# Design Considerations of *table-top* FELs

DESY, June 20; recap of *FLS 2006, May 15, 2006*

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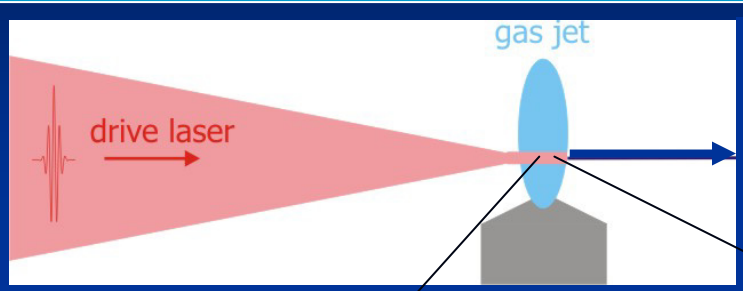
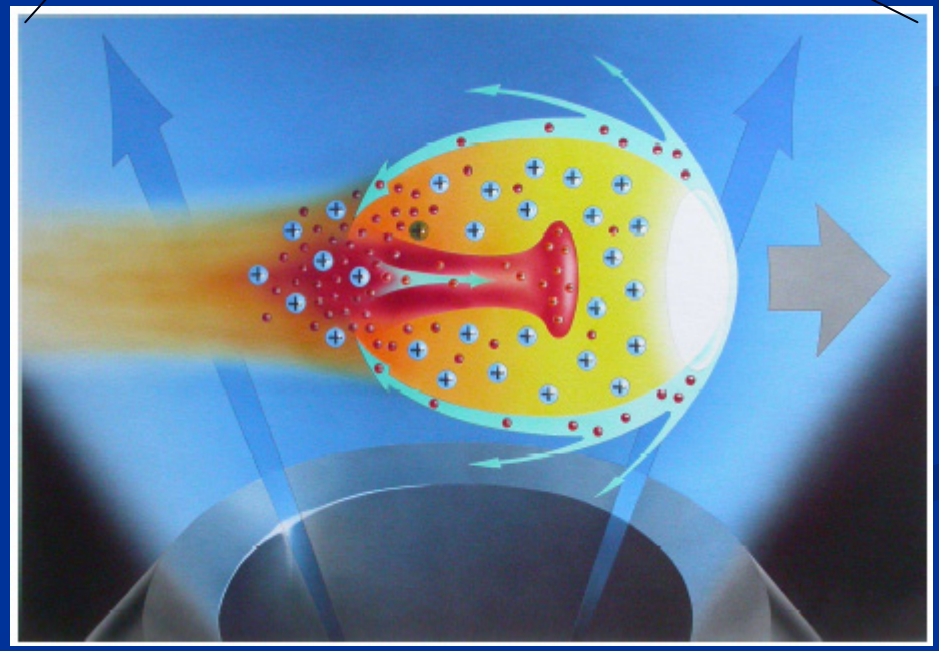
- laser-plasma accelerators
- principal possibility of *table-top* FELs
- possible VUV and X-ray scenarios
- *new* experimental status
- critical points review
- cooperation with DESY…

# Laser-Plasma accelerators: “bubble acceleration”

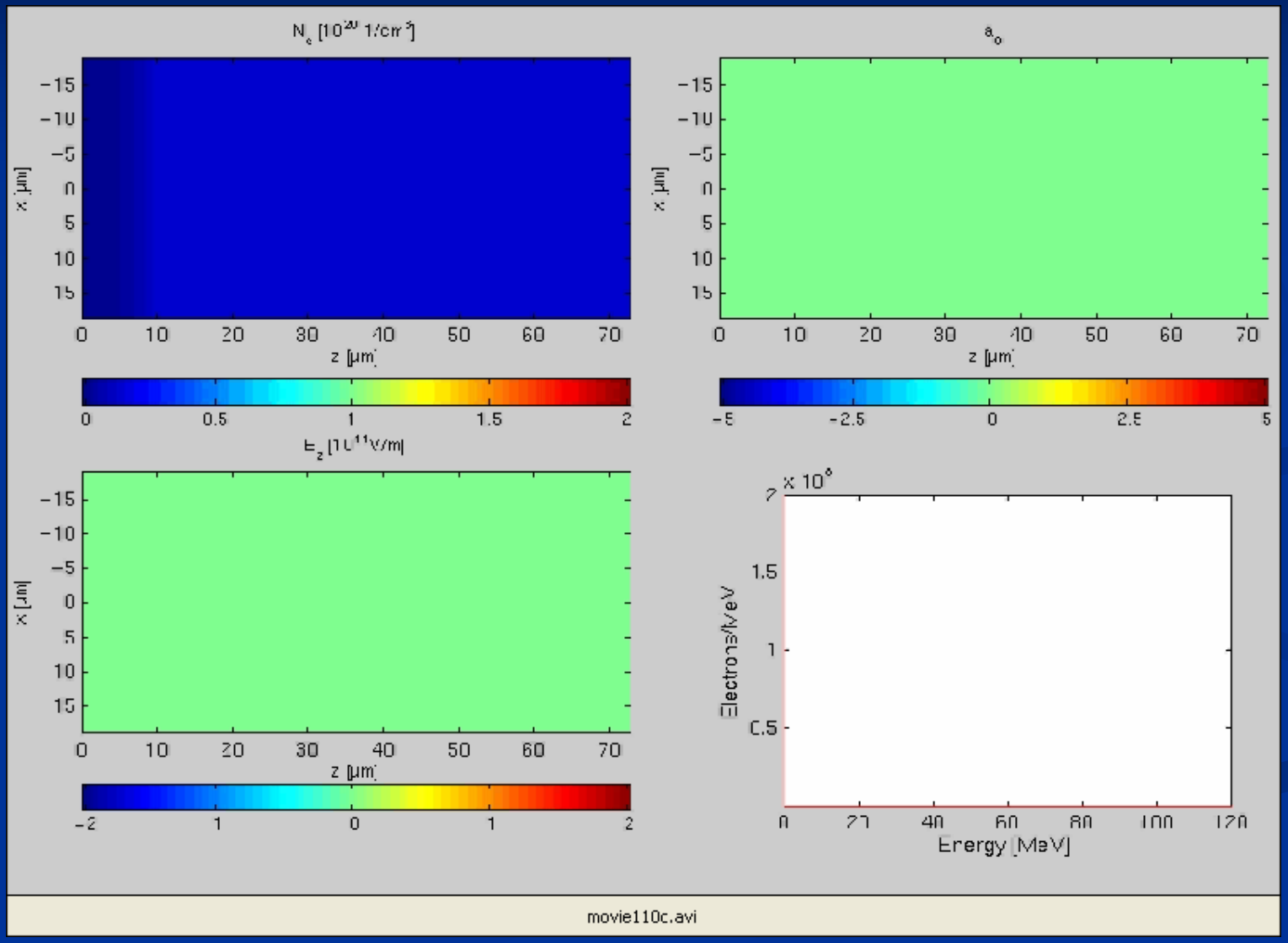
TW laser,
5-50 fs

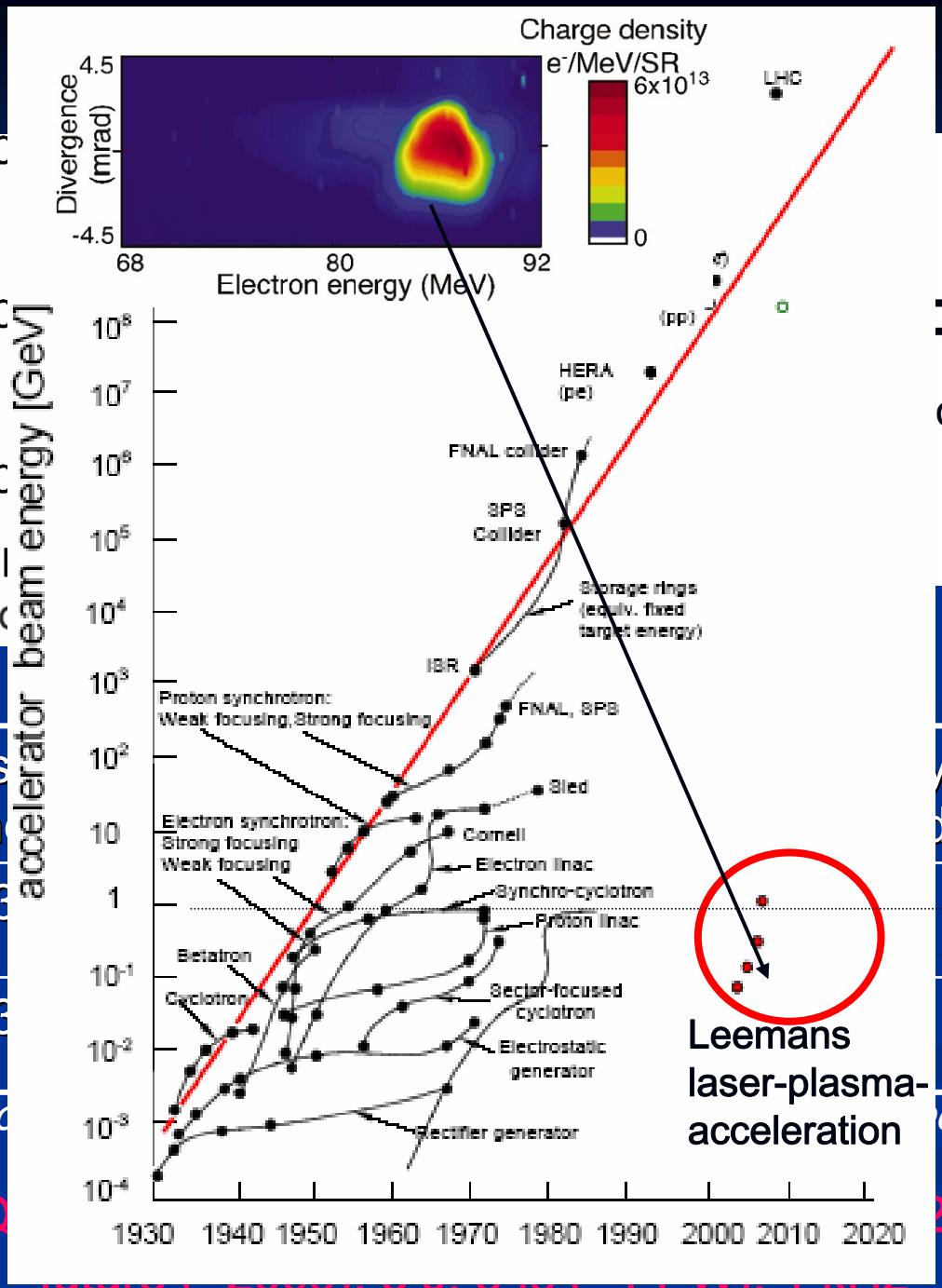



electron bunch:
e.g. 170 MeV (LOA),
1.2 GeV (Berkeley)

# M. Geissler PIC code 5fs, a=5






= 300 µm

capillary

| year | las… en… | …y …d | divergence |
|---|---|---|---|
| 2004 | 0.3 | | 3 mrad |
| 2006* | 1.3 | | 1.6 mrad |

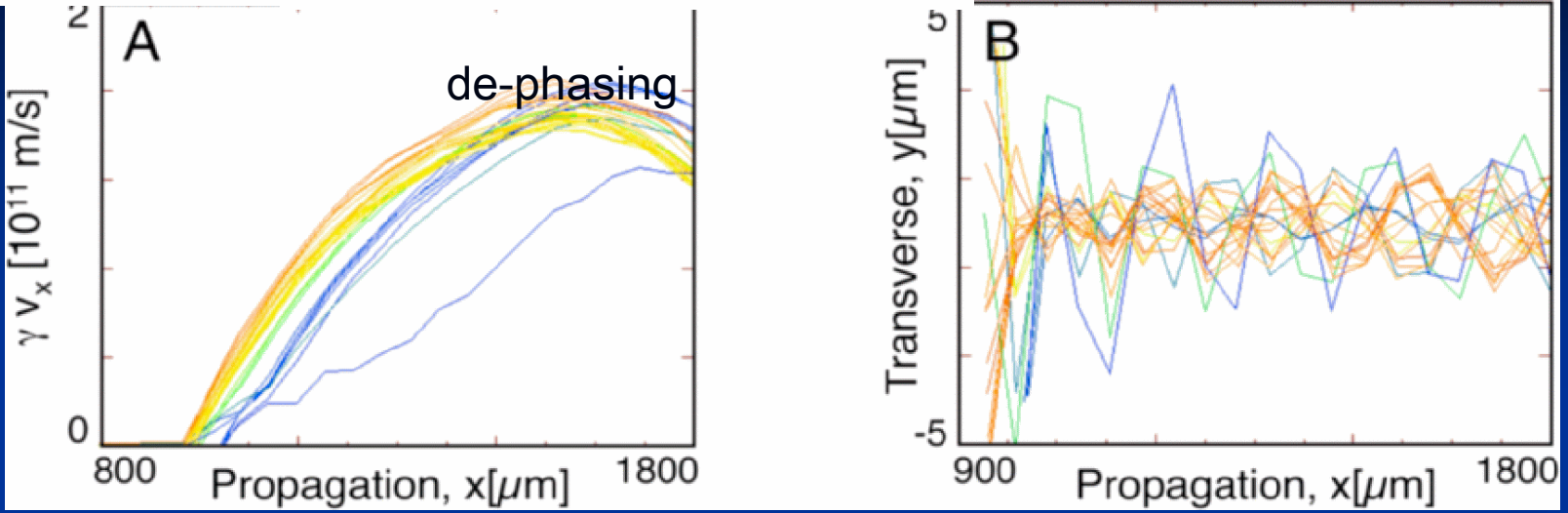
* presented at *And… …d to Science*

MPQ… …2 J

future (~2008): 3 J, 30 fs (~100 TW), 1 kHz

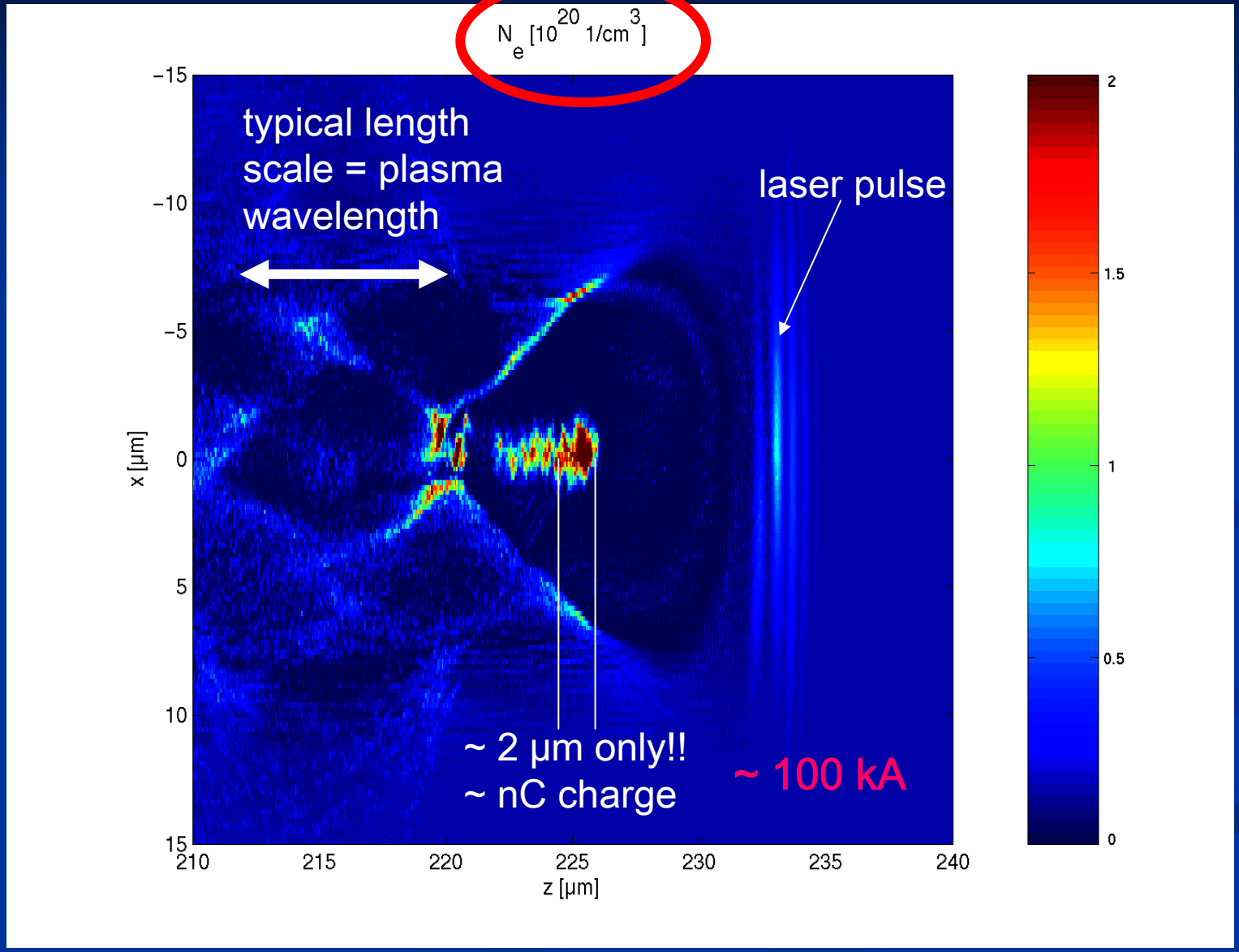
# Improvement by capillaries

Geddes *et al.* Phys. Plasmas **12**, 056709 (2005)




- discharge introduces parabolic electron density
- laser guiding beyond Rayleigh length → higher energies
- de-phasing: reducing energy spread
- ion-channel: reducing electron beam diameter and divergence
- possible scenario: bubble turns into linear wakefield → GeV- energies with ~0.1% energy spread
- started cooperation with Simon Hooker (Oxford)

# Important feature: ultra-high current



# Principal possibility for *table-top* FELs

simplest estimate: ideal 1d Pierce parameter (no energy spread, emittance, diffraction, time-dependence)

current : few 100kA (classical: 5 kA)

und. period : few mm (class. few cm)

$$L_{gain,\mathrm{ideal}} = \frac{\lambda_u}{4\pi\sqrt{3}\rho}$$

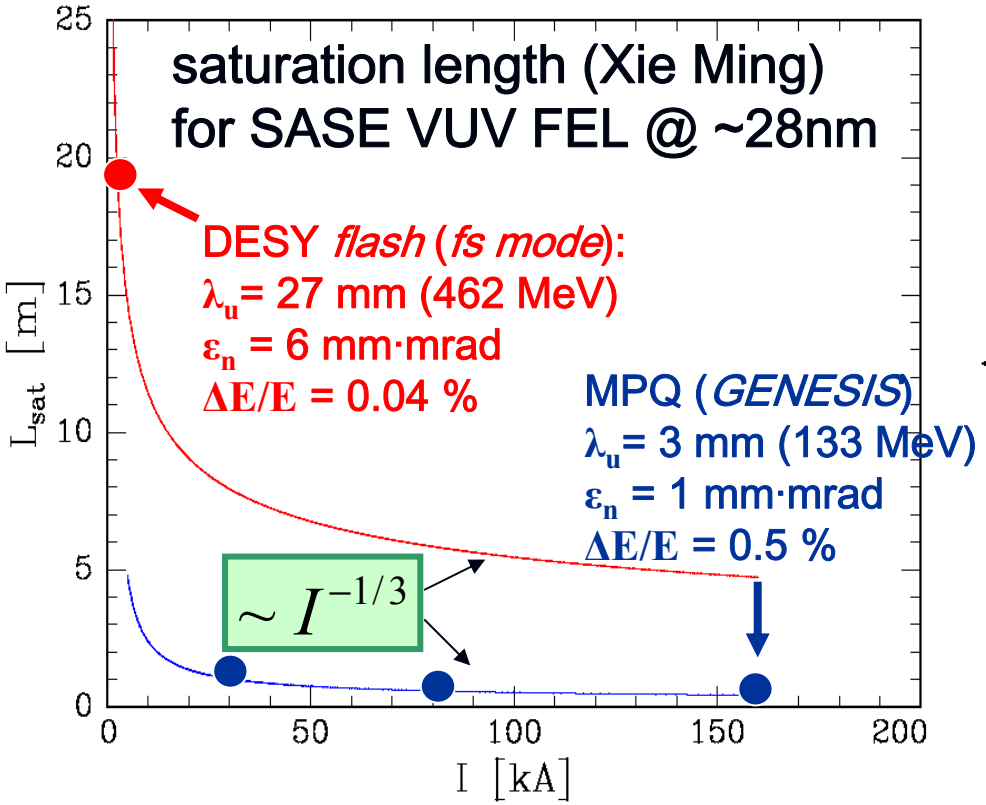
$$\rho = \frac{1}{2\gamma}\left[\left(\frac{I}{I_A}\right)\cdot\left(\frac{\lambda_u A_u}{2\pi\sigma_x}\right)^2\right]^{1/3}$$

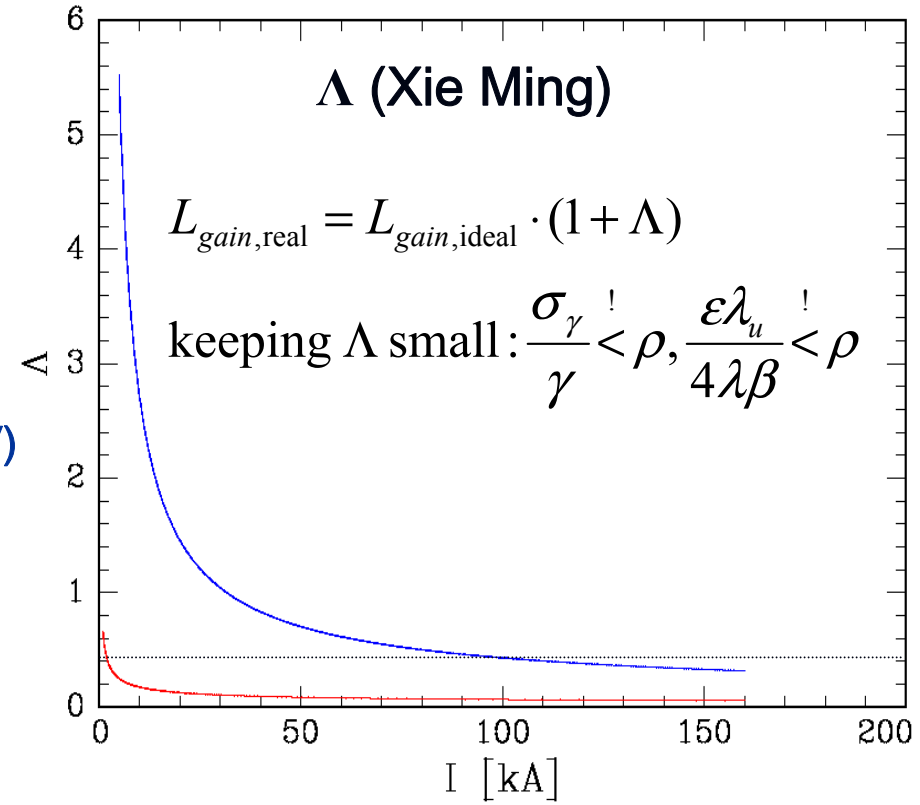
beam diameter (optimal!)

$$L^{XieMing}_{gain,\mathrm{real}} = L_{gain,\mathrm{ideal}}\cdot(1+\Lambda)$$

$$L_{sat} \approx 15\cdot L_{gain}$$

# Constraints for *table-top* FELs



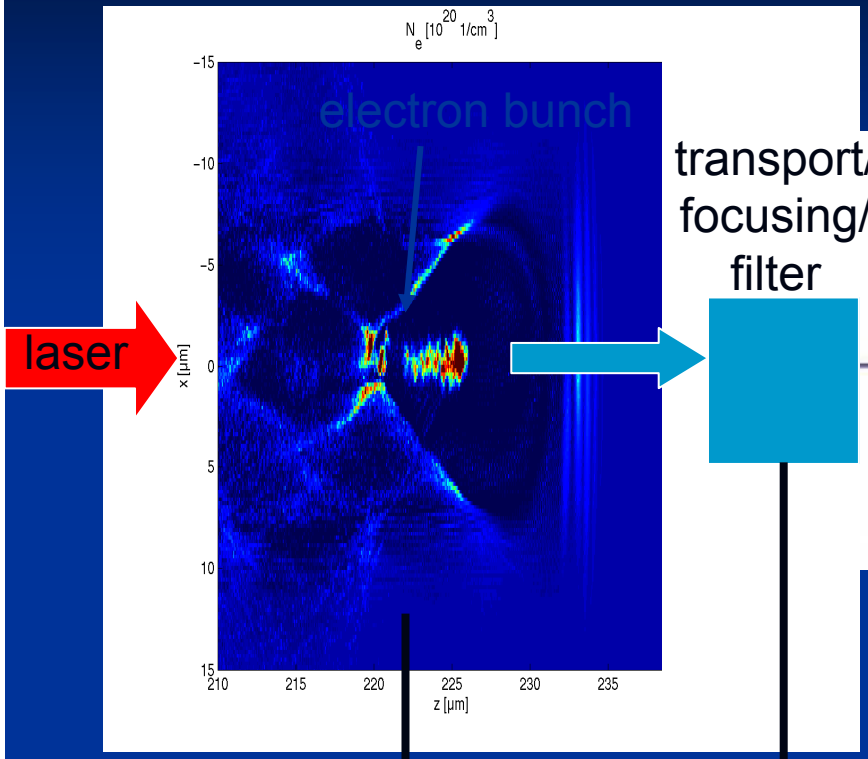




- not only table-top size, but sufficient **output power:**

$$P_{sat} \sim \left(\frac{1}{1+\Lambda}\right)^2 \cdot (I \cdot \lambda_u)^{4/3}$$

reduction in $\lambda_u$ allows a reduction in $\gamma$, but needs ultra-high current for keeping $\rho$ and also saturation power large enough

# Start-to-End Simulations




laser

transport/
focusing/
filter

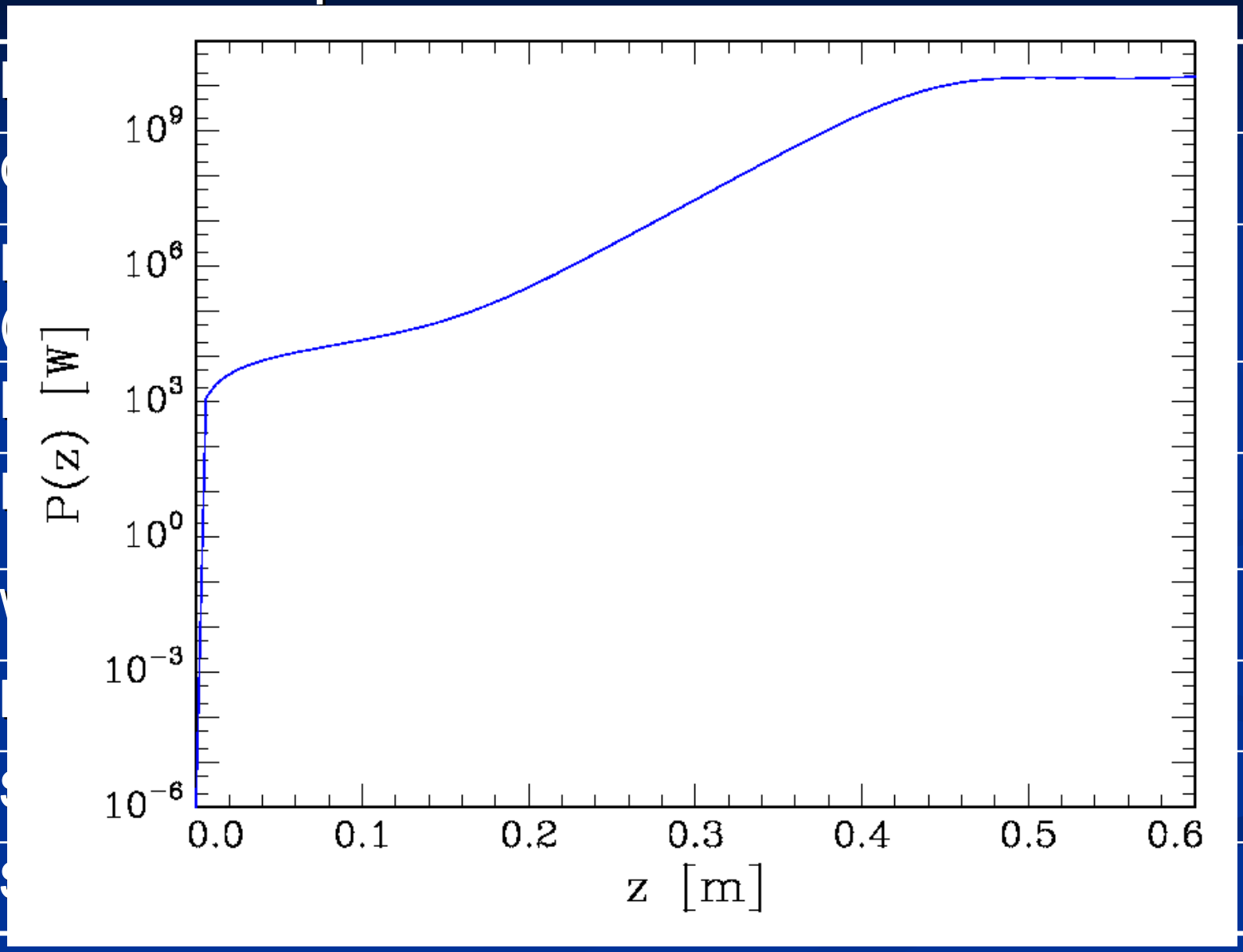
FEL undulator

own 3d
PIC code

GPT,
Geant

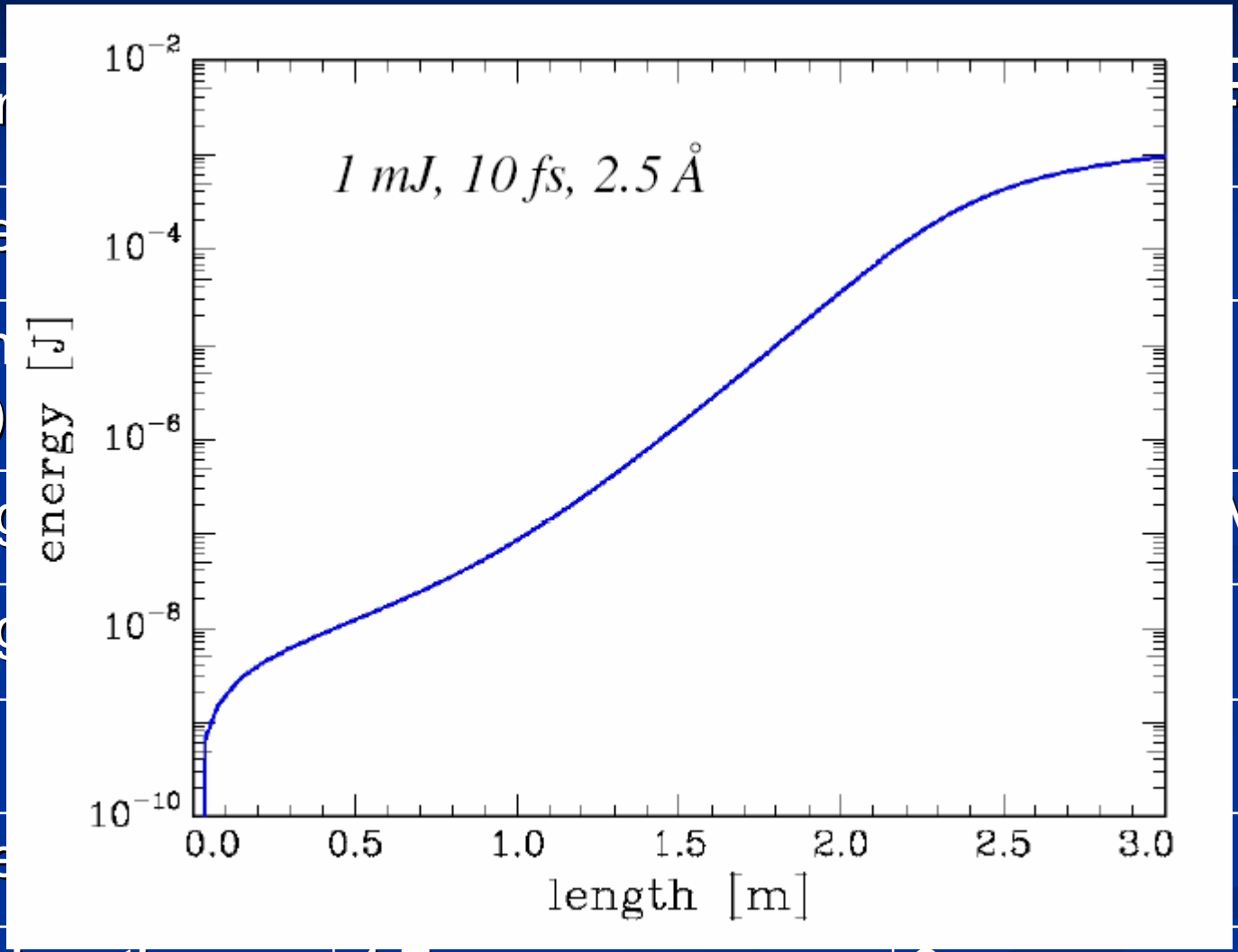
CSRTrack, Spur;
GENESIS 1.3

# A possible first VUV case

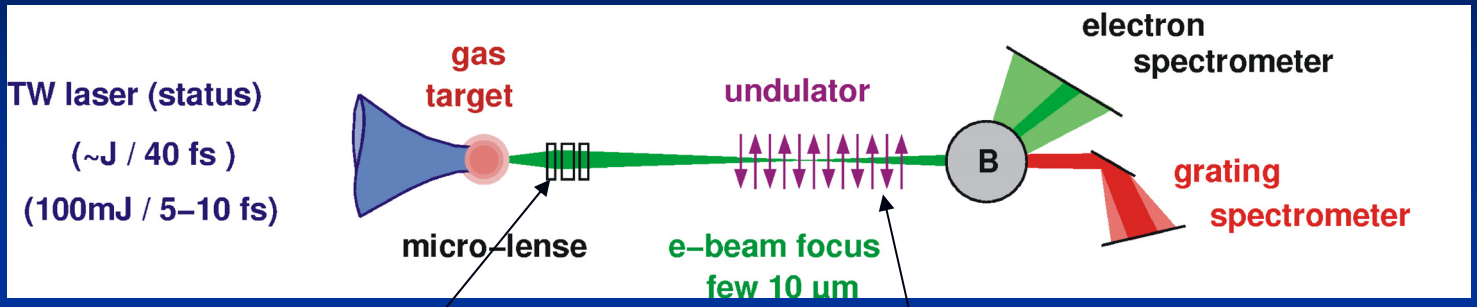


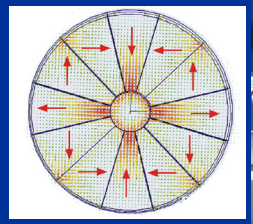
# International competition and a possible first table-top XFEL case

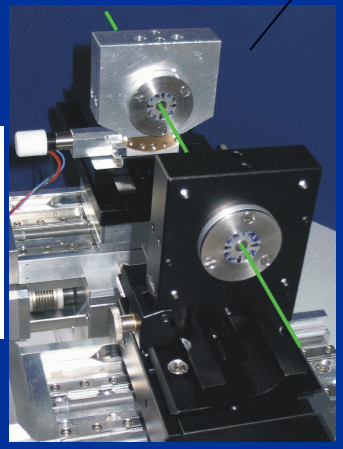
| Parar | | FEL) |
|---|---|---|
| Curre | | |
| Norm (rms) | | |
| Energ | | V |
| Energ | | |
| Und. | | |
| Wave | | |
| Und. length | 4.7 m | 3 m |

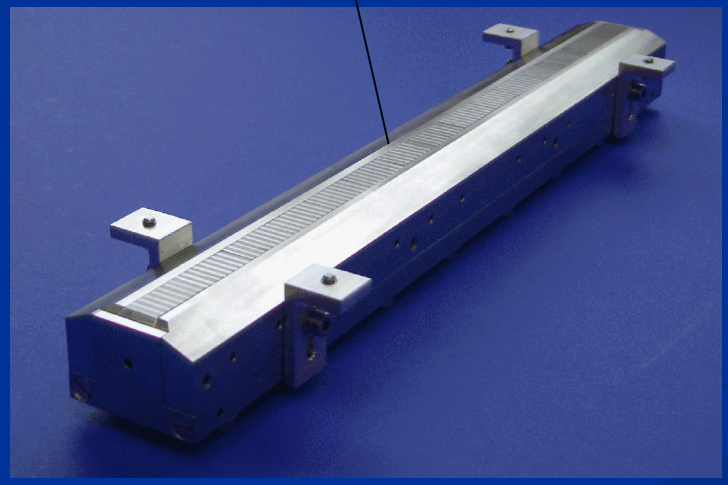


# New Experimental Status







undulator:
60 periods, 5 mm period, 1.6 mm gap
~1 T field on axis

few days ago:
40 MeV electrons

# Critical Points Review

- **space charge** influence due to ultra-dense bunches
  - HOMDYN (*L. Serafini*): for 1 GeV correlated energy spread 0.5 %, no debunching
  - GPT/CSRtrack runs (see next talk)
  - simple analytical estimates in agreement with GPT
  - linear energy chirp can be compensated with tapering
- **transverse coherence**
  - $\varepsilon < \frac{\lambda}{4\pi}$ valid only for spontaneous source, here: gain guiding
  - calculate growth rate of next higher mode with GENESIS
  - transverse coherence important for focusing only?
- **peak brilliance**: $10^{32}$ @ 5 keV - comparable with LCLS!
  ($10^{12}$ phts/0.1%BW, $\theta$=15μrad, $\sigma_x$=30μm, $\tau$=10fs)

# Cooperation with you…

- verify our GPT results with ASTRA
- verify entire feasibility study (publishing a joint paper)
- discuss beam features in detail (slice energy spread, etc.)
- for experiments: diagnostic methods (FROG)
- open questions, such as maximum photon energy

- what could *you* learn from *us*????