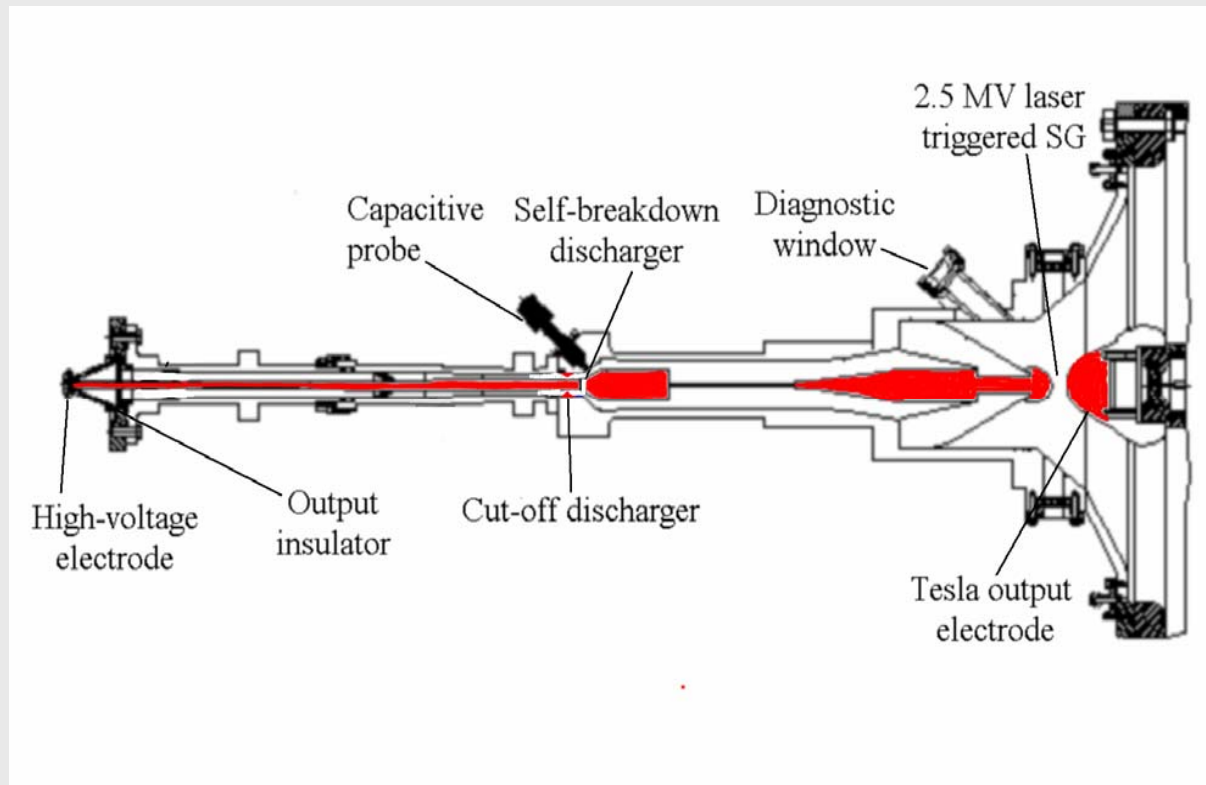
## Megavolt Pulser



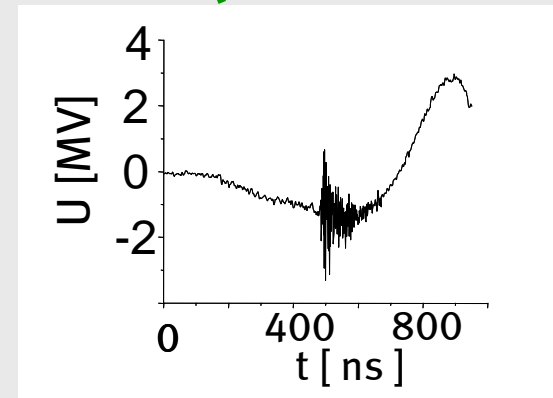
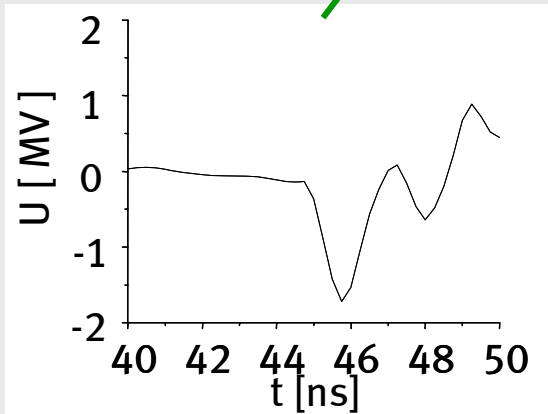
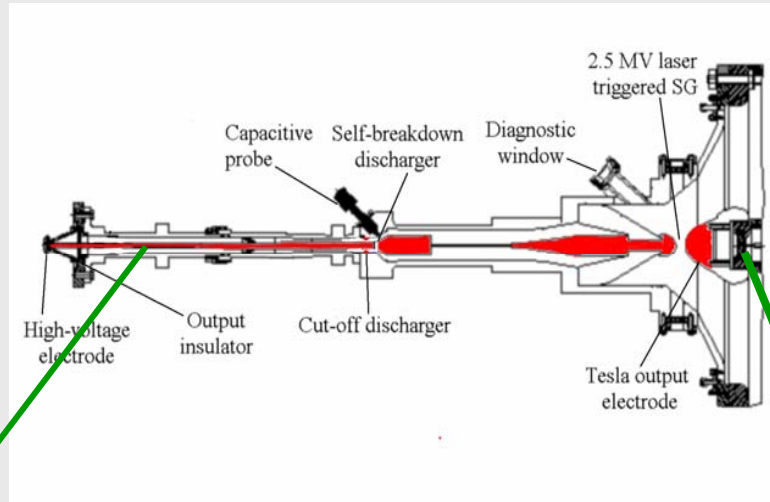
## Megavolt Pulser



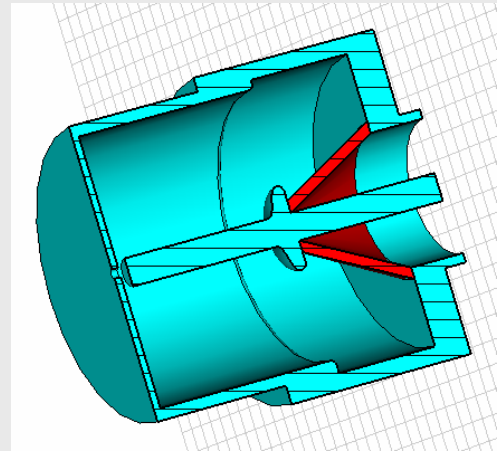
## Pulse Forming Line



## Pulse Forming Line



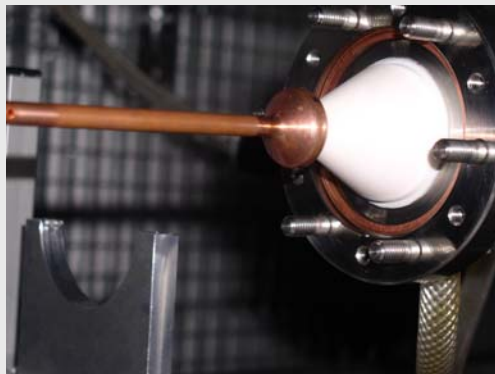
## Vacuum Diode



3.5 MV pulses  
3 mm Acceleration Gap

> 1 GV/m

Cathode

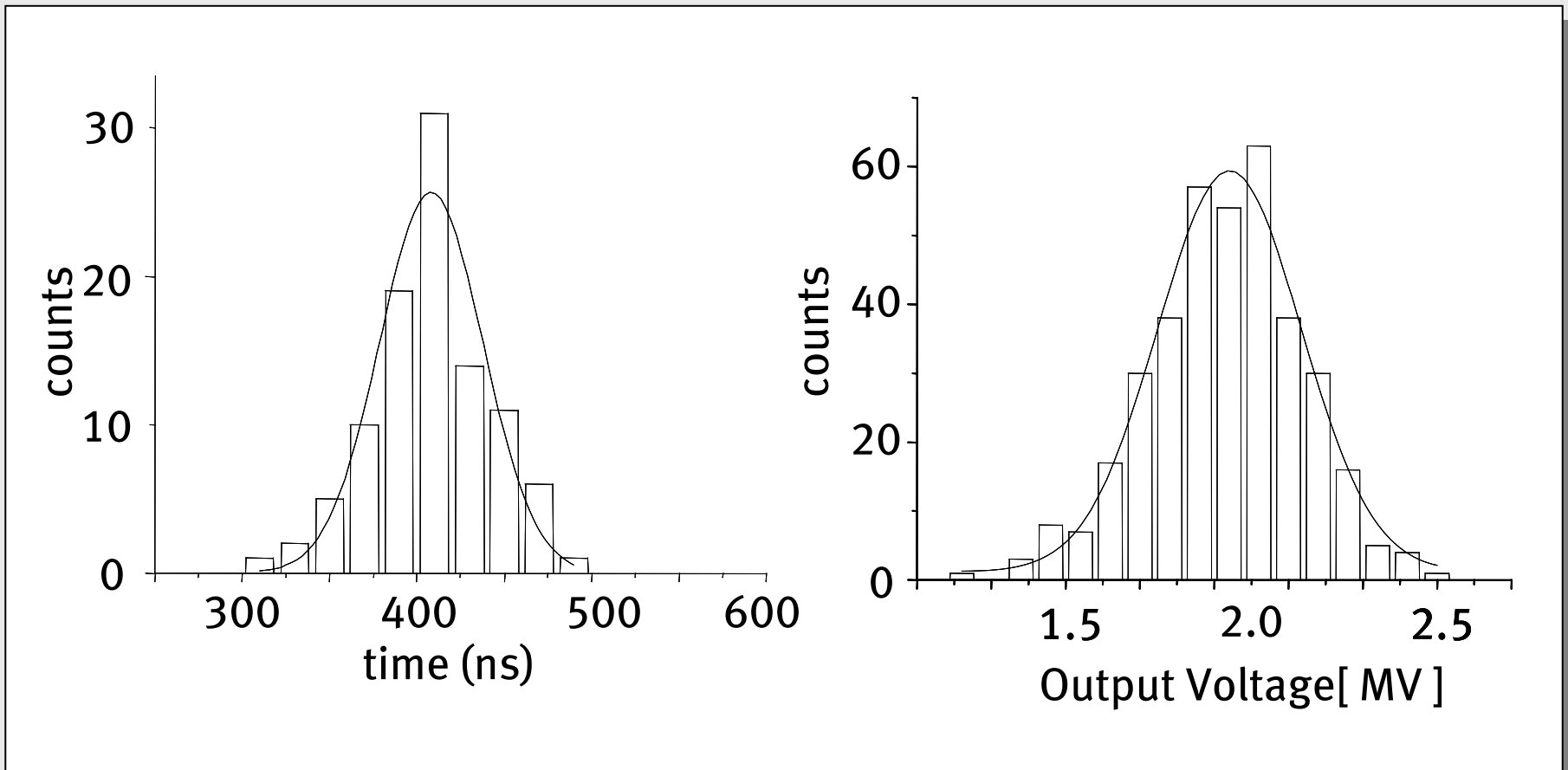


Anode

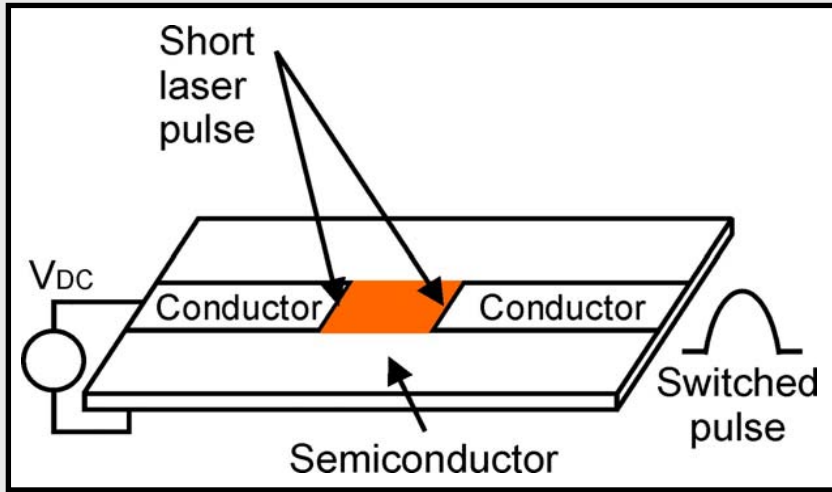




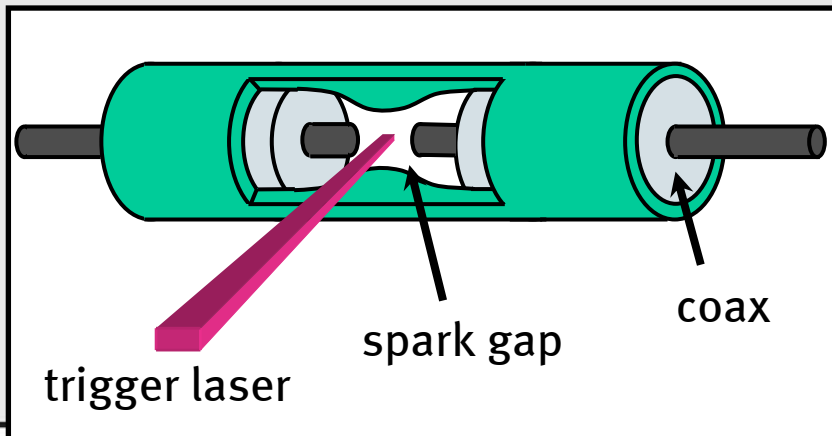
## Jitter



## Semiconductor switch vs laser triggered spark gap

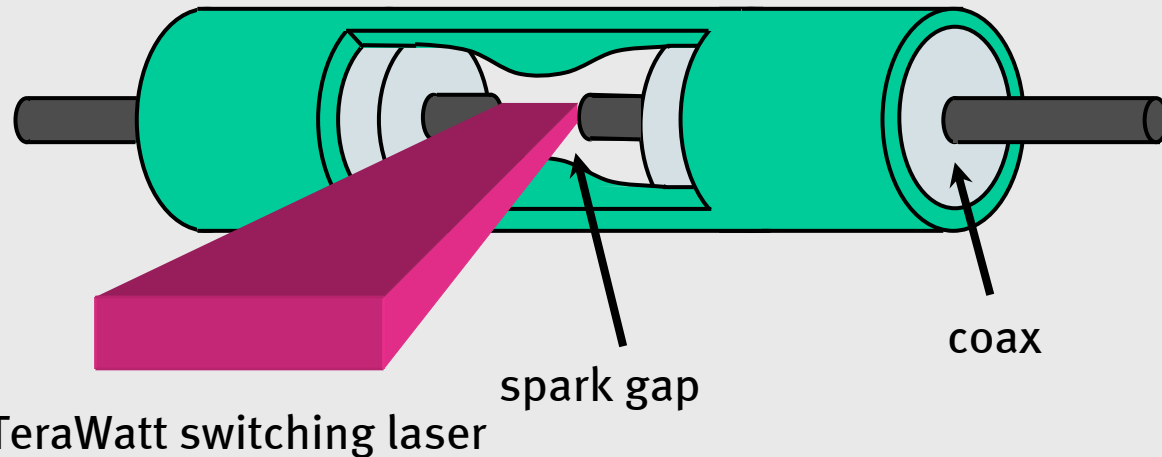


- 😊 Fast (ps rise time)
- 😊 Almost no time jitter
- 😞 No recovery after breakdown
- 😞 Limited to 'low' power



- 😊 High voltages, high currents
- 😊 Good recovery after breakdown
- 😞 Slow (sub-ns rise time)
- 😞 Large time jitter due to stochastic breakdown processes

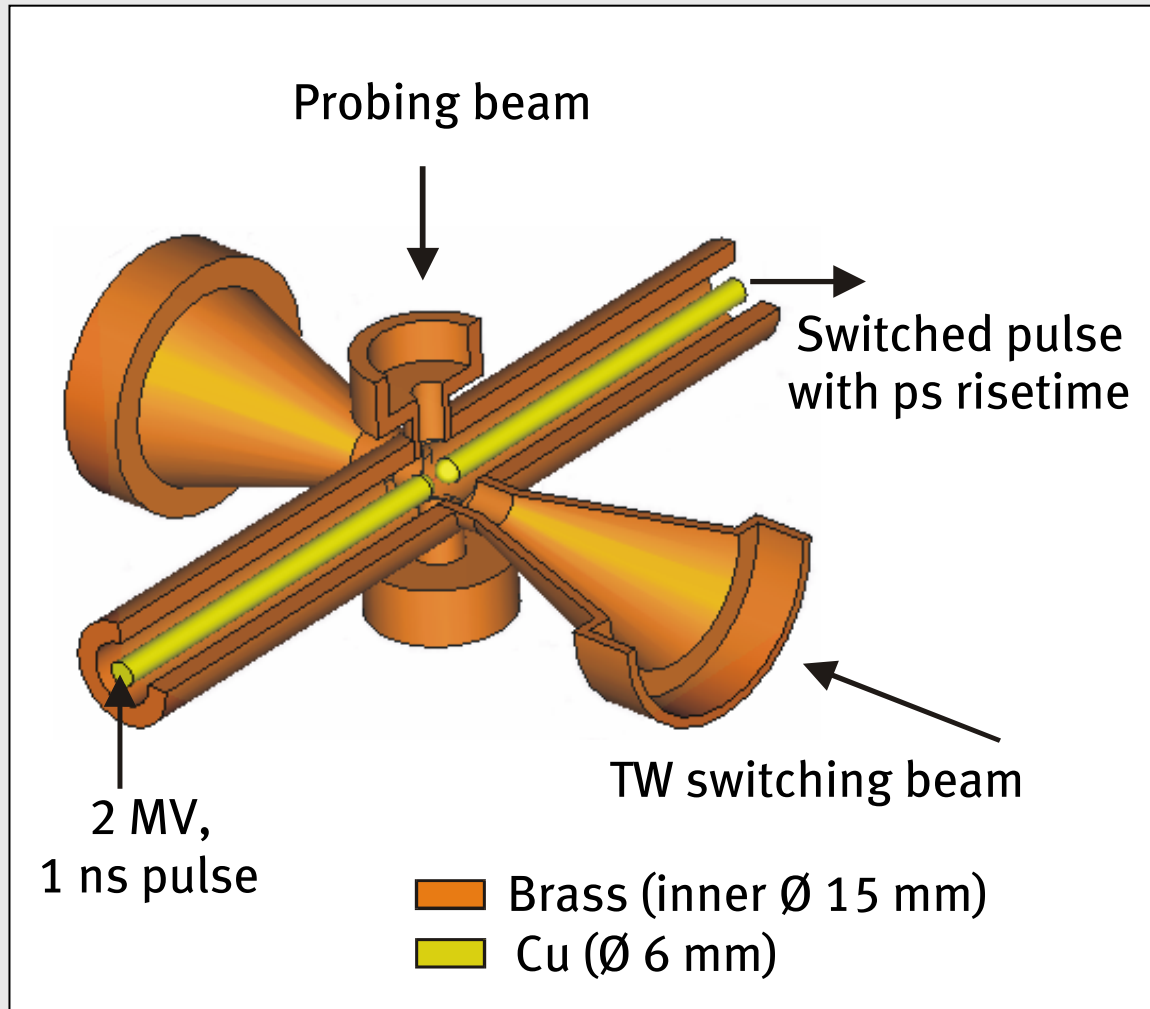
## Photoconductive switching of a spark gap



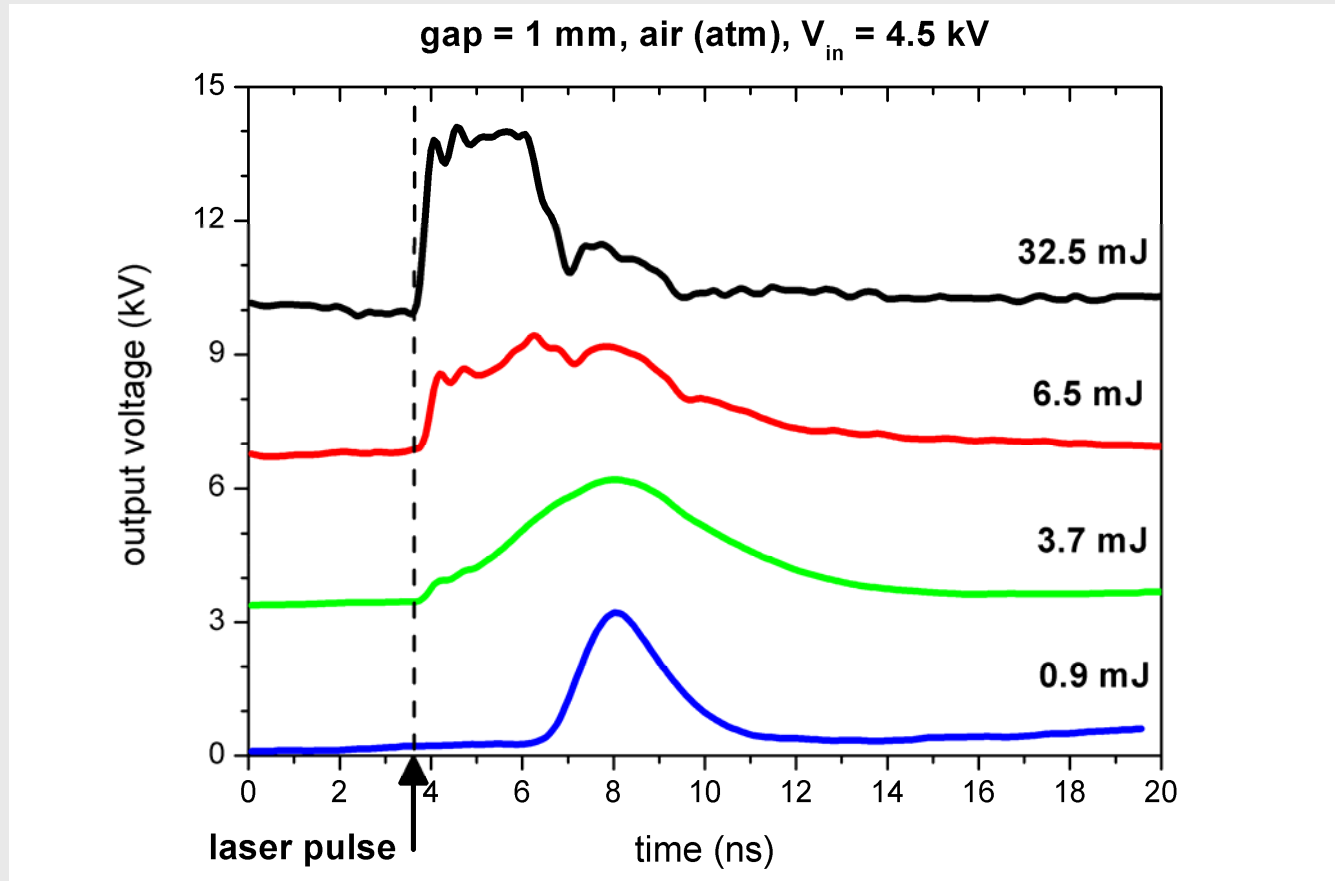
Ionization of the complete gap with high power fs laser

- 😊 High voltages, high currents
- 😊 Fast switching by fs laser (ps rise time)
- 😊 Almost no jitter (no stochastic breakdown processes)

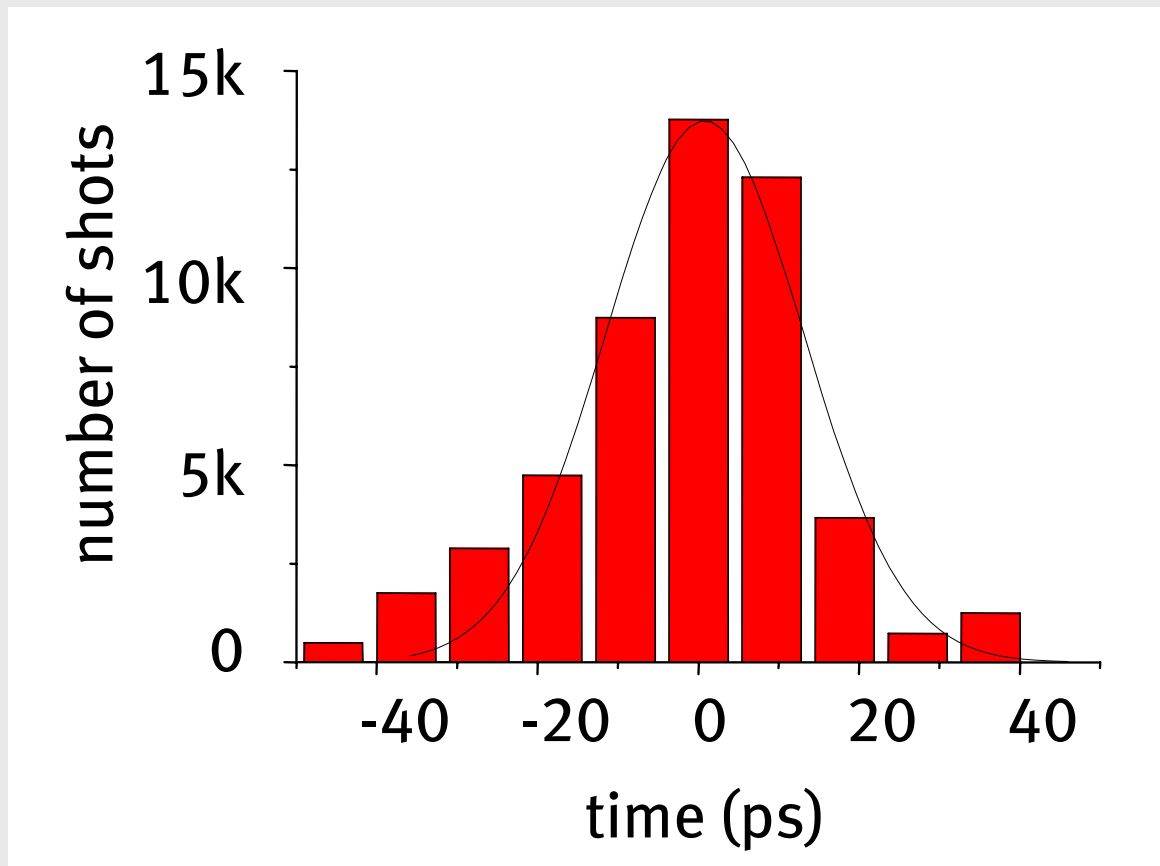
## Photoconductive switching spark gap setup



## switched pulses @ different laser energies



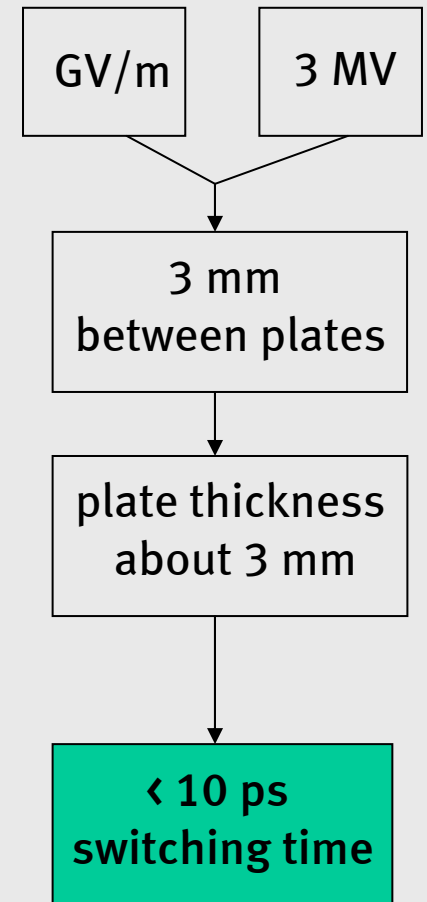
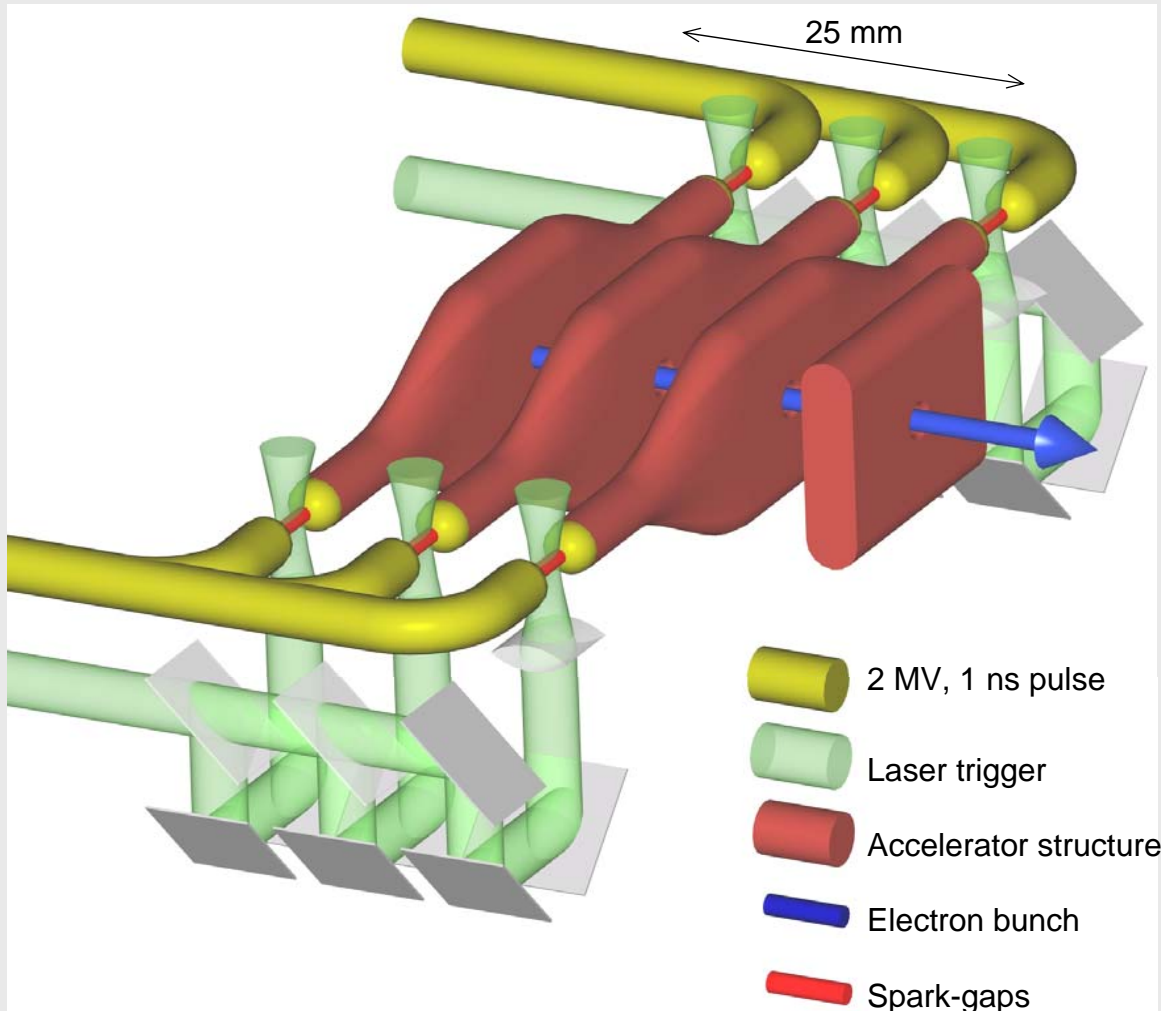
jitter:  $\sigma = 12$  ps



## Summary of Results

- 2 MV, 1 ns pulses produced by Tesla Transformer with Pulse Forming Line
- Jitter 20-70 ns
- Photoconductive Spark Gap Switch demonstrated at 5 kV
- Jitter < 10-15 ps

## 'Artistic' impression of a multistage accelerator





## Conclusions

For Future Accelerators:

More Pulsed Power

Better Pulsed Power