DITANET

‹‹ novel **DI**agnostic **T**echniques for future particle **A**ccelerators:
A Marie Curie Initial Training **NET**work ››

Carsten P. Welsch
- On behalf of the DITANET Consortium -

MARIE CURIE ACTIONS

PEOPLE

By now...

- ...familiar with many different diagnostic techniques;
- ...know solutions to (past) problems;
- ...(hopefully) fascinated by width of field.

Questions

- What are the present challenges ?
- What is not (yet) known ?

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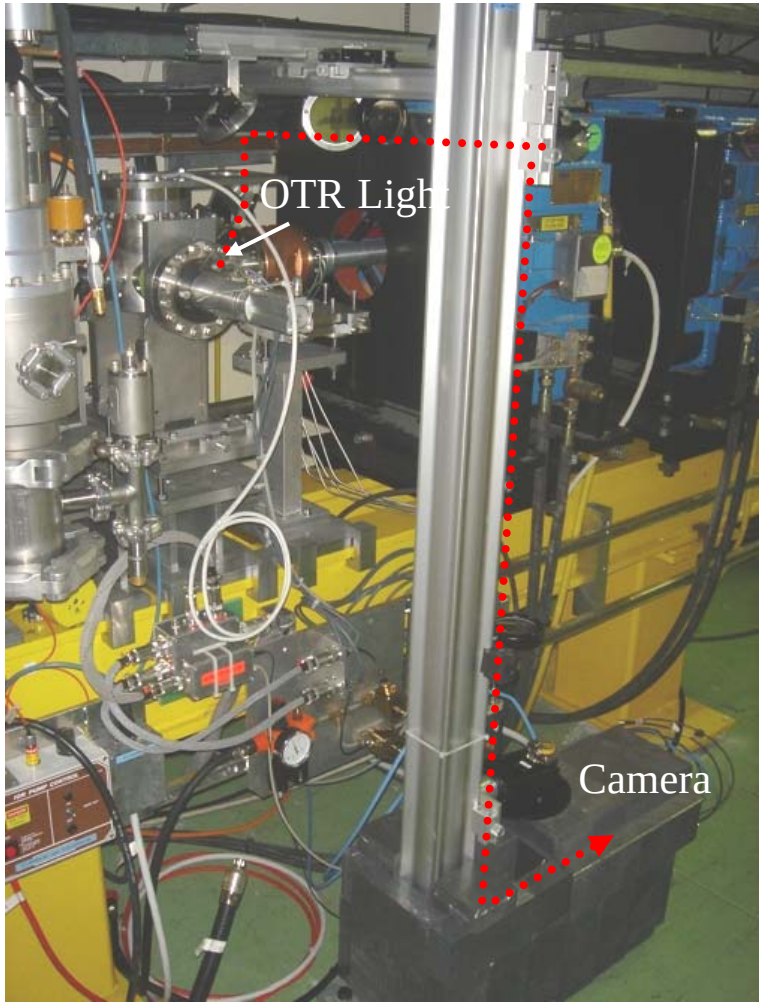
A „typical“ Monitor



- Material sciences
- Thermodynamics
- Electro-Magnetism
- Optics
- Mechanics
- Electronics
- Nuclear Physics
- …

⇨ Multi-disciplinary field !

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Outline

- What is DITANET ?
- Some words on the network structure
- Research
- Training
- What does it mean to you ?

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What is DITANET ?

- One of the largest Marie Curie Initial Training Networks ever funded by European Union !
- Aim: Training young scientists.
- Gives industry an important role.
- Allows for inter-sectorial collaboration.
- Recognized importance of beam diagnostics at European level !

(in physics top 12, 2007 – under extreme competition)

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The DITANET Consortium

Network Participants










Associated Partners












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Including Partners From Industry

Full Network Partner	Offer research training & **Recruit** eligible researchers	Level 1
Associated Partner	Provide research training, **complementary skills courses,** (communication, enterprise cycles, innovation, IPR, …) **secondments**	Level 2
	Member of the **Supervisory Board**: definition of skills requirements for targeted researchers	Level 3

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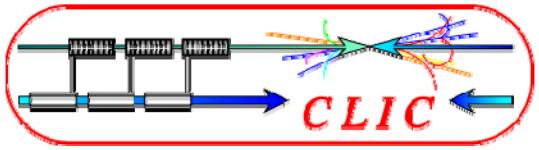
Examples from the Research Program

XFEL

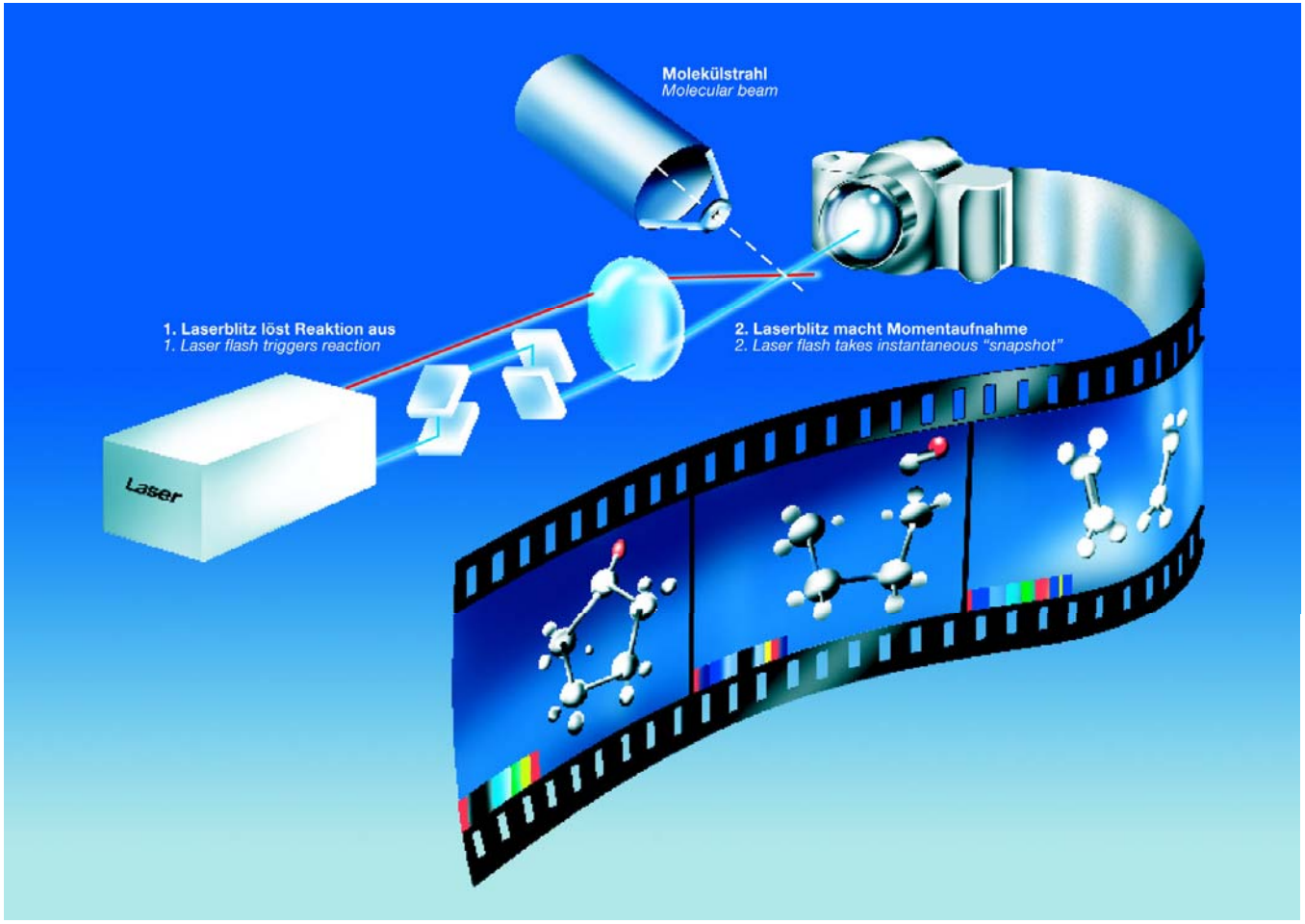


CTF3

USR @ F(L)AIR

Pushing the limits of beam diagnostics...

Molecular Imaging with the XFEL



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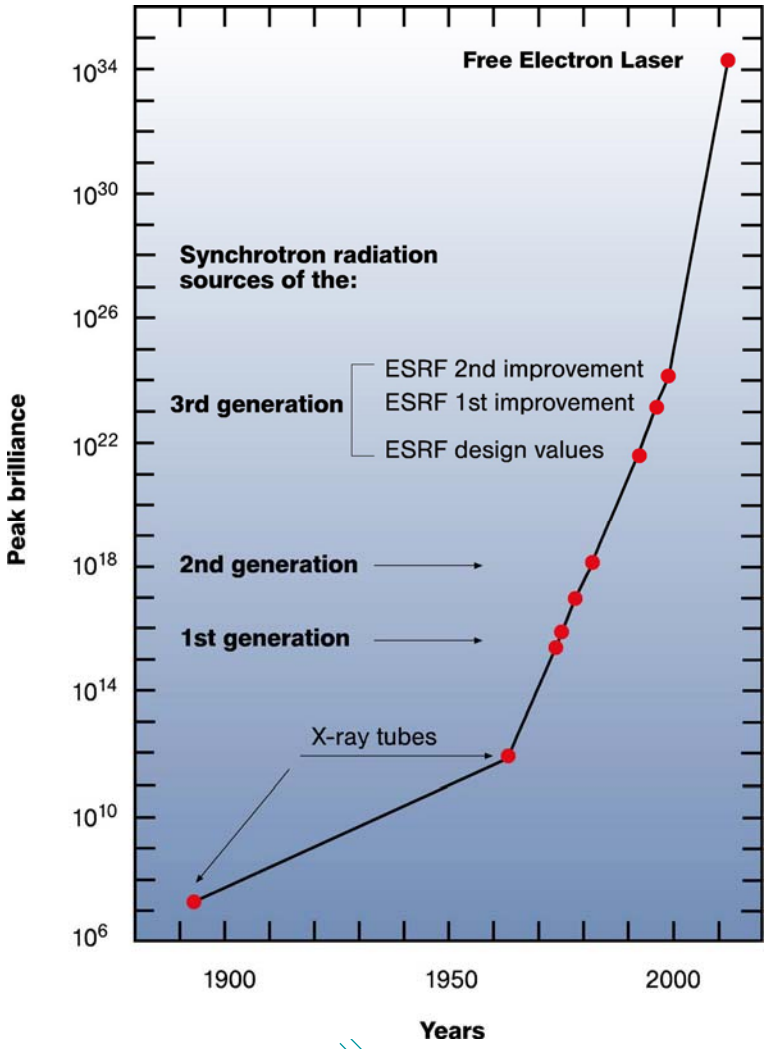
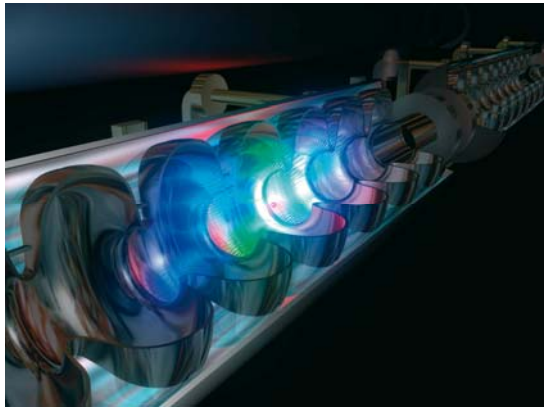
The XFEL Project



TESLA Technology



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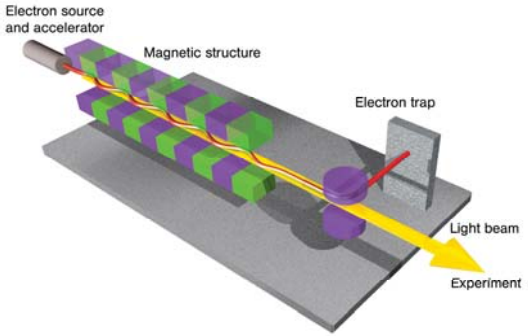
Light Generation



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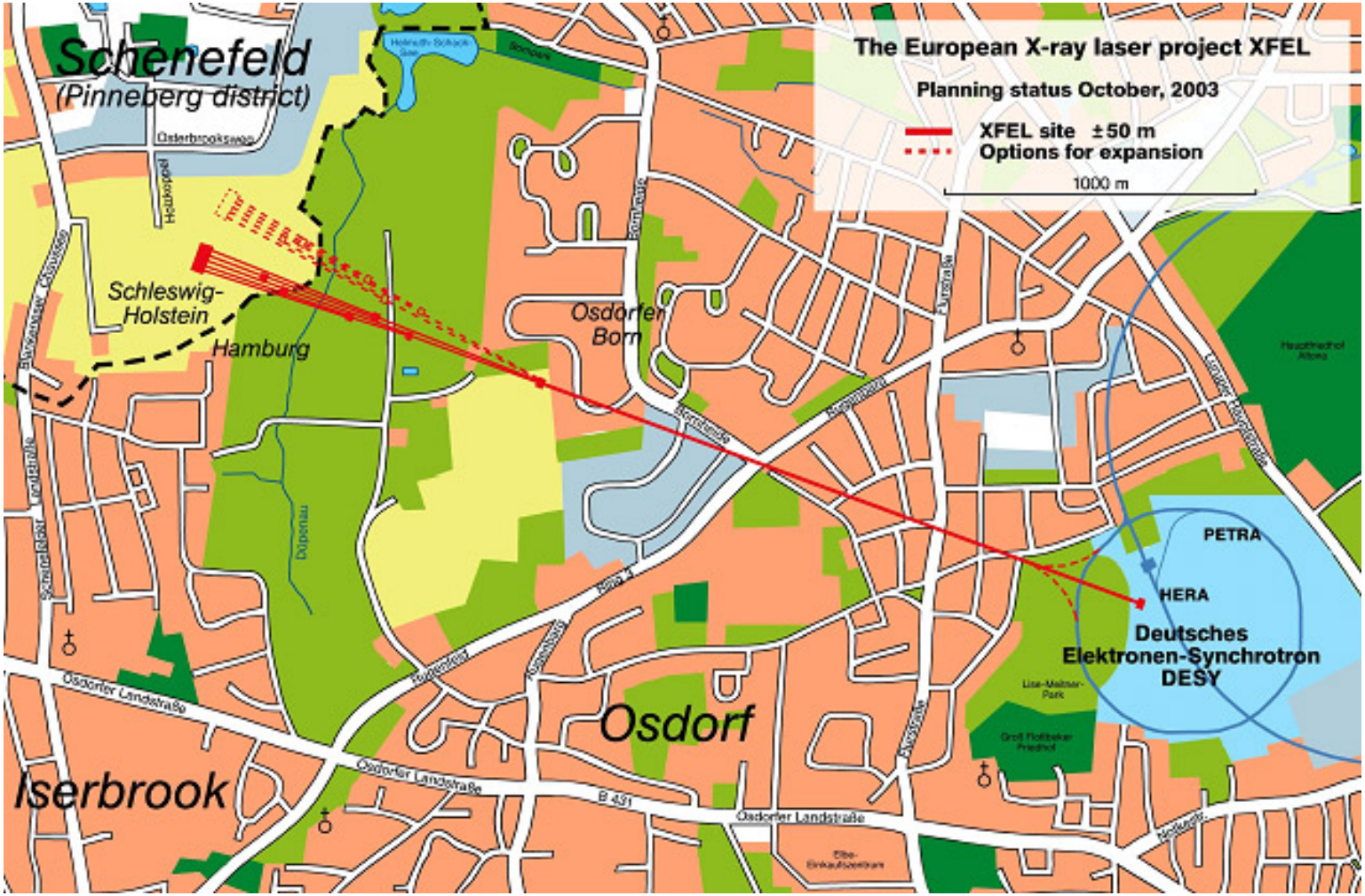
The XFEL Project



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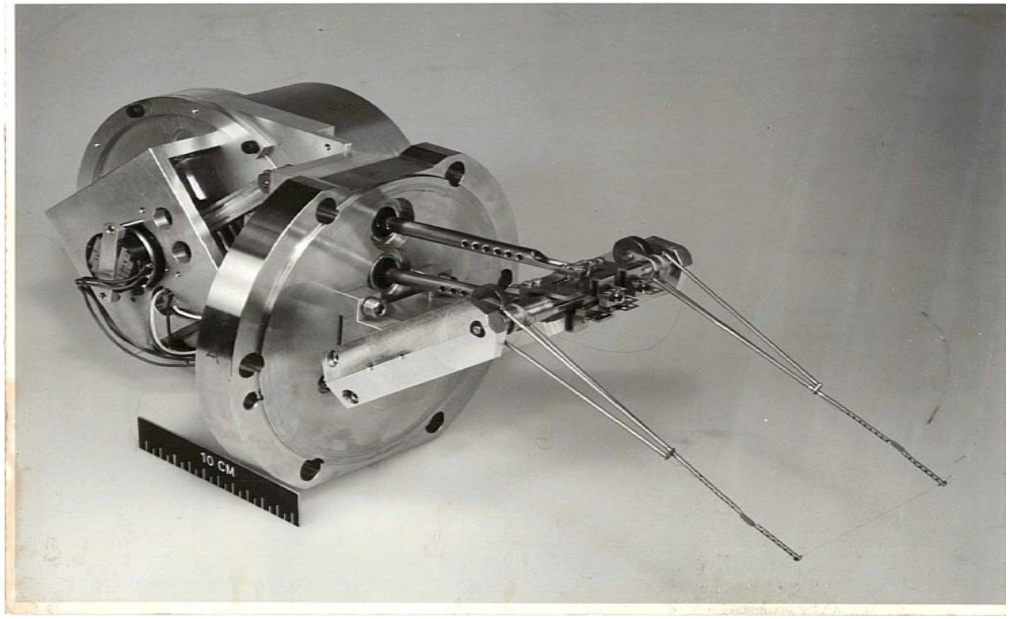
Wire Scanners

..established for measurements in accelerators.

<u>Advantages</u>:

- Resolution: 1 μm
- Reliable
- Direct



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Challenge: Heat Load on Wire

$$-\frac{dE}{dx} = \frac{4\pi}{m_e c^2} \cdot \frac{nz^2}{\beta^2} \cdot \left(\frac{e^2}{4\pi\varepsilon_0}\right)^2 \cdot \left[ln\left(\frac{2m_e c^2 \beta^2}{I \cdot \left(1-\beta^2\right)} - \beta^2\right)\right]$$

$$T = C \cdot \frac{dE}{dx} \cdot d' \cdot N \cdot \frac{1}{c_p \cdot G} \left[°C\right]$$

T_{max} ~ 2000°C

$$N = \frac{d' \cdot f_{rev}}{\nu} \cdot \left(NB \cdot n_{Bunch}\right)$$

⇨ Required: Speed of 10-20 m/s with 1 μm resolution.

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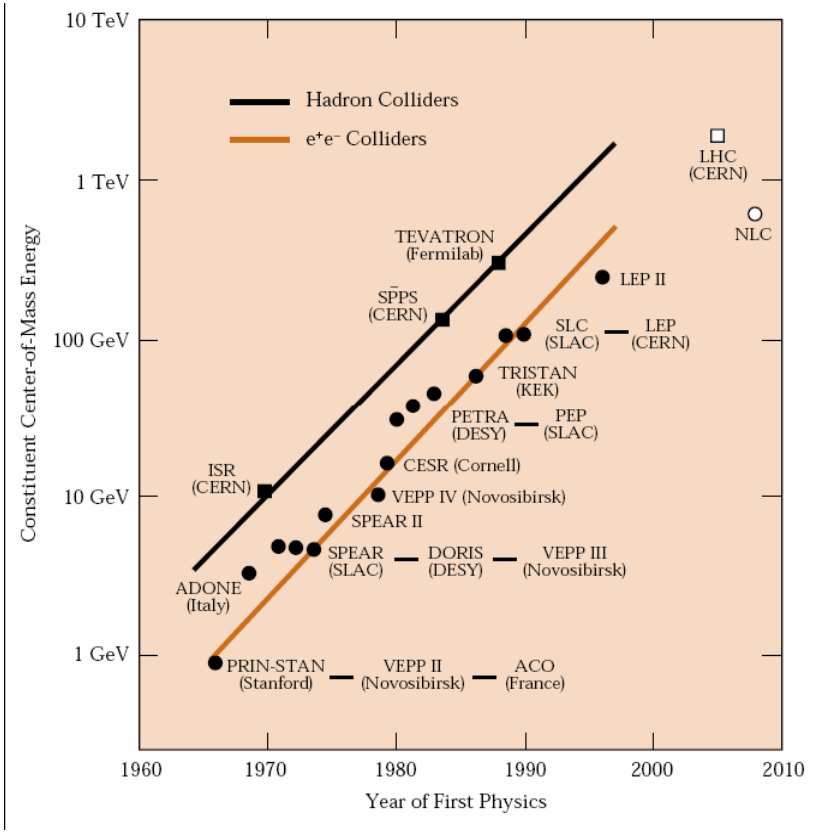
Why highest Energies ?

- Particle accelerators are indispensable tools to understand nature at smaller and smaller scales.
- Since the 70ies, most new revelations through colliders.



- Energy increase by Factor ten every 8 years !
- Hadron-Collider at the energy frontier.
- Lepton-Collider for precision physics.
- **LHC** start in 2008
- Consensus for a lepton collider with E_{cm} > 500 GeV to complement the LHC physics.

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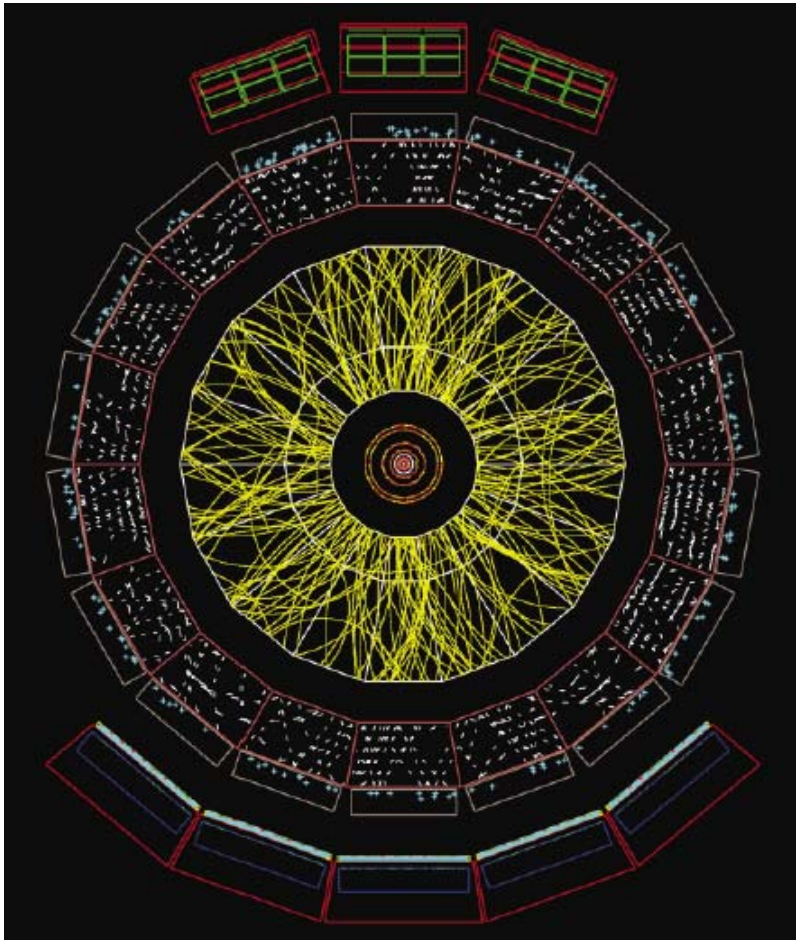
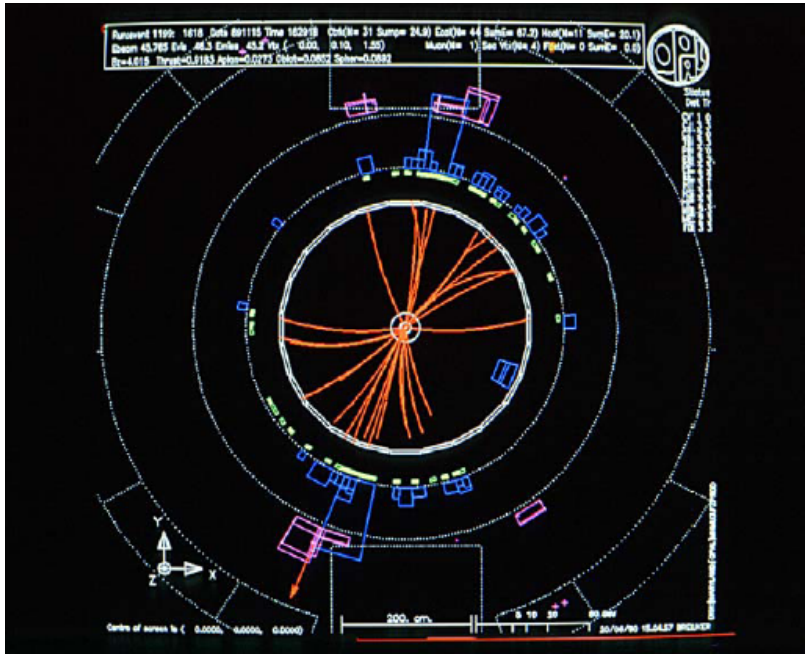
Differences

Hadron collision



Simulation of a lead-lead collision in the ALICE detector

Lepton collision



Display from OPAL showing the decay of a Z into two jets of particles, originating from a quark-antiquark pair

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Physics Motivations

- Higgs physics
  - Tevatron/LHC should discover Higgs (or something else)
  - LC explore its properties in detail
- Supersymmetry
  - LC will complement the LHC particle spectrum
- New physics
  - Extra spatial dimensions
  - New strong interactions
  - . . .

New territory to discover
beyond the standard model

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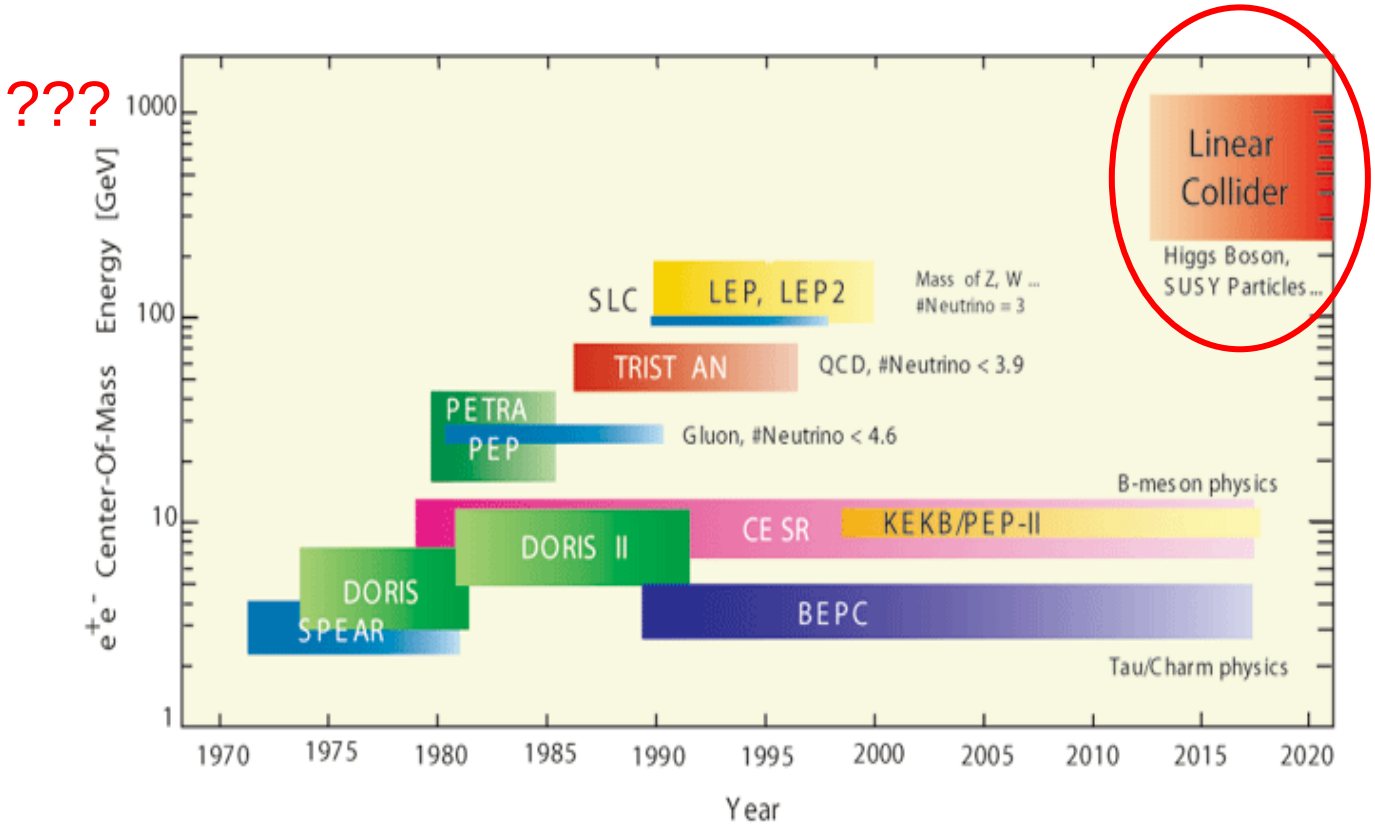
At the Energy Frontier



Wait for the LHC results (~ 2010).

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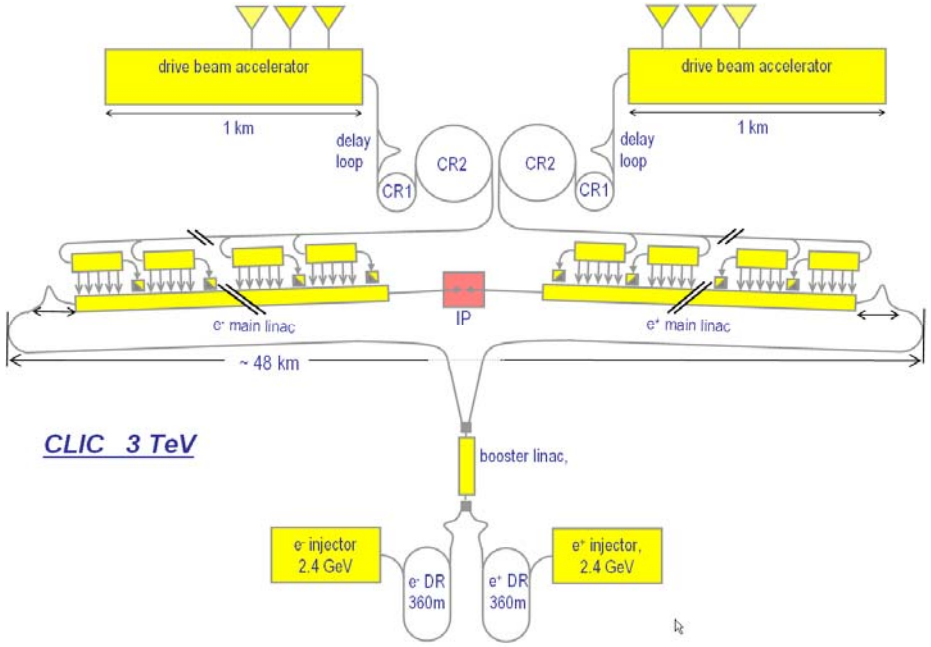
CLIC

Compact **L**inear **C**ollider



1. High Gradient (100 MV/m)

- Length: < 50 km
- Normal conducting structures
- High rf frequency (12 GHz)

2. Two Beam Scheme

- Suited for high frequencies
- Cost effective, highly efficient
- Simple tunnel, no active elements

3. Central Injector Complex

- "Modular" design
- can be built in stages

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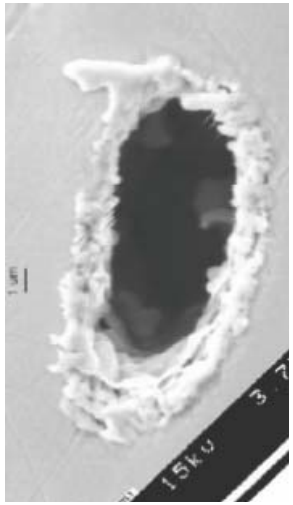
Linear Collider: Challenges

Measure very small beam size.

Linac: $\sigma \sim 1$ mm

Final Focus: $\sigma \sim 1$ nm (!)

High beam charge 10^9 / 10^{12} nC/cm^2.



Thermal limit for ‚best' materials is

(C, Be, SiC,…) ~ 10^6 nC/cm^2

New diagnostic concepts required !

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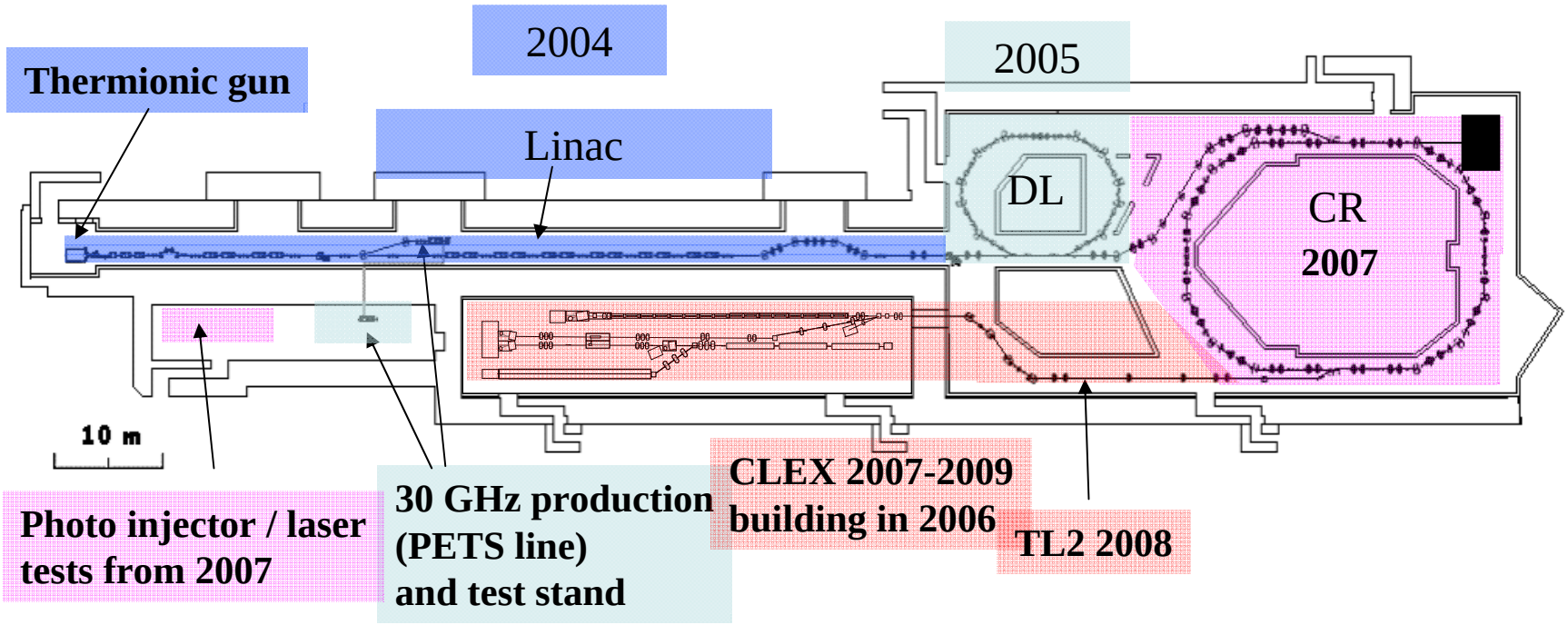
CTF3 - Overview



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CTF3: An Ideal Experimental Platform

- Time-resolved spectroscopy
- Beam Halo Monitoring *(more details will follow right away...)*
- Simulation of CDR; compare to measurements
- Beam position monitors
- ITB instrumention

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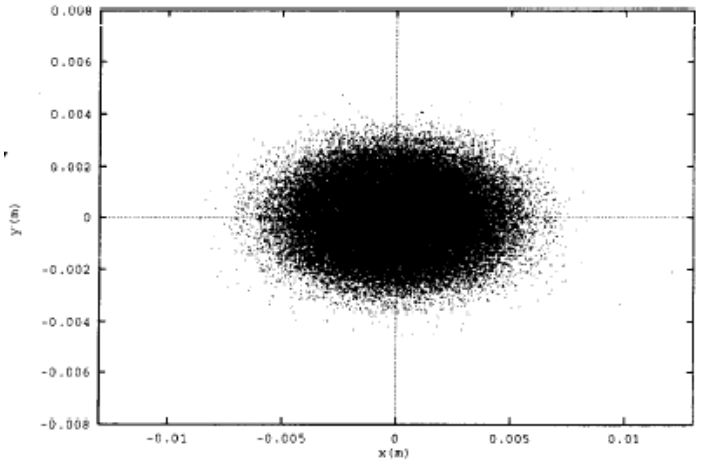
Definition: What is 'Halo' ?

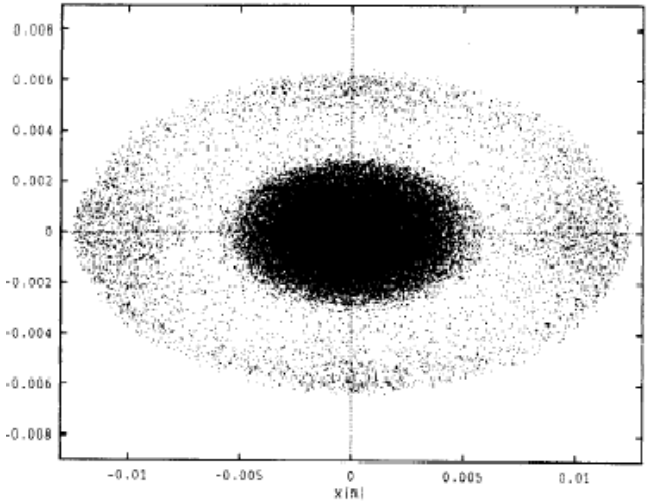
General definition difficult to make:

Accelerator physicists

Instrumentation specialists

Low density / difficult to measure





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Halo: Why do we care ?

- Less transmission, more radiation
- Activation of vacuum chamber
  - *Maintenance more difficult*
  - *Higher cost*
- Different reasons
  - *Dispersion*
  - *Mismatch*
  - *Scattering (beam - gas, intra-beam, Touschek)*
  - *Noise*
  - *Space charge*
  - *....*
- **Goal**: Understand mechanisms !

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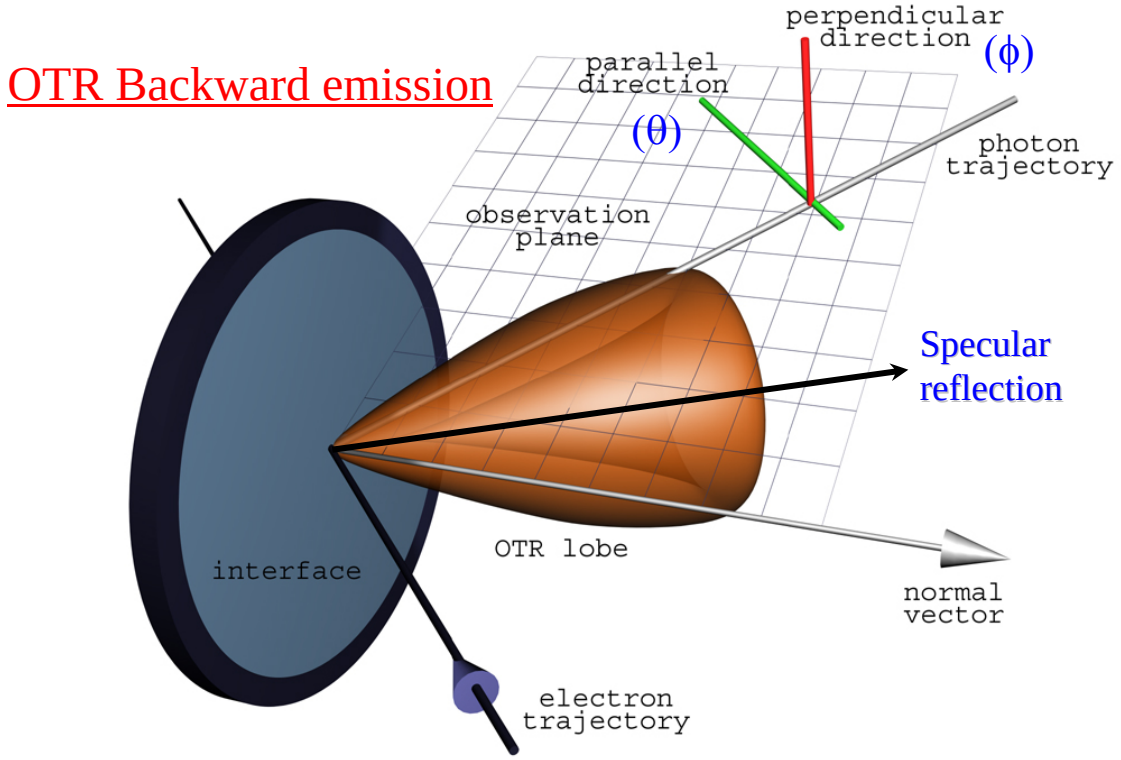
OTR characteristics

Created when e^- beam penetrates two materials with different permittivities.



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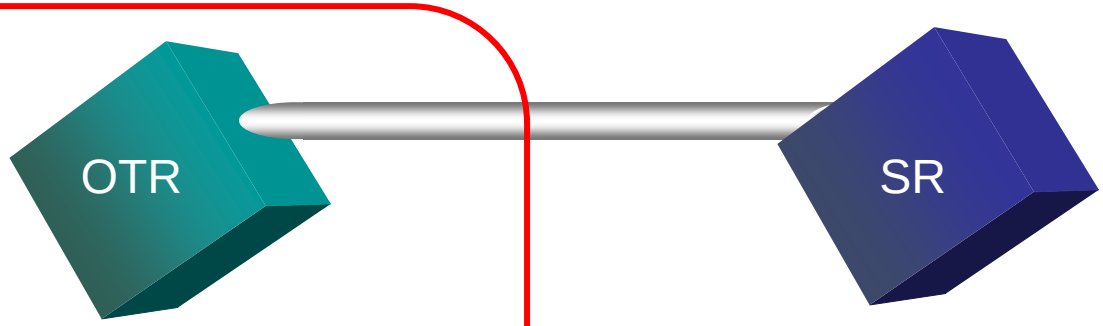
A Brief *(incomplete)* Comparison



OTR

\+
- Screen choice
- Linear, directive Signal
- Fast time response
- Add. Info *(ε, x', y',..)*

–
- Destructive
- Installation/Maintenance
- Max. beam charge

SR

\+
- Non-destructive
- Highly directive
- Good signal if E~150 MeV

–
- Only in bends or chicane
- Alignment of line
- Diffraction limited

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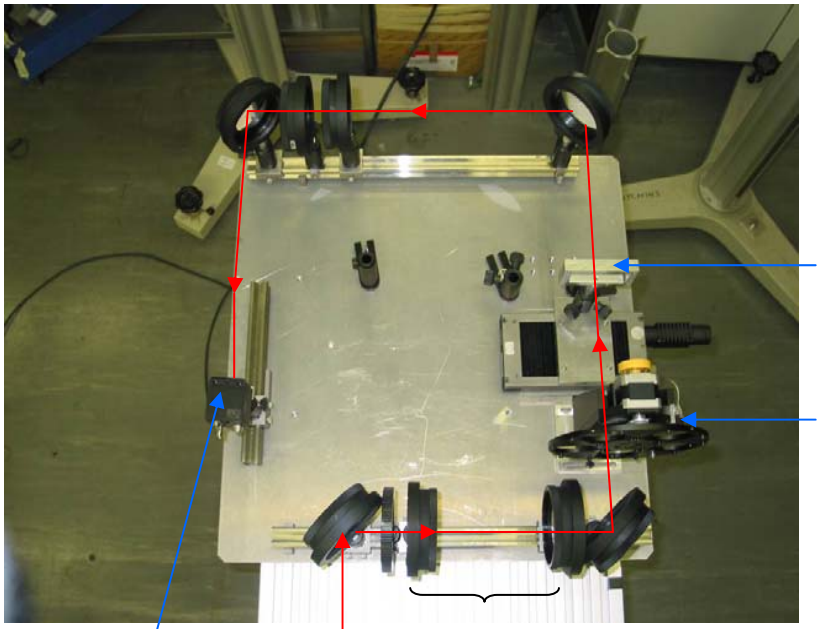
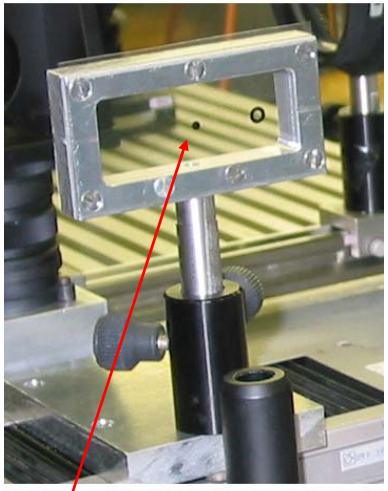
Lab Setup





Mask: spot printed on polyesther foil

- On / Off *(beam core)*

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Proc. EPAC04
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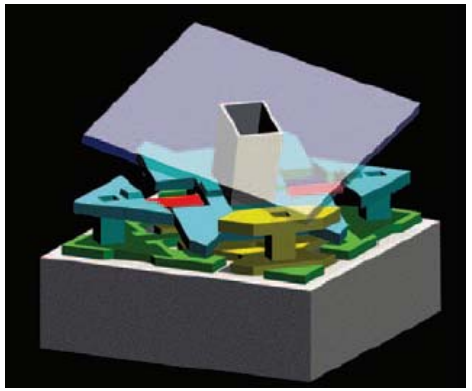
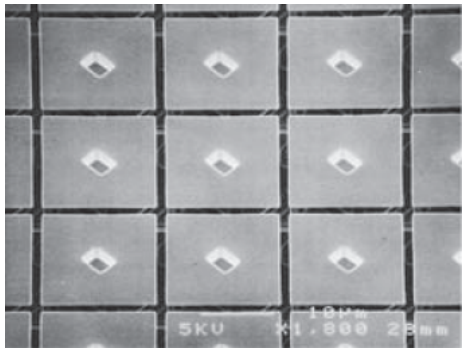
Micro Mirror Array

Micro **E**lectro-**M**echanical device

- 1024 x 768 pixels (XGA)
- USB Interface
- high-speed port 64-bit @ 120 MHz for data transfer
- up to 9.600 full array mirror patterns / sec (7.6 Gbs)
- 16 μm in size
- +/- 10° of rotation
- Switch of 15 μs physically, 2 μs optically





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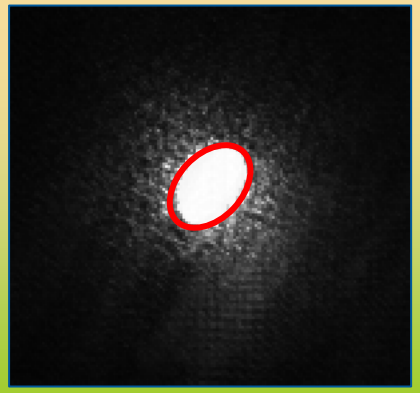
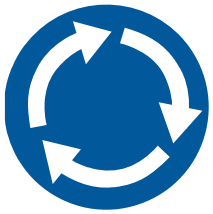
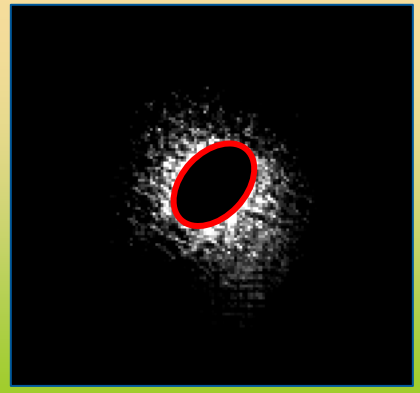
Measurement

(1) Aquire profile

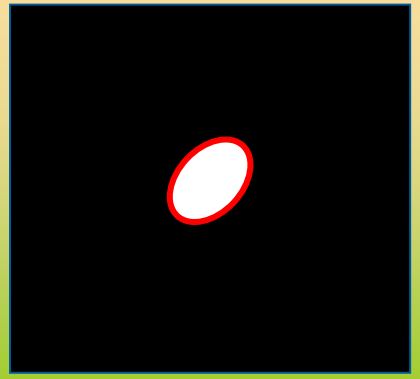


(2) Define core





(4) Re-Measure



(3) Generate mask

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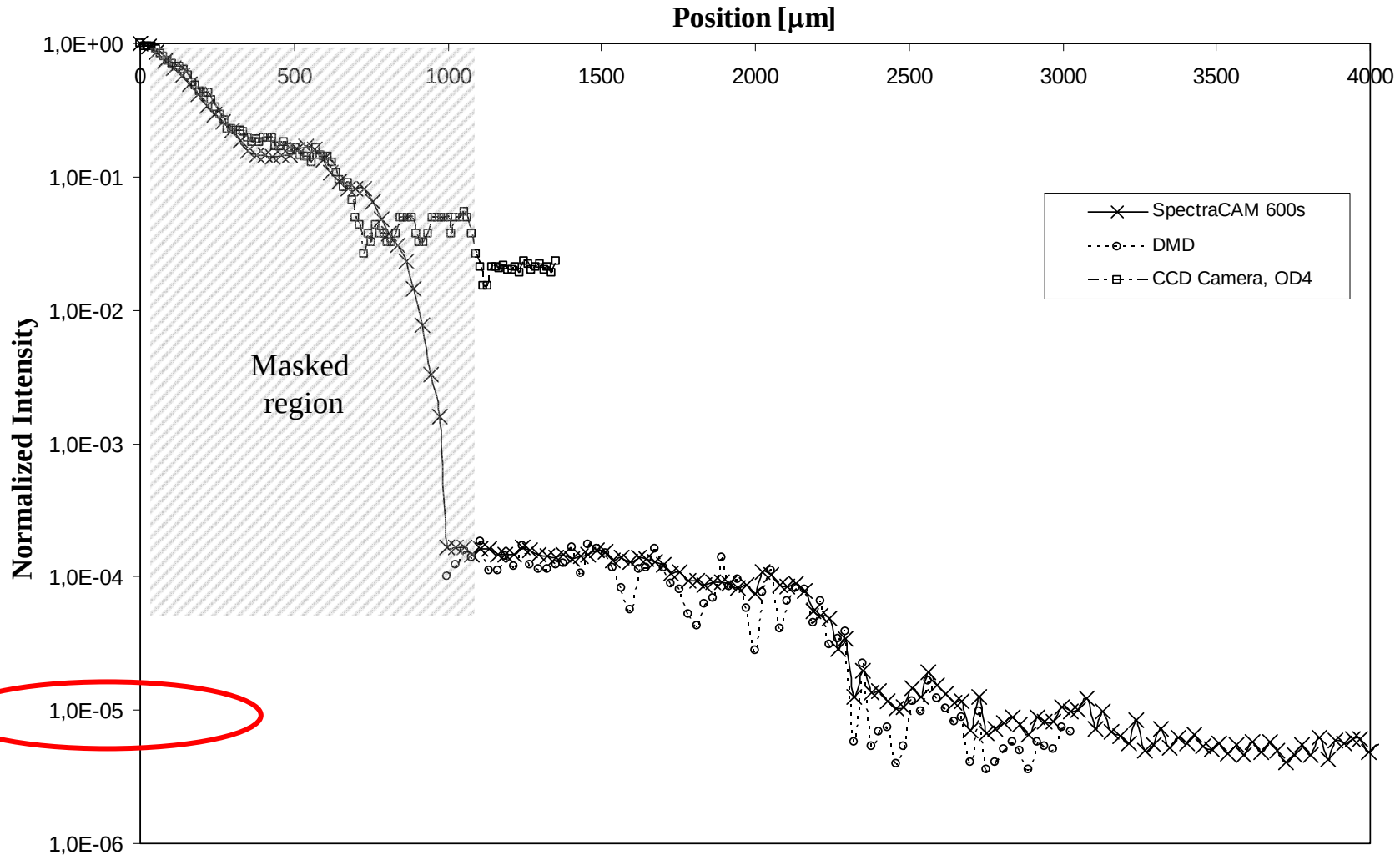
Results from Measurements



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Next Steps

- Test MMA setup in running machine
- Improve software / automate process
- Adapt to new Test Beam Line
- Combine with CID camera ?

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Antiprotons: Fundamental Questions

Do we understand the interaction between
Matter and antimatter ?

Is CPT valid ?

Is the effect of gravitation equal
on matter and antimatter ?

What is the structure of antiprotonic
atoms und ions?

Do we understand the correlation between electrons
in simple systems ?

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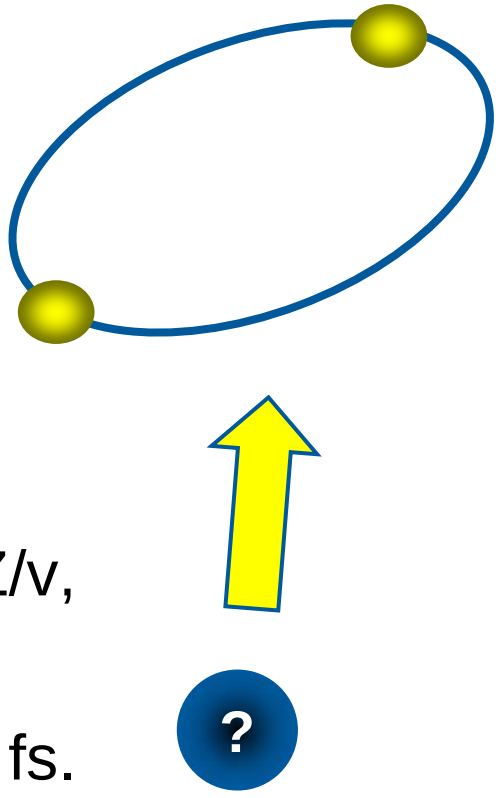
The task:

Few-body problem: Interaction with "clean" projectile.



<u>Important</u>:

- No (or only few) add. reaction channels,

- Possibility to control perturbation strength Z/v,

- Variation of interaction time between as => fs.

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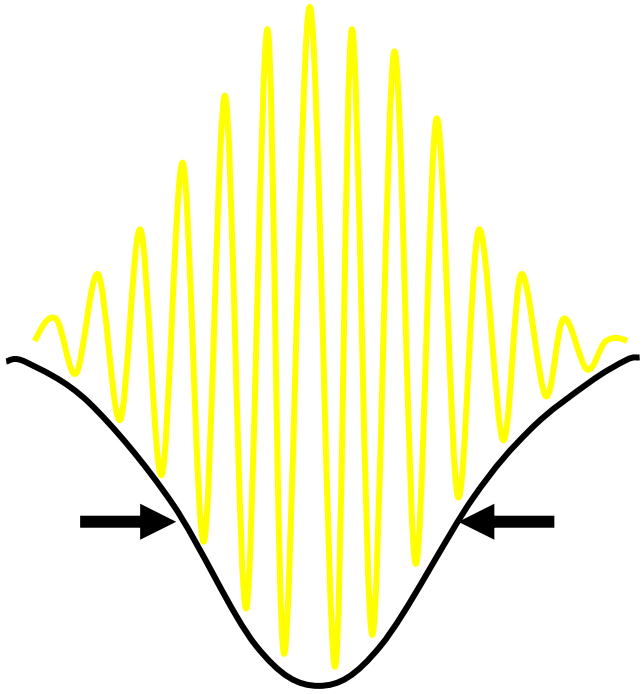
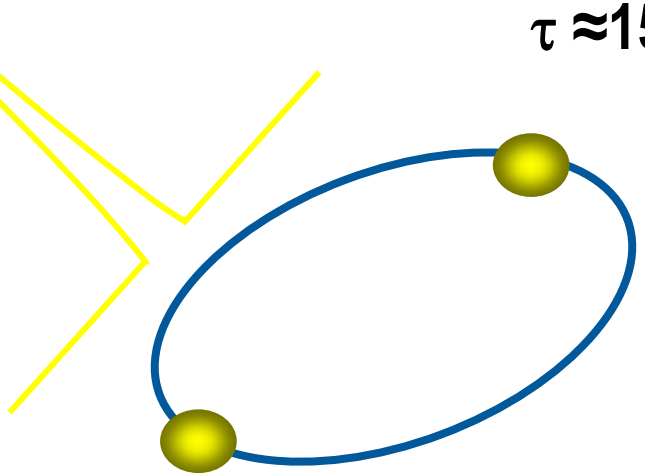
Why Antiprotons ?



$\tau \approx 150$ as



t =30 …6… 3.5 fs

I ≥ 10^{15} W/cm^2

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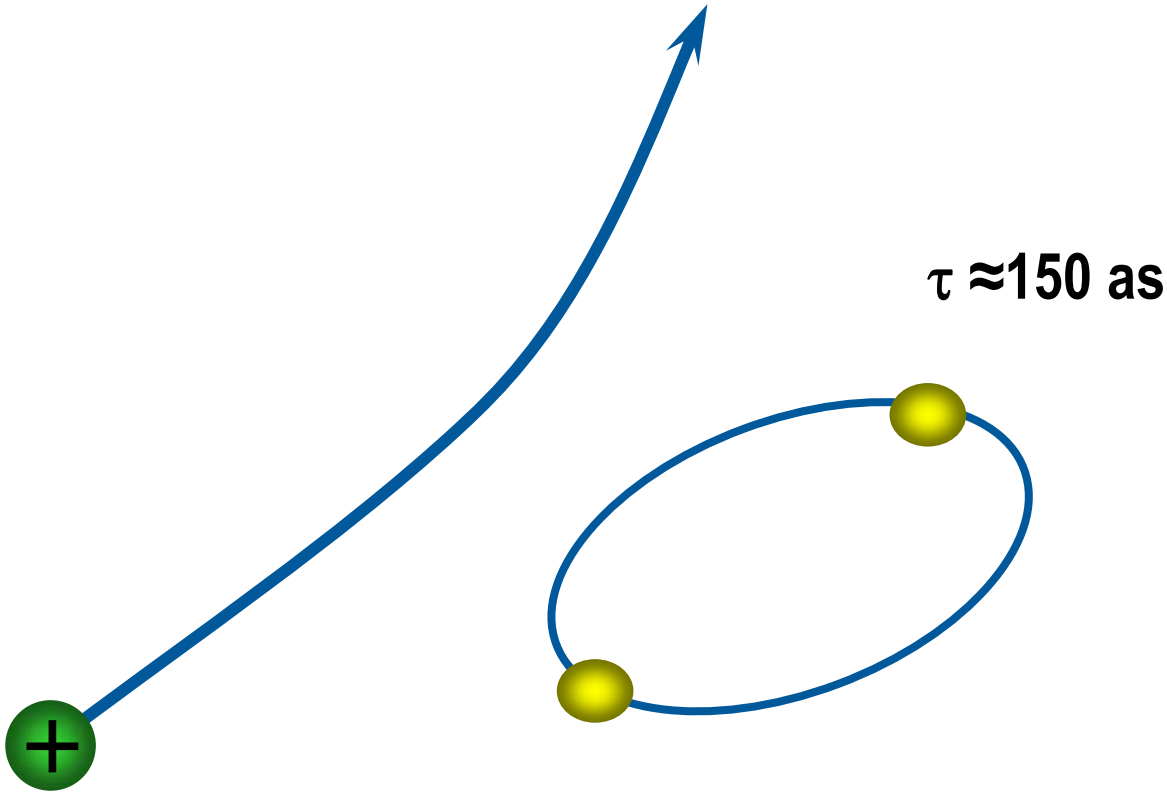
Why Antiprotons ?

Laser

Pos. Ions



$\tau \approx 150$ as

Dominated by capture !

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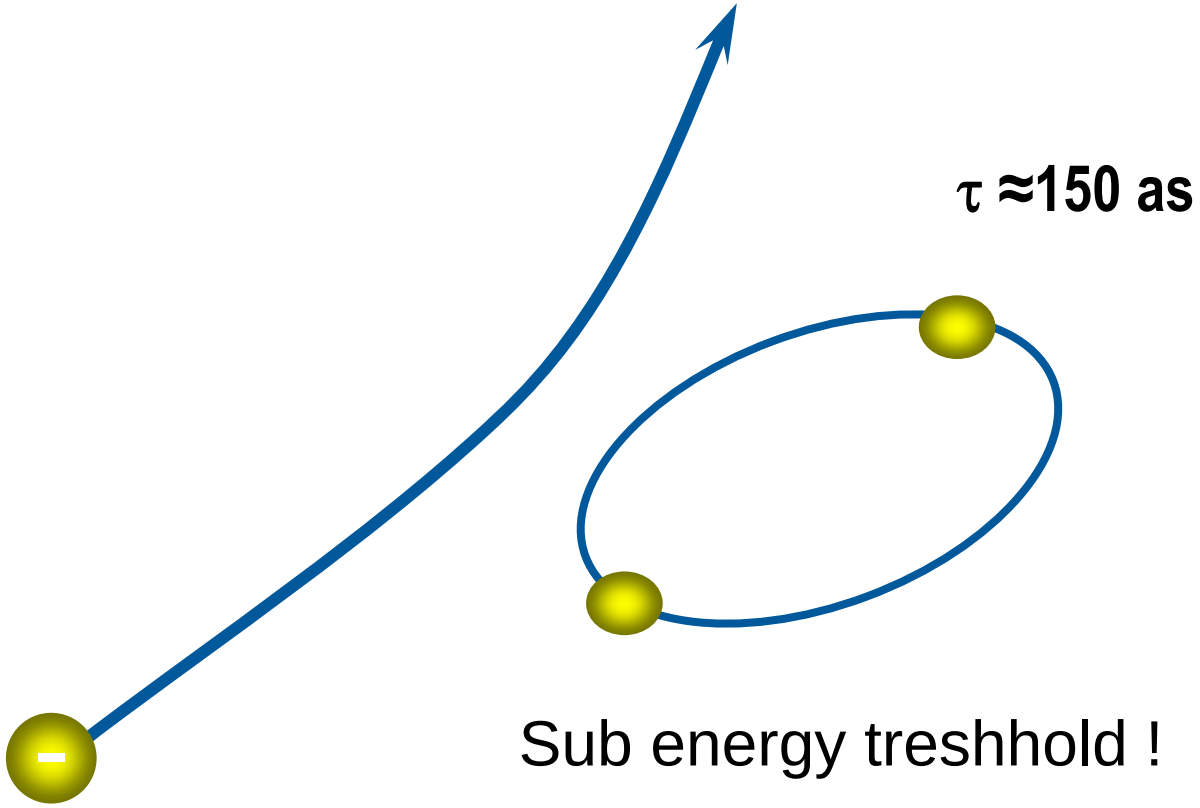
Why Antiprotons ?

Laser

Pos. Ions

Electrons



Sub energy treshhold !

Antiprotons !!!

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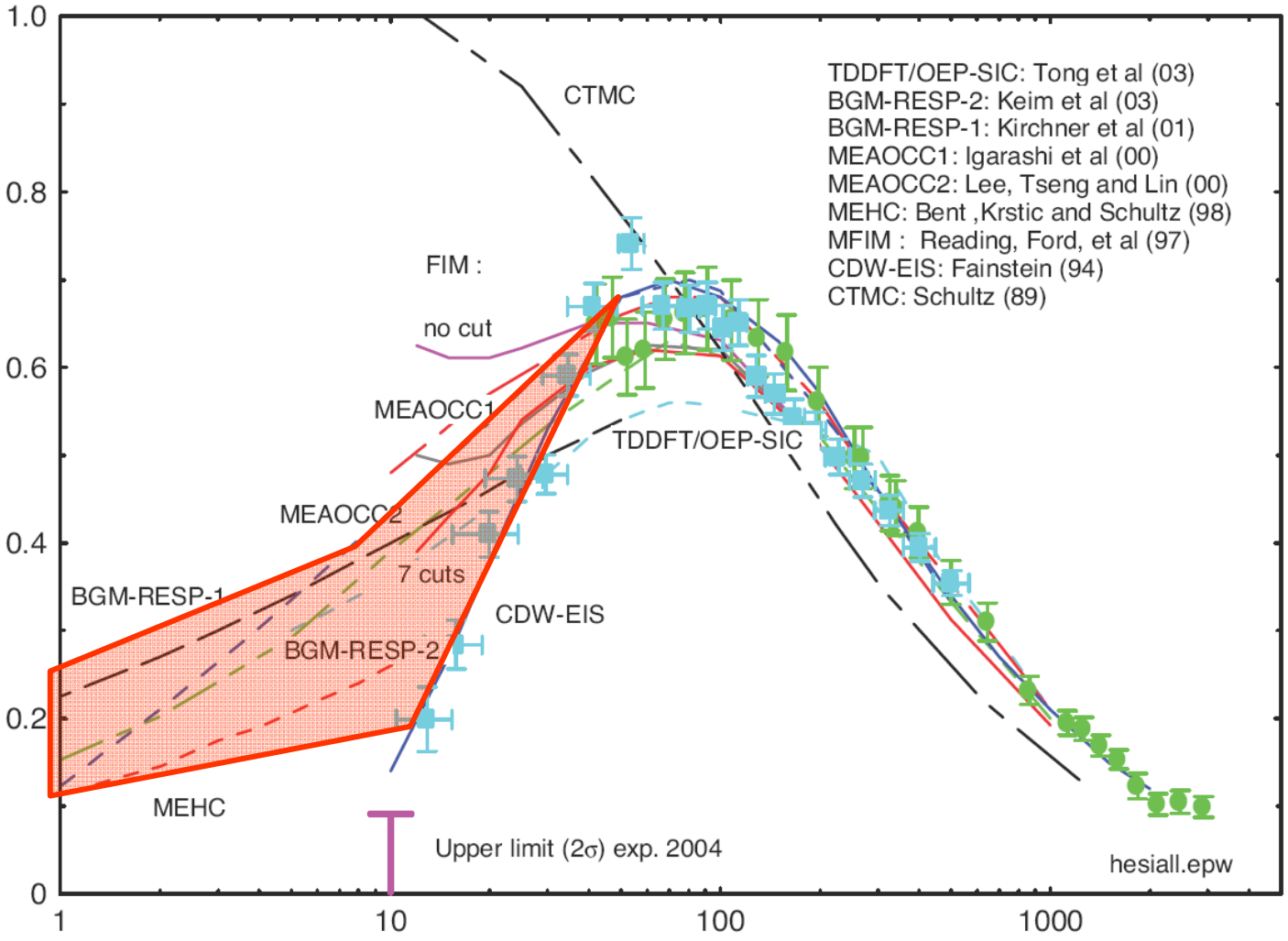
Antiprotons: Existing Measurements



ASACUSA results (2004)

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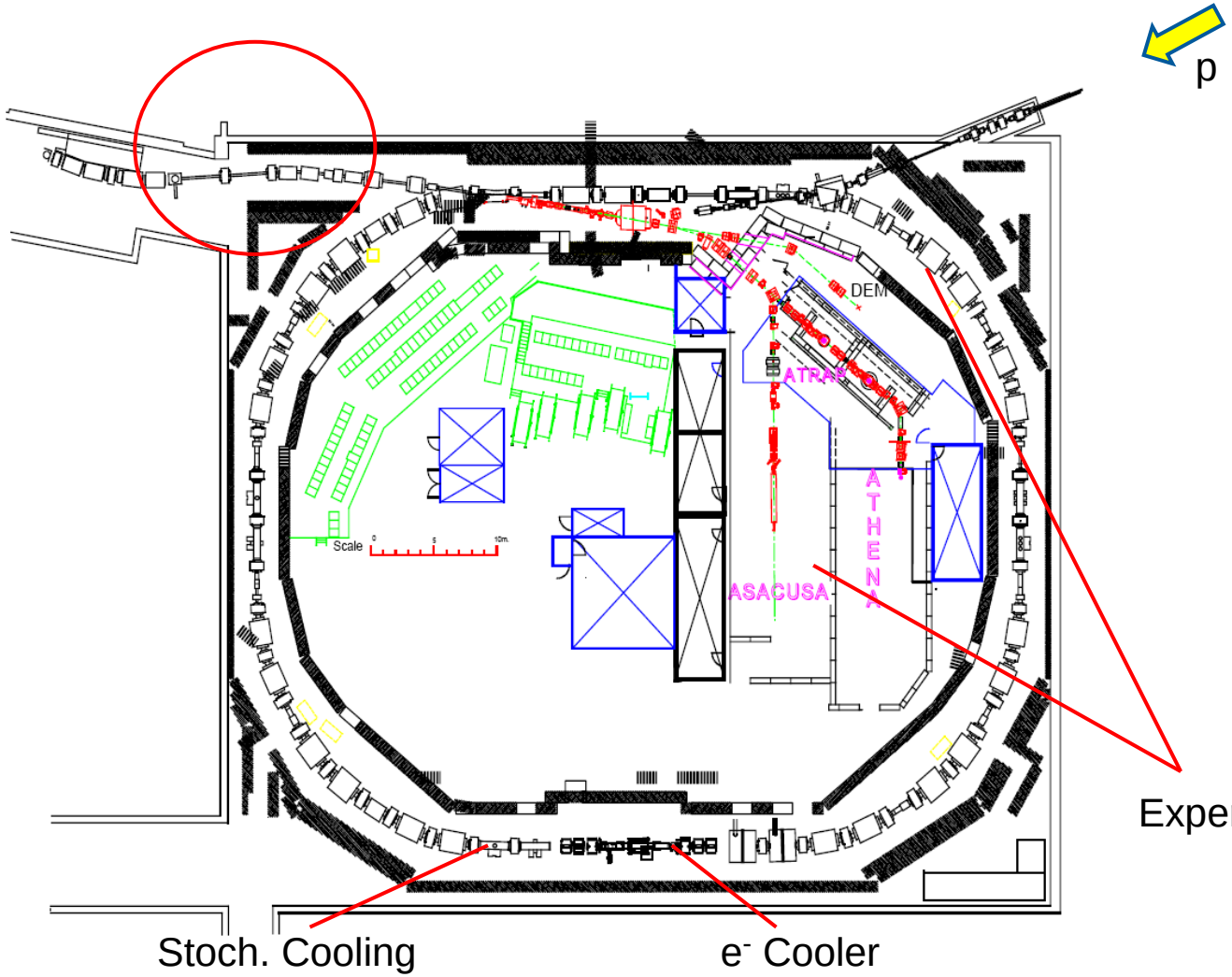
Present Situation: AD @ CERN

Target

26 GeV/c p

➡ 3.57 GeV/c $\bar{p}$

Yield: $4 \cdot 10^{-6}$



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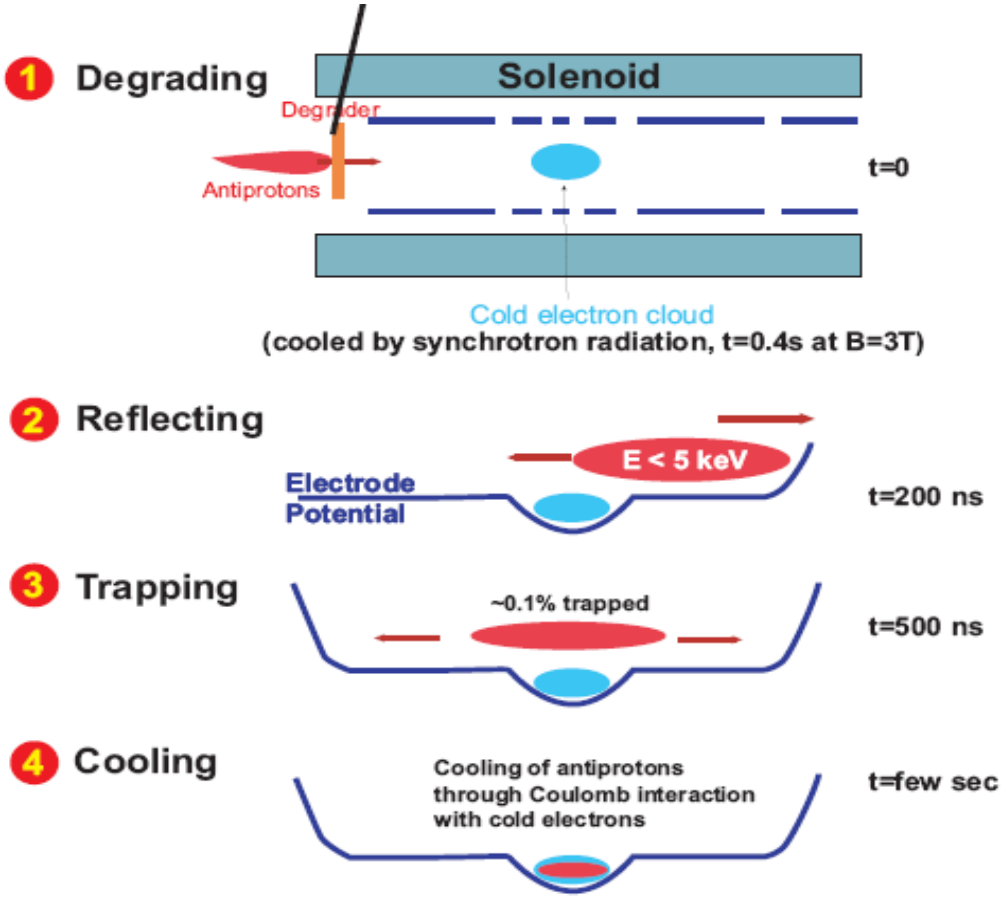
Problem: 5 MeV too high for trapping !



- > 99.9 % of pbars lost in degrader.

  ~ 10.000 pbars/shot

- ASACUSA: RFQ-D

  ~ 2.000.000 pbars/shot

<u>BUT</u>: $\Delta E/E$, $\varepsilon_{x,y}$

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FAIR – Facility for Antiproton and Ion Research

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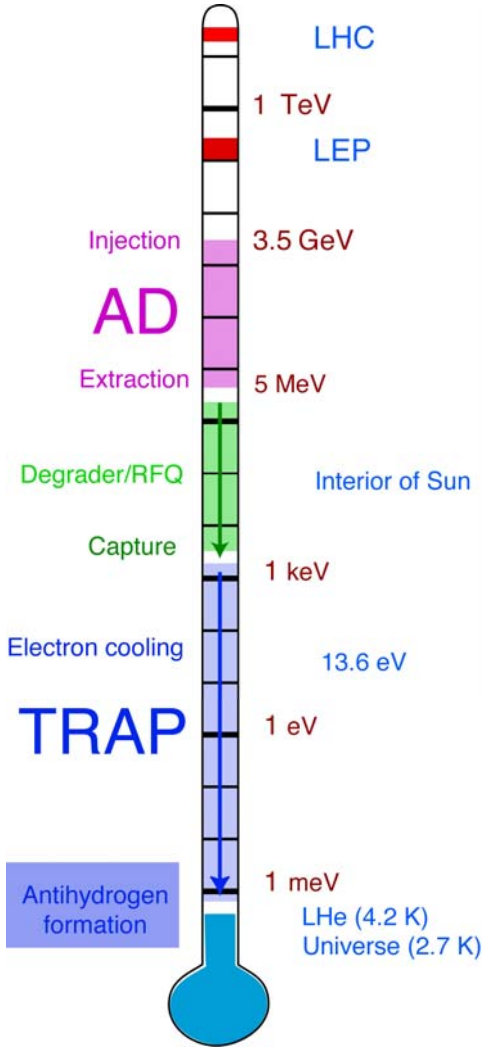
Challenges

Antiprotons and Positrons are created at very high energies (GeV).

H-atom is a weakly-bound system:

E (1s) = - 0.000 000 013 6 GeV

Deceleration & Cooling necessary !



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Idea: (add some) FLAIR to FAIR

- ***Austria*** (SMI, Vienna,TU)
- ***Canada*** (York, TRIUMPF)
- ***Denmark*** (Aarhus, ISA)
- ***Germany*** (GSI, Dresden, Frankfurt, MPQ, Giessen, MPI-K, FJZ, Mainz, Tübingen, Berlin)
- ***Hungary*** (KFKI, ATOMKI, Debrecen)
- ***India*** (VECC)
- ***Italy*** (Brescia, Firenze, Genova)
- ***Japan*** (RIKEN, Tokyo)
- ***Netherlands*** (Amsterdam, FOM)
- ***Poland*** (Warsaw, Soltan Inst.)
- ***Russia*** (JINR, Moscow, VNIIM, St. Petersburg, Troitsk, Moskva)
- ***Sweden*** (MSL, Stockholm)
- ***UK*** (Queens, Wales)
- ***USA*** (Harvard, Pbar Labs, New Mexico, Texas, Indiana)

150 Scientists ***15 Countries*** ***50 Institutes***

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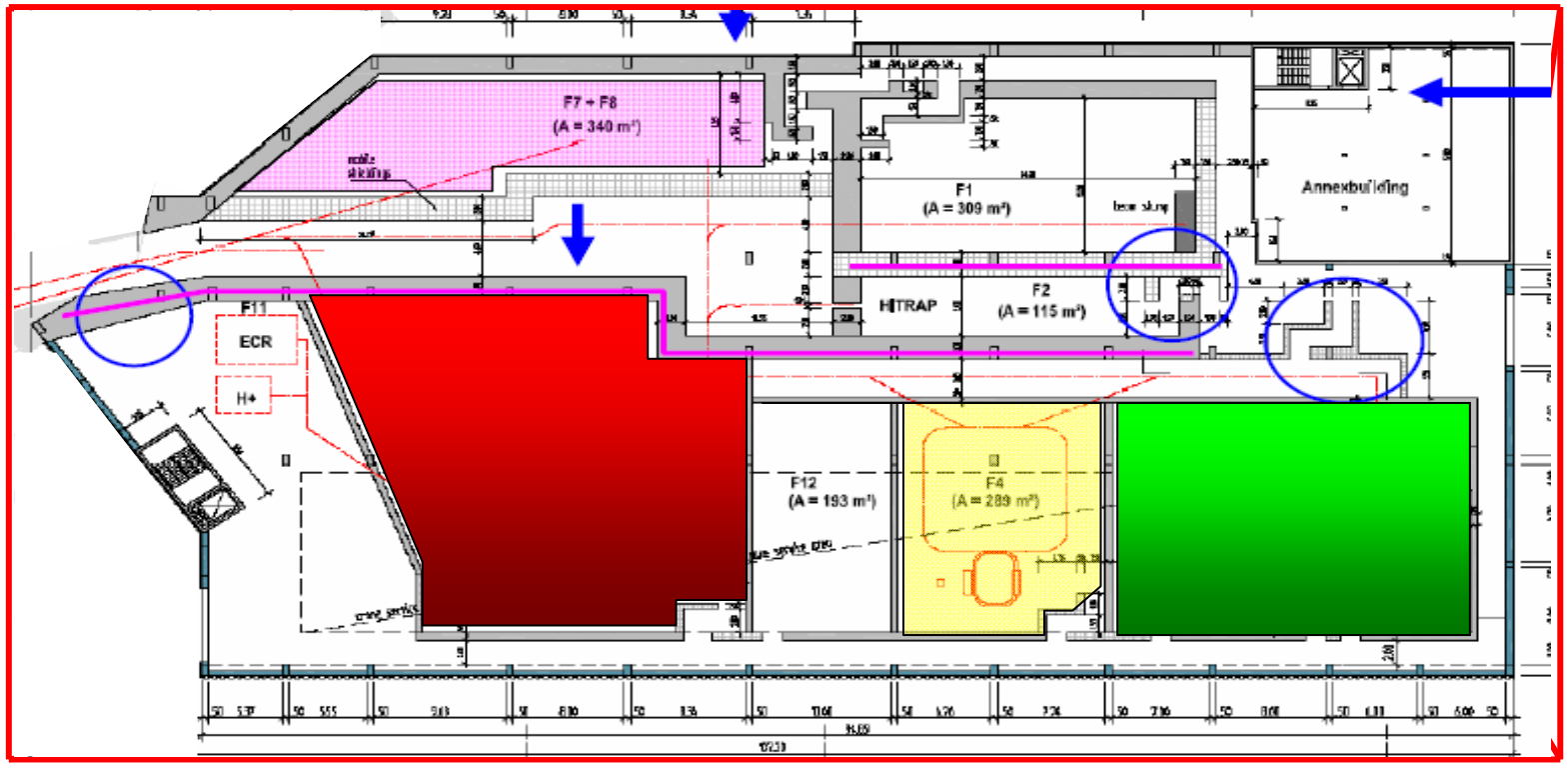
FLAIR @ Facility for Antiproton and Ion Research



30 MeV - 300 keV

300 keV - 20 keV

keV - ... eV

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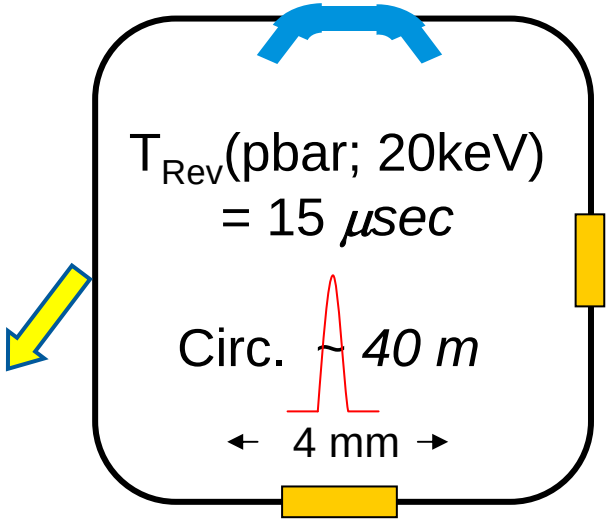
USR - Goals

- Variable to lowest energies
  - 300 keV ~ 20 keV
- High luminosity for in-ring experiments
- Well-defined extracted beams:
  - Small emittance
  - Small momentum spread
- Multi-user operation:
  - 2 straight sections for in-ring experiments
  - Slow and fast extraction
  - Additional beam lines possible
- Central requirements
  - Δt ~ 500 nsec for Injection in traps
  - Δt ~ 2 nsec / 10^4 ions for collision studies



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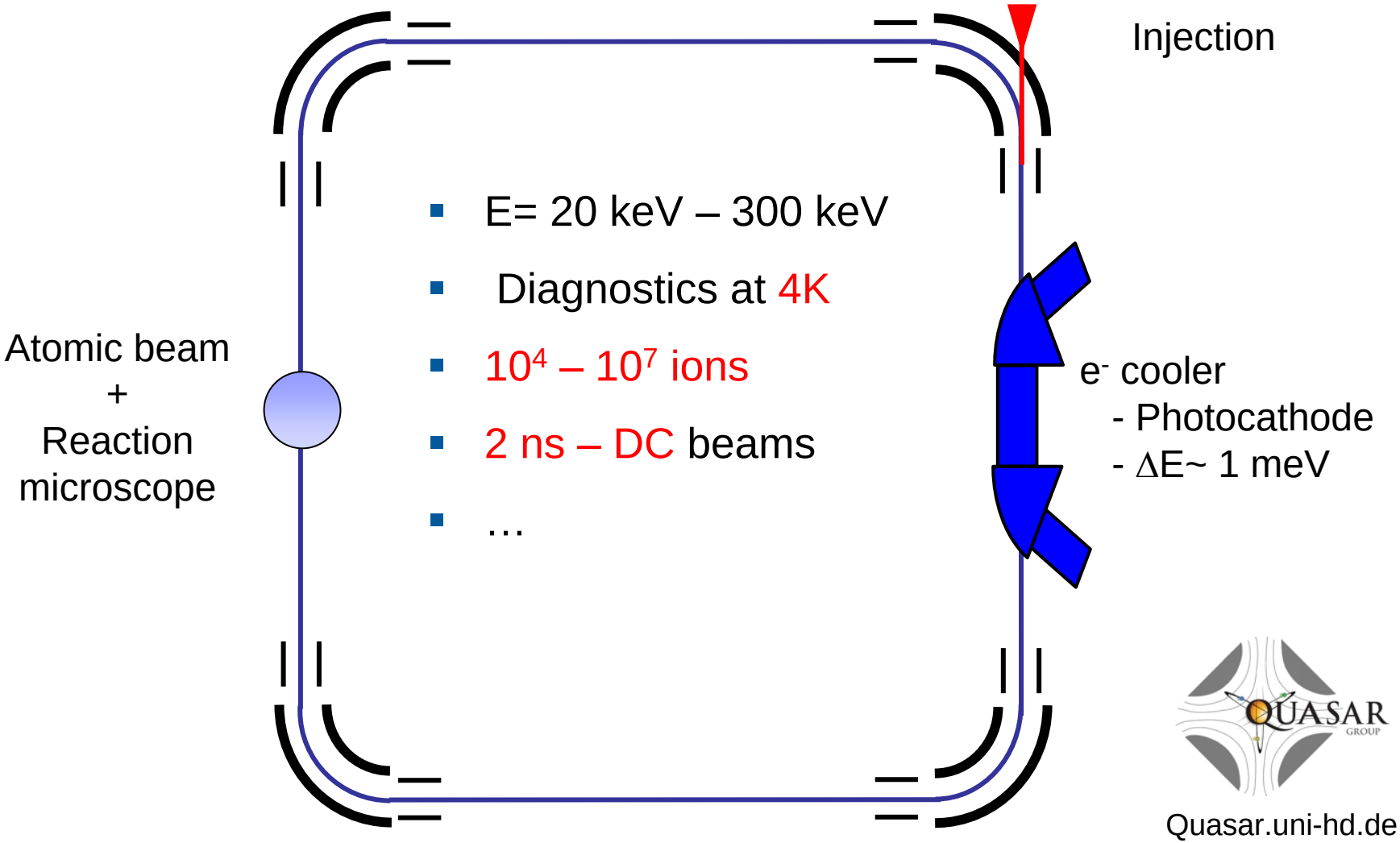
USR - Challenges



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DITANET: Training

- Local training by host
- Network-wide schools on diagnostic techniques
- Inter-network exchange of researchers
- Secondments to partners from industry
- Training in complementary skills

Motivation: *Ideal* Training.

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Outreach

- DITANET schools in 03/2009 (London) and 09/2010 (Stockholm)
- DITANET conferences in 2009 and 2011 (DIPAC ?!)
- Mini-Symposia, workshops throughout 4 years

Open to external participants.

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Conclusion

- Unique opportunity to push this field;
- Developments through joint effort between research centers, Universities and the private sector;
- Innovative approach to training of young researchers;
- Many events interesting for whole community;
- Stimulation of research careers in beam diagnostics.

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