Pulsed DC acceleration

Pulsed DC Acceleration

Seth Brussaard

Waldur Symposium 2006 ‘Pulsed Power’

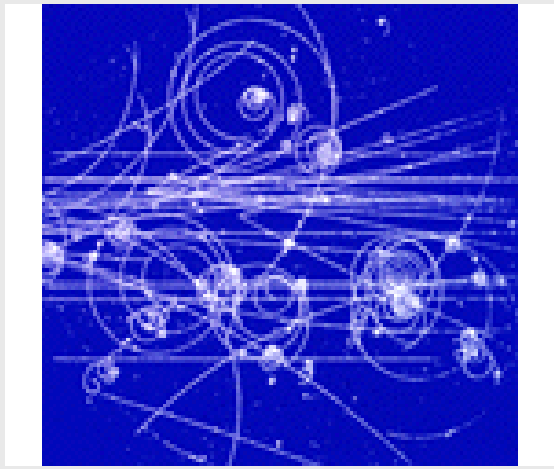
Outline

Accelerators

The Future of Accelerators

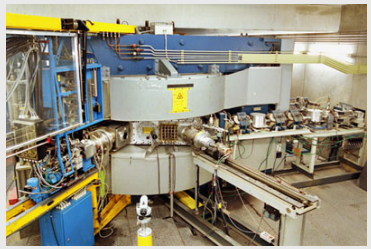
Pulsed DC Acceleration

CERN



Accelerators

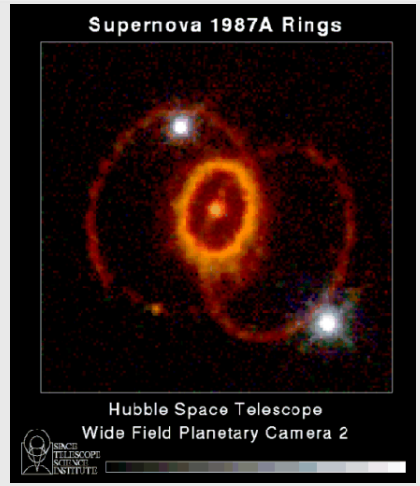
CRT



Cyclotron

Synchrotron

Collider



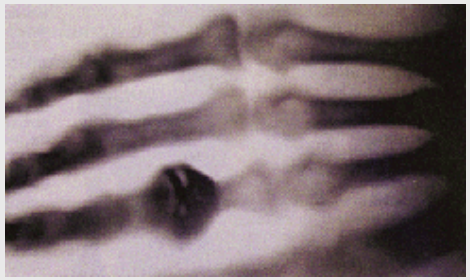
Supernova

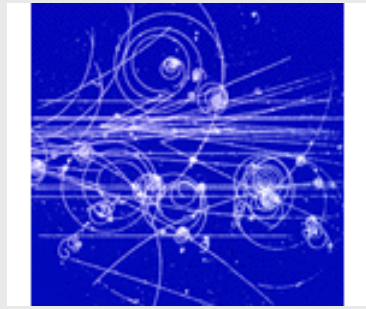
10 keV

10 MeV

10 GeV

10 TeV





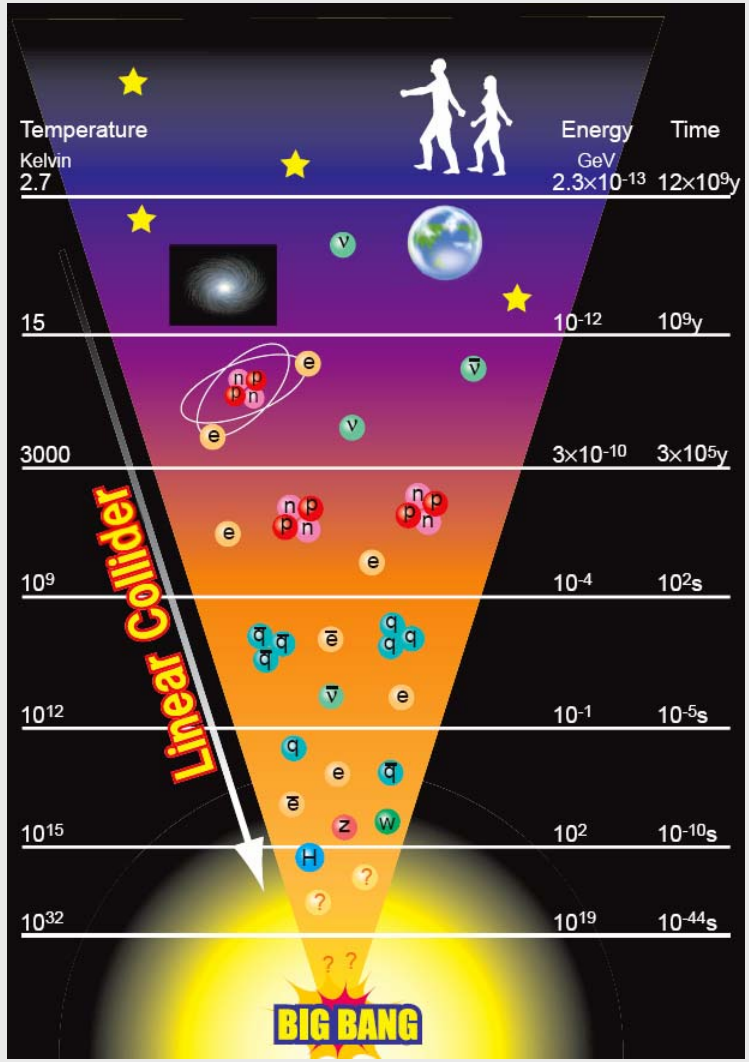
Future Accelerators

ILC: International Linear Collider

XFEL: X-ray Free Electron Laser

ILC: International Linear Collider

P.Grannis, Michigan State



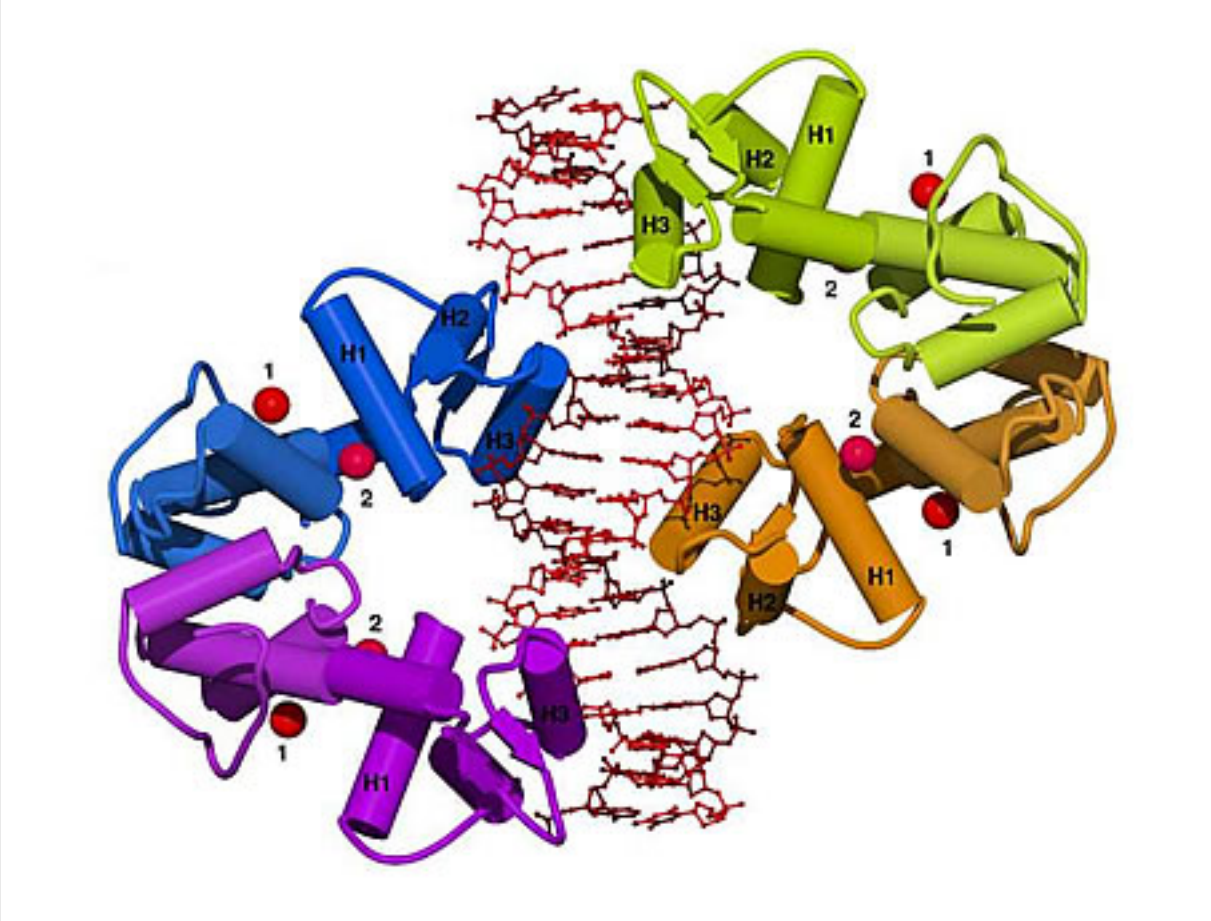
ILC →

ILC: International Linear Collider

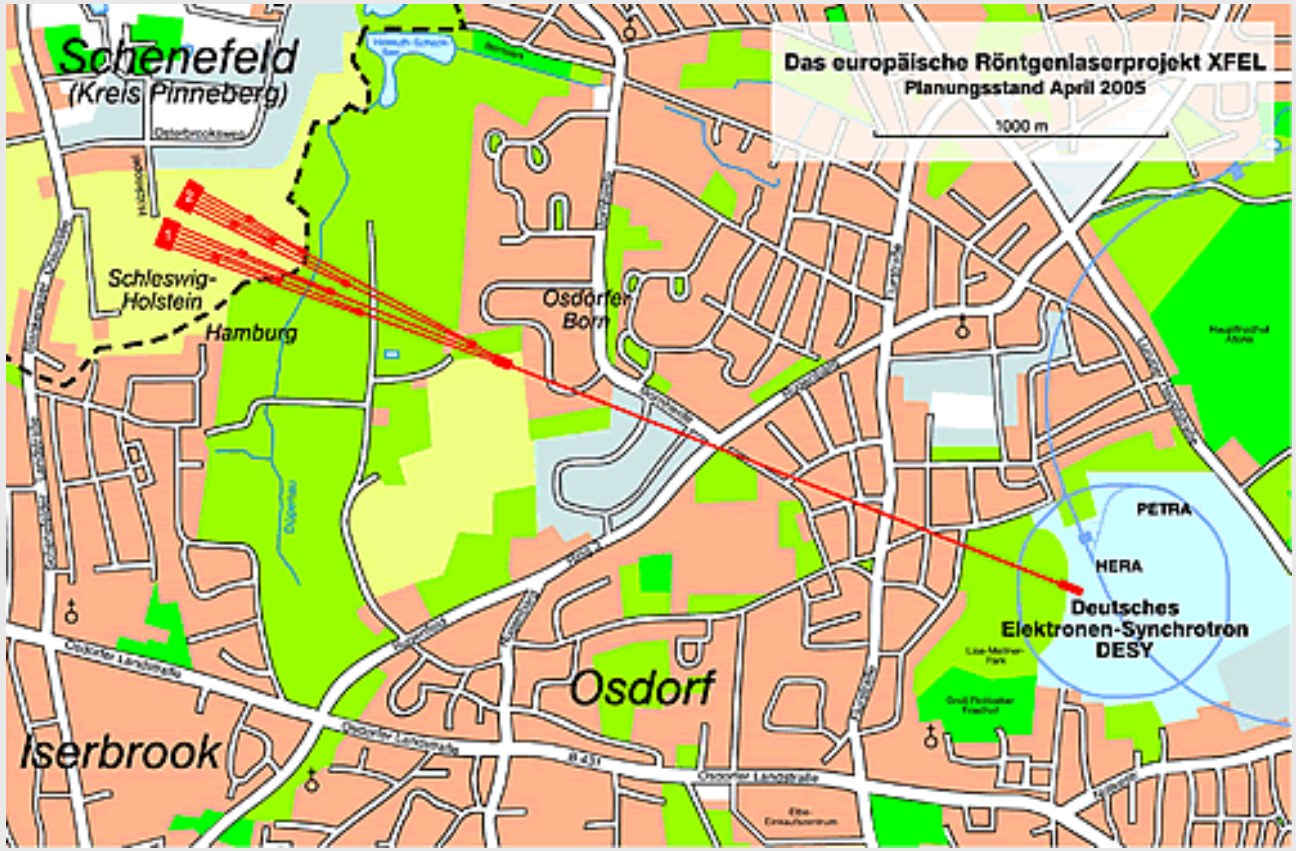
Superconducting RF Cavities

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

XFEL: X-Ray Laser



XFEL: X-Ray Laser



Scaling Laws

Smaller Details	Better time resolution
↓	↓
Higher Energy	Shorter Pulses
↓	↓
More (Pulsed) Power	Higher Peak Current
↓	↓
Larger Accelerator	New Accelerator Concepts
↓	↓
More €	More Research

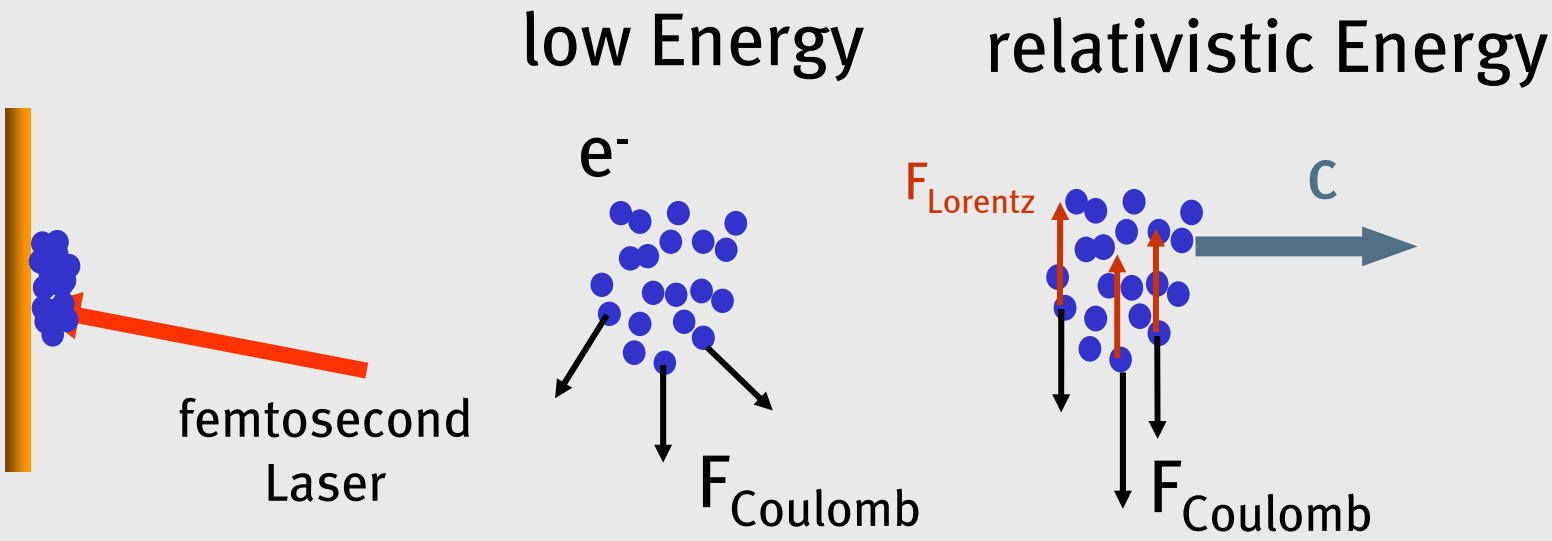
Challenges for Future Accelerators

Shorter Bunches

with

More Electrons

Brightness


low Energy
relativistic Energy
e-
femtosecond
Laser
F Coulomb
F Lorentz
c
F Coulomb

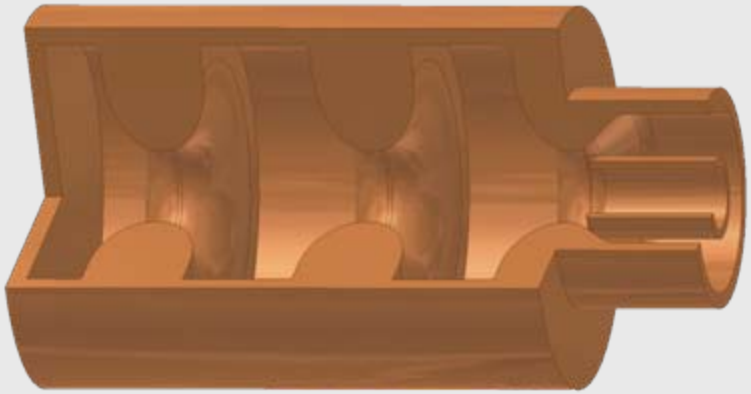
Getting to the speed of light fast

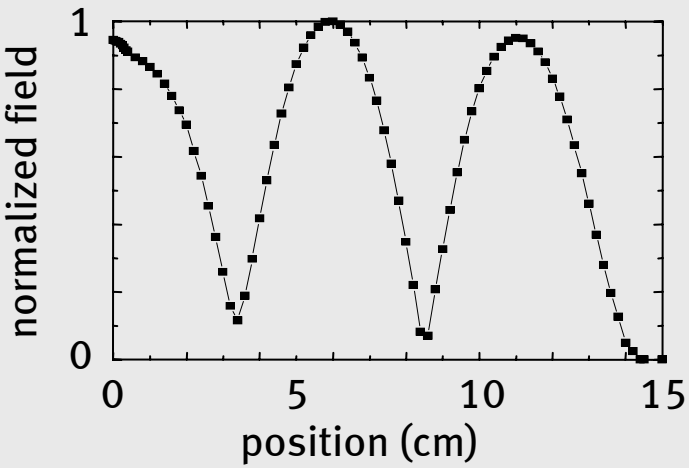
Electron Rest Mass: 0.511 MeV

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°

Getting to the speed of light fast

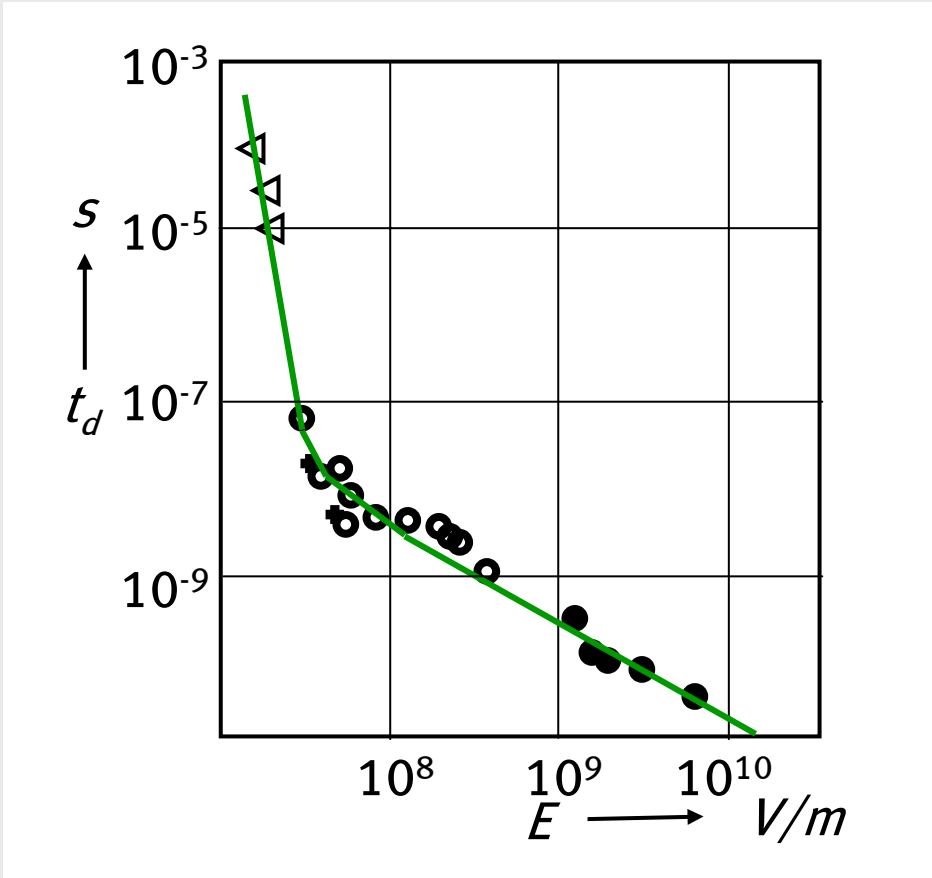
Electron Rest Mass: 0.511 MeV

Accelerate to a few MeV

over a shorter distance

Breakdown

Breakdown needs time



A. Emelyanov

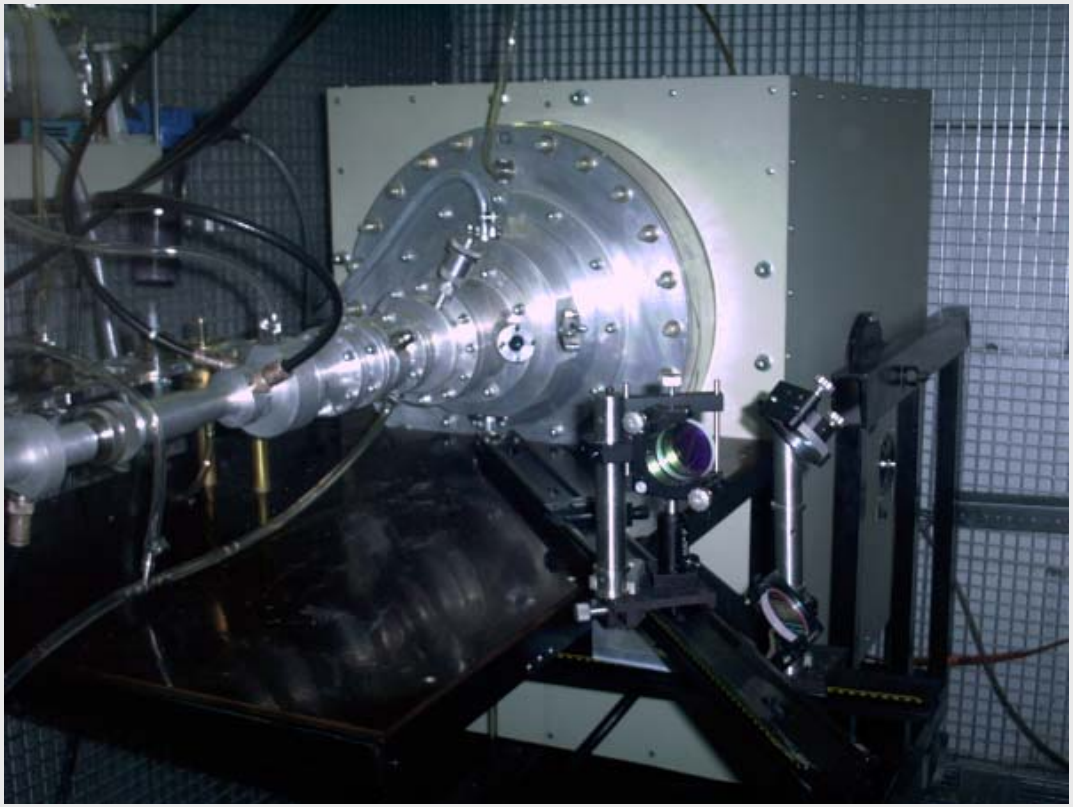
Pulsed DC Acceleration

Make MegaVolt pulses

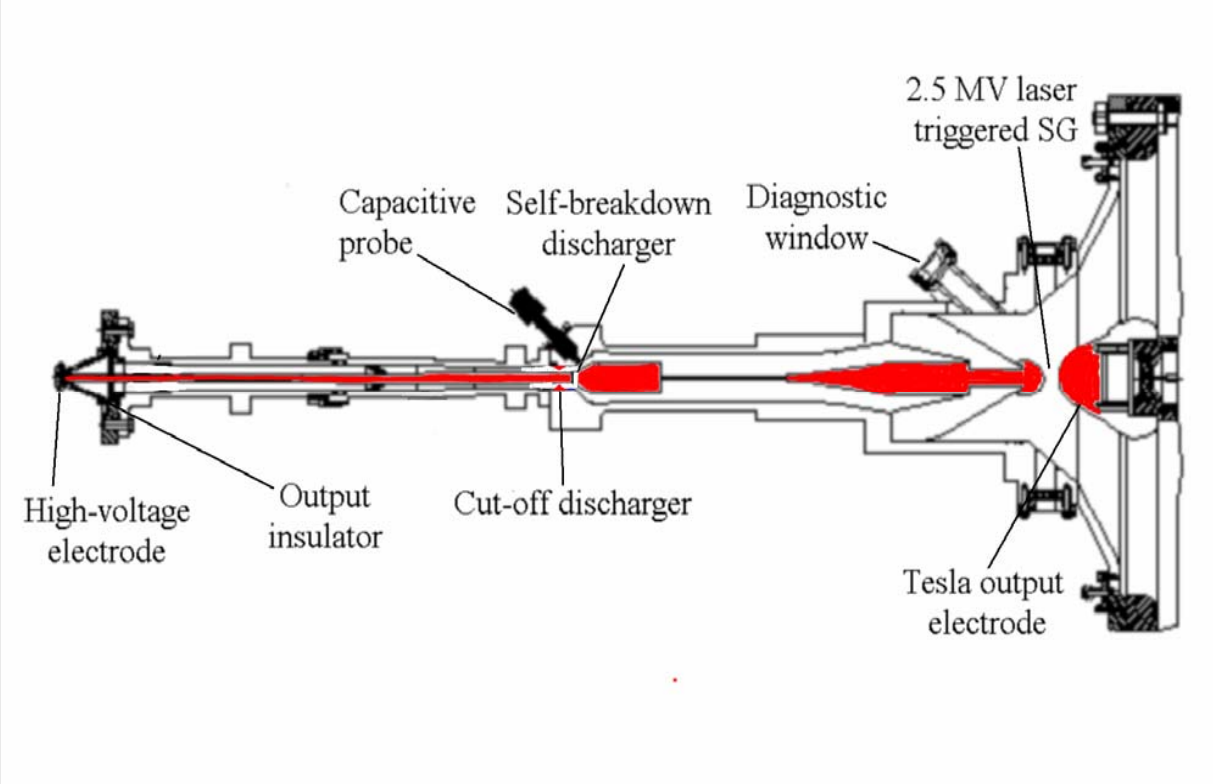
that are shorter than 1 nanosecond

Megavolt Pulser

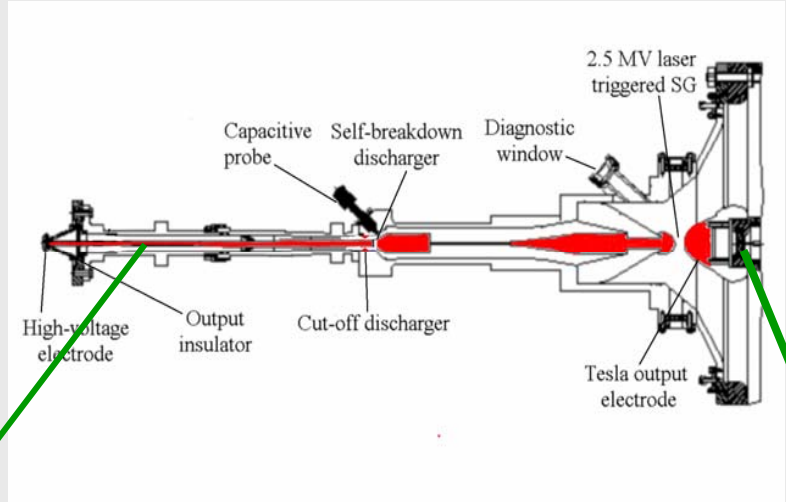
Megavolt Pulser

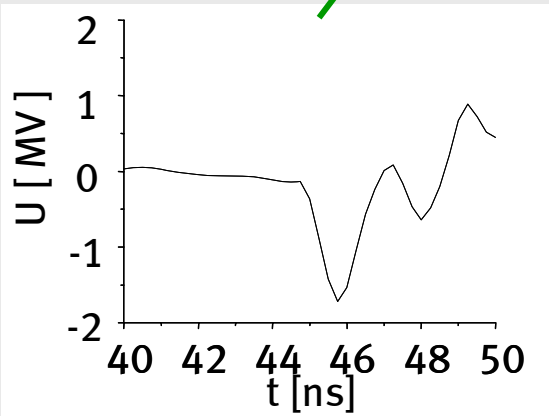


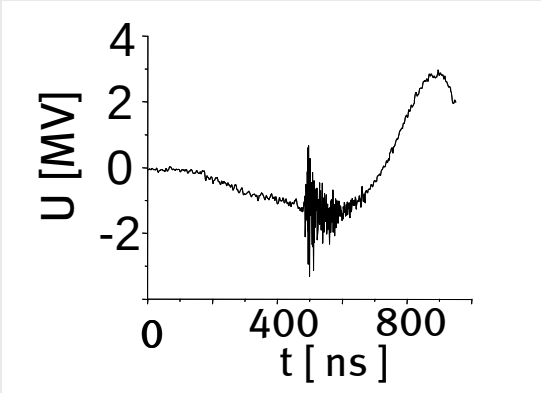
Pulse Forming Line



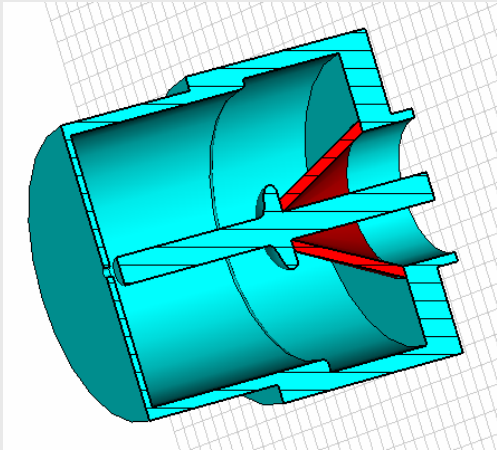
Pulse Forming Line







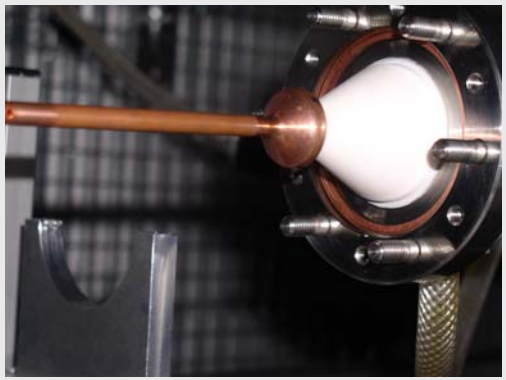
Vacuum Diode



3.5 MV pulses
3 mm Acceleration Gap

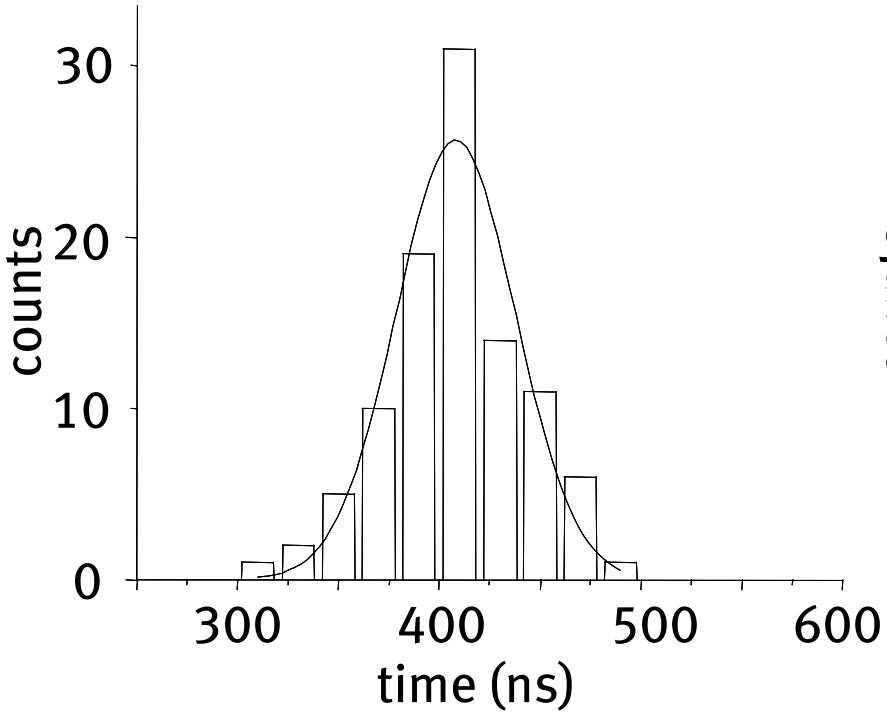
› 1 GV/m

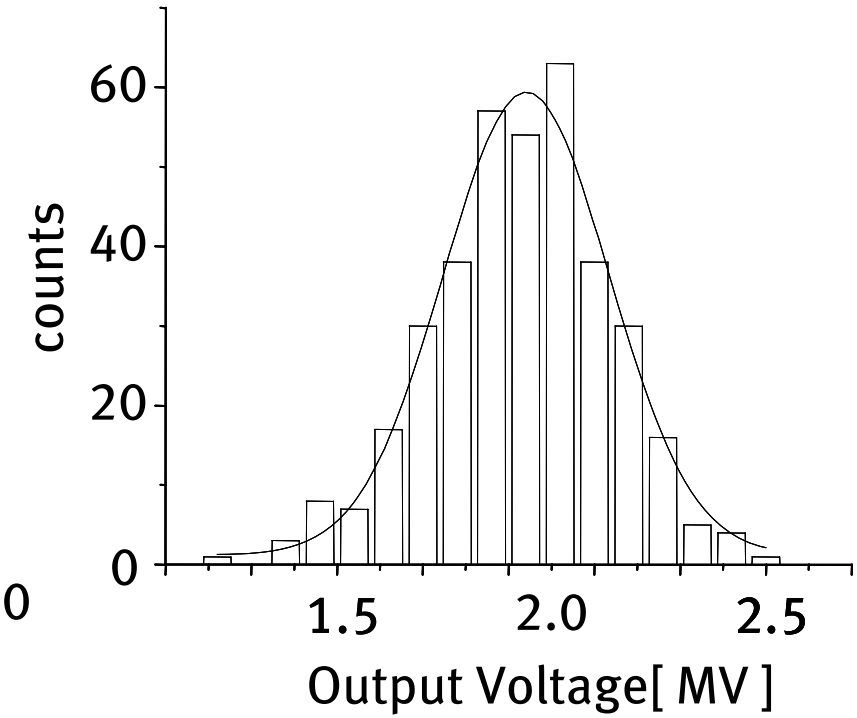
Cathode



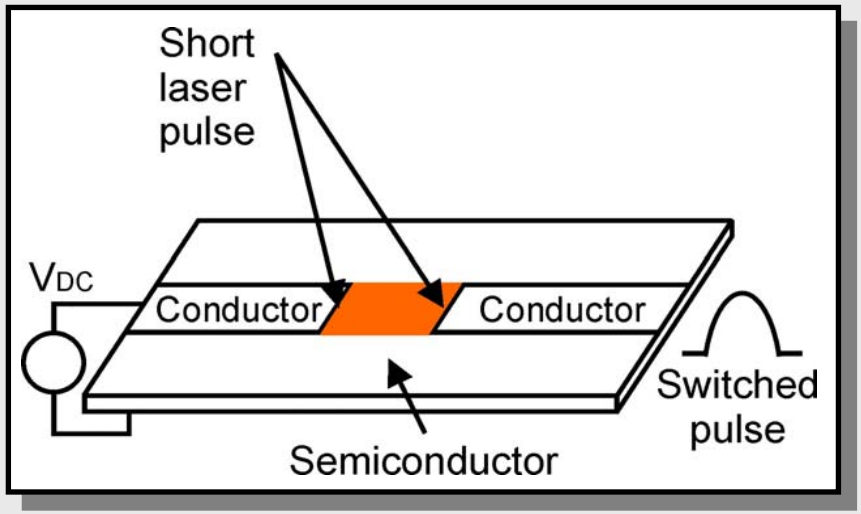
Anode

Jitter

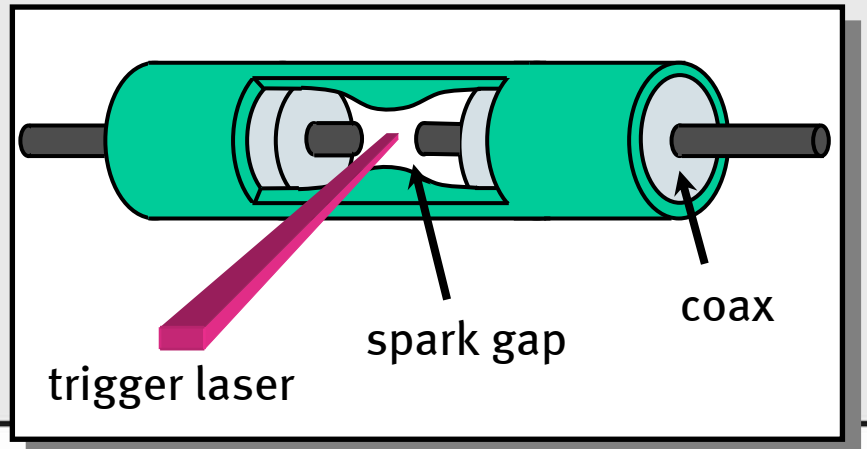

30
20
10
0
counts
300
400
500
600
time (ns)


60
40
20
0
counts
1.5
2.0
2.5
Output Voltage[MV]

Semiconductor switch vs laser triggered spark gap

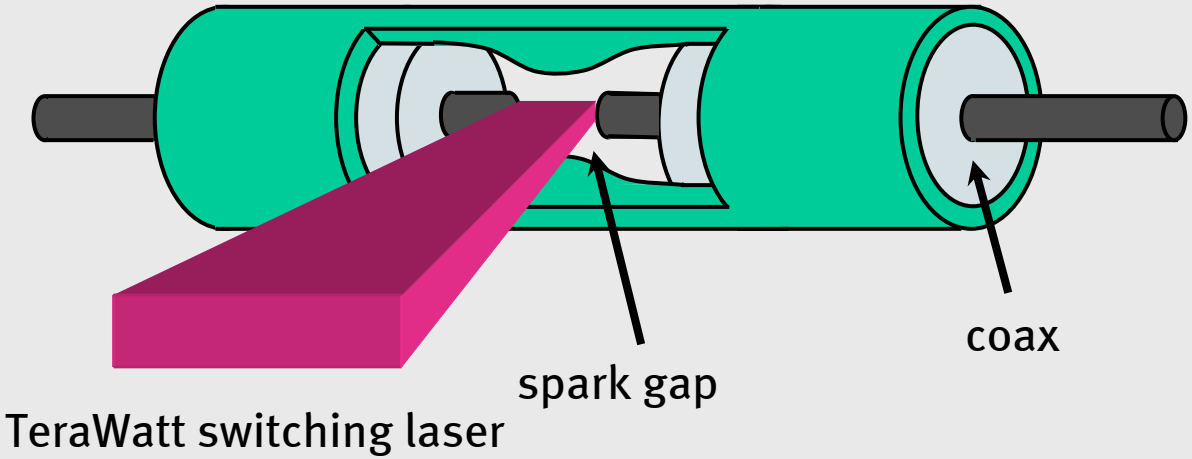


- ☺ Fast (ps rise time)
- ☺ Almost no time jitter
- ☹ No recovery after breakdown
- ☹ Limited to 'low' power



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

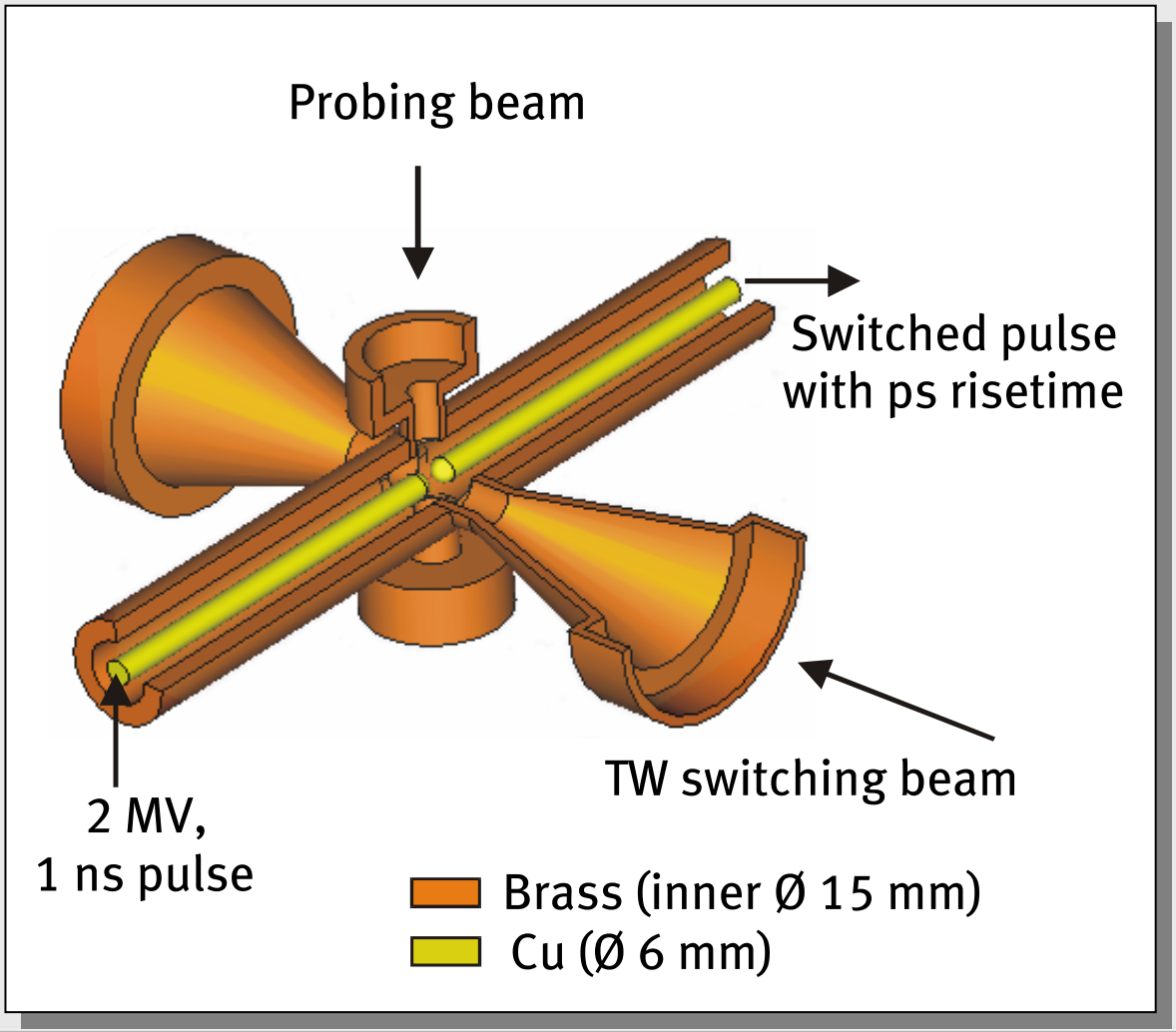
Photoconductive switching of a spark gap



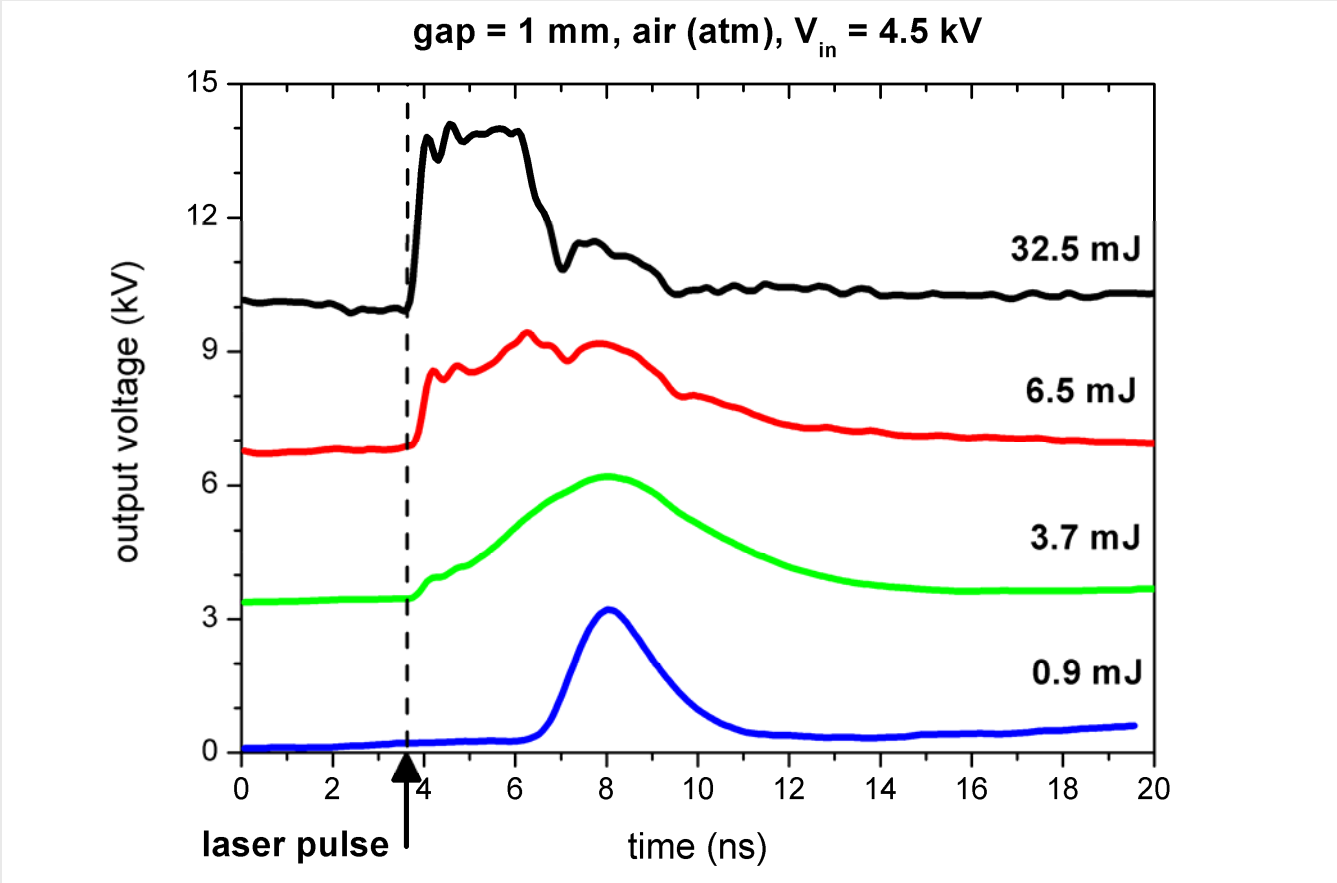
Ionization of the complete gap with high power fs laser

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

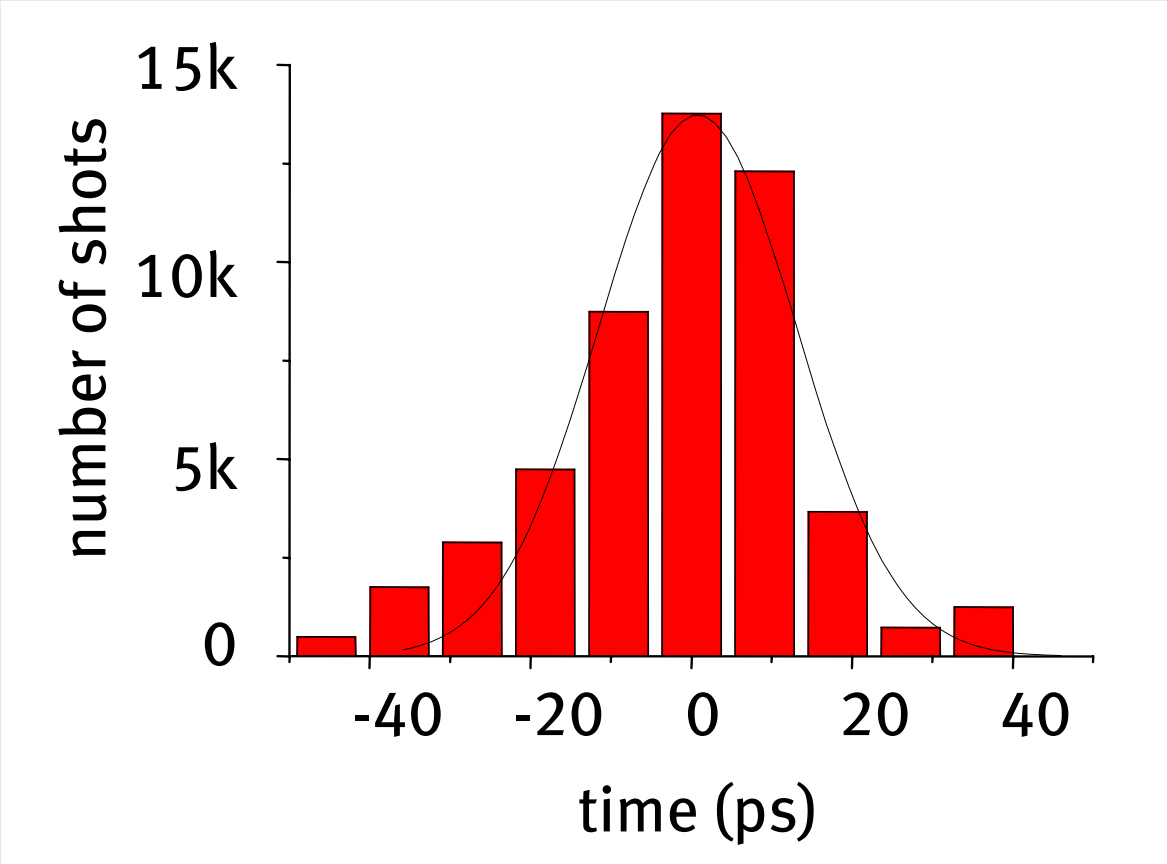
Photoconductive switching spark gap setup



switched pulses @ different laser energies



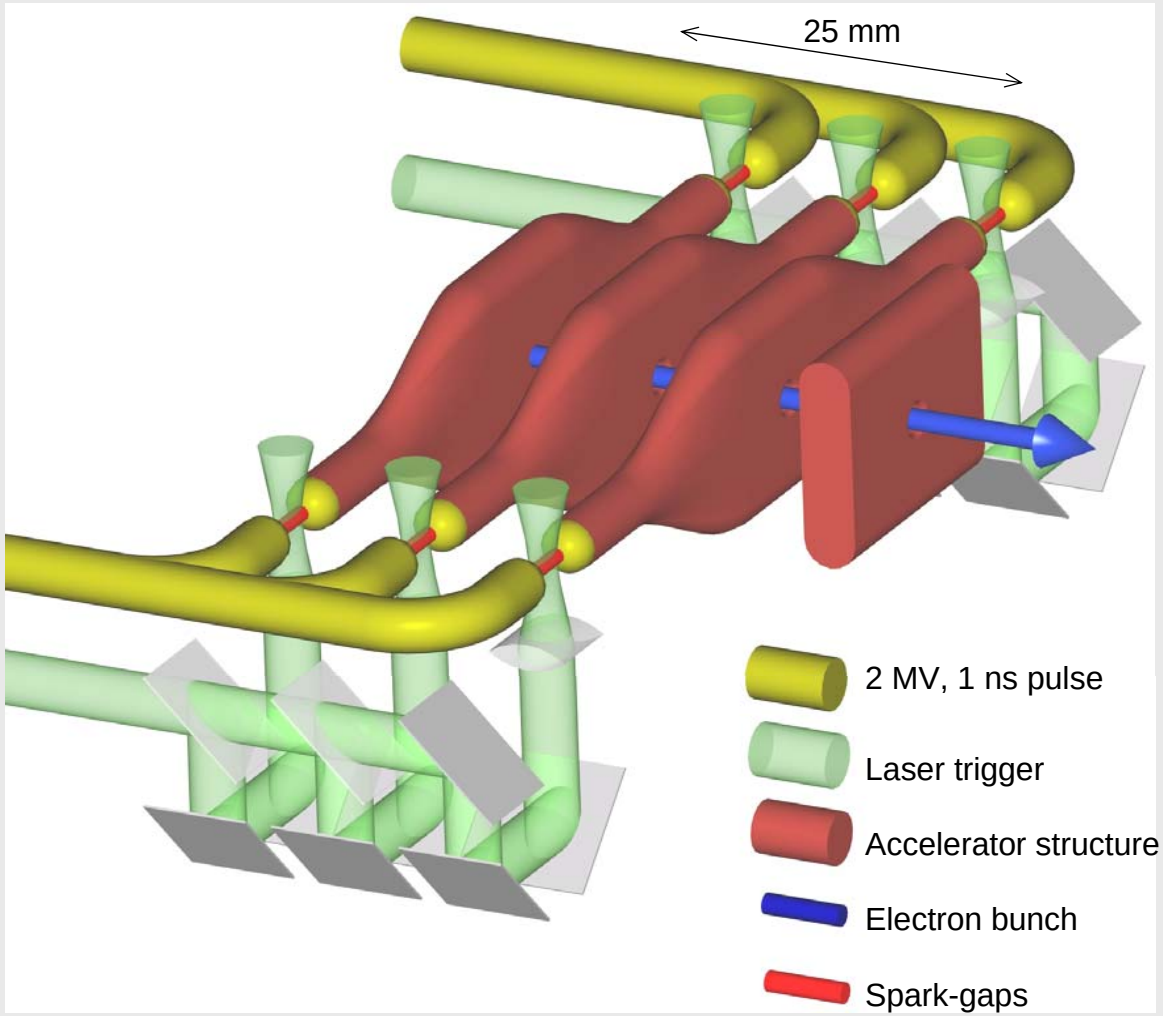
jitter: σ = 12 ps



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



GV/m

3 MV

3 mm between plates

plate thickness about 3 mm

‹ 10 ps switching time

Conclusions

For Future Accelerators:

More Pulsed Power

Better Pulsed Power