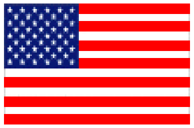
Flat e- beams production at FNPL photoinjector (E-886)

- FNPL is a collaborative effort amongst several institutes and universities to operate a high-brightness electron photo-injector dedicated to fundamental beam physics and advanced accelerator R&D
- Main support comes from FNAL & North Illinois Center of Accelerator & Detector Development (NICADD)

- Collaborators includes:



U. of Chicago, U. of Rochester, UCLA,
U. of Indiana, U. of Michigan, LBNL, NIU,
U. of Giorgia, Jlab, Cornell University

DESY, INFN-Milano, IPN-Orsay
CEA-Saclay

The FNPL experiment (E-886)

- **Since mid 90's:** FNAL operates a high brightness photo-injector (A0 now FNPL)

- Copy of FNPL was installed at TTF-1 (DESY) and supported SASE-FEL operation (100 nm)

Main beam parameters:

E= 16 MeV

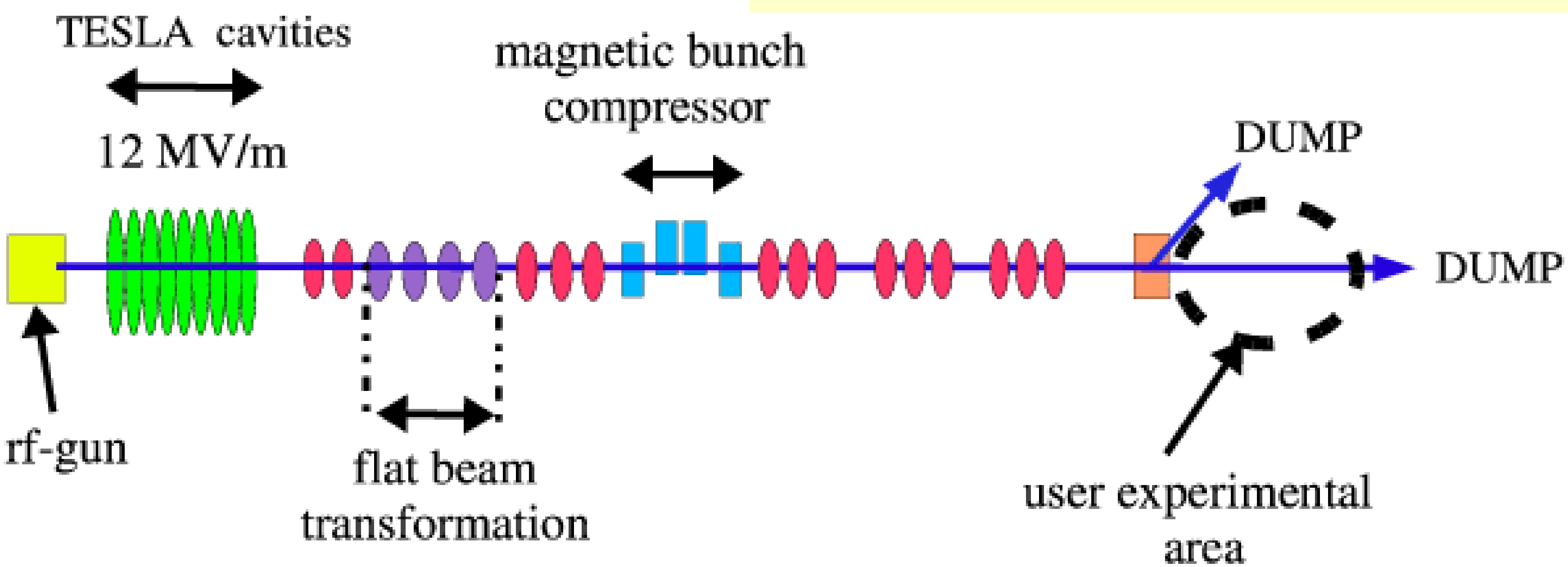
Q= 0 to 15 nC,

ε_T =3.7 mm-mrad (1 nC)

δp/p=0.25 % (1 nC)

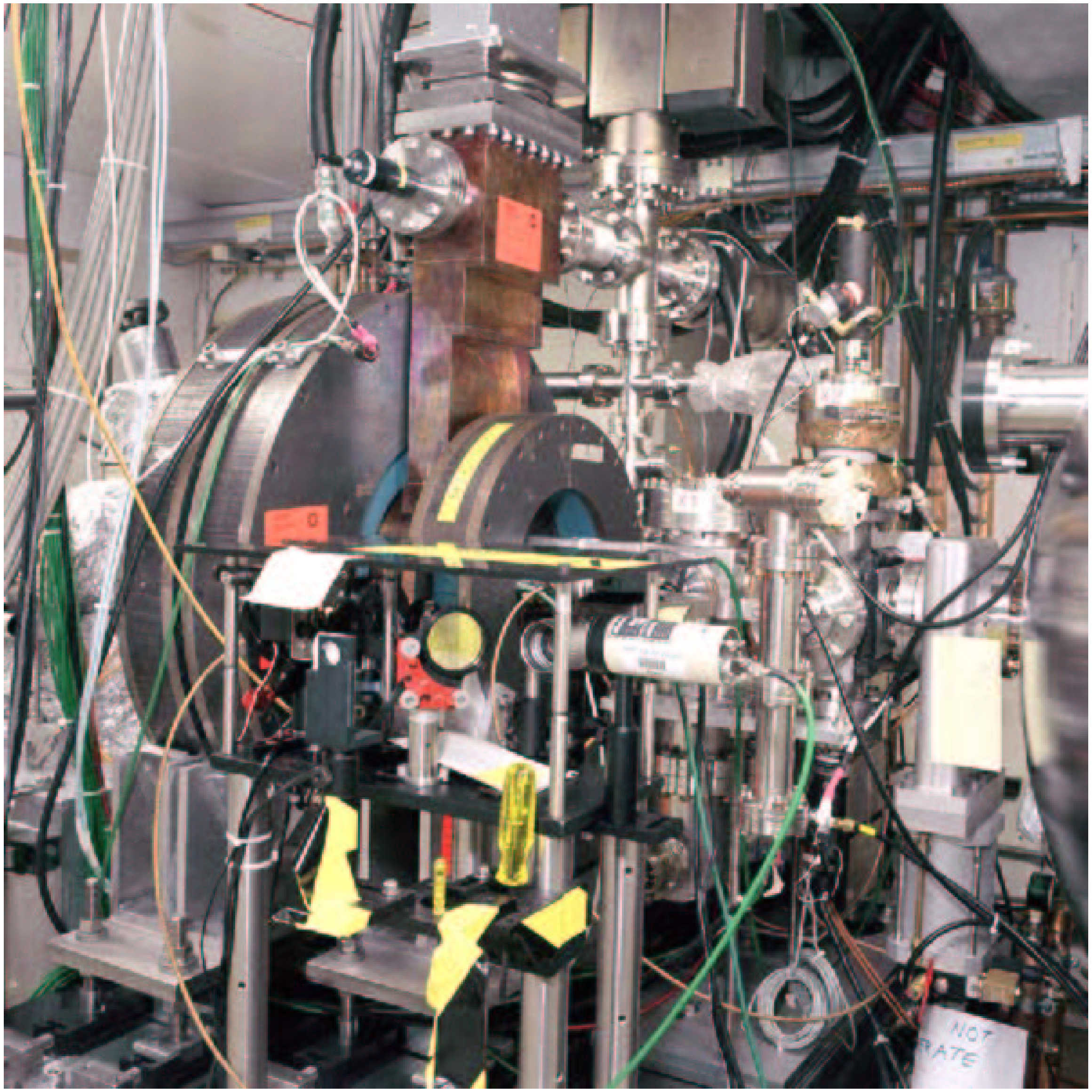
I_{peak} = 75-330 A (BC off)

I_{peak} = 200-1700 A (BC on)

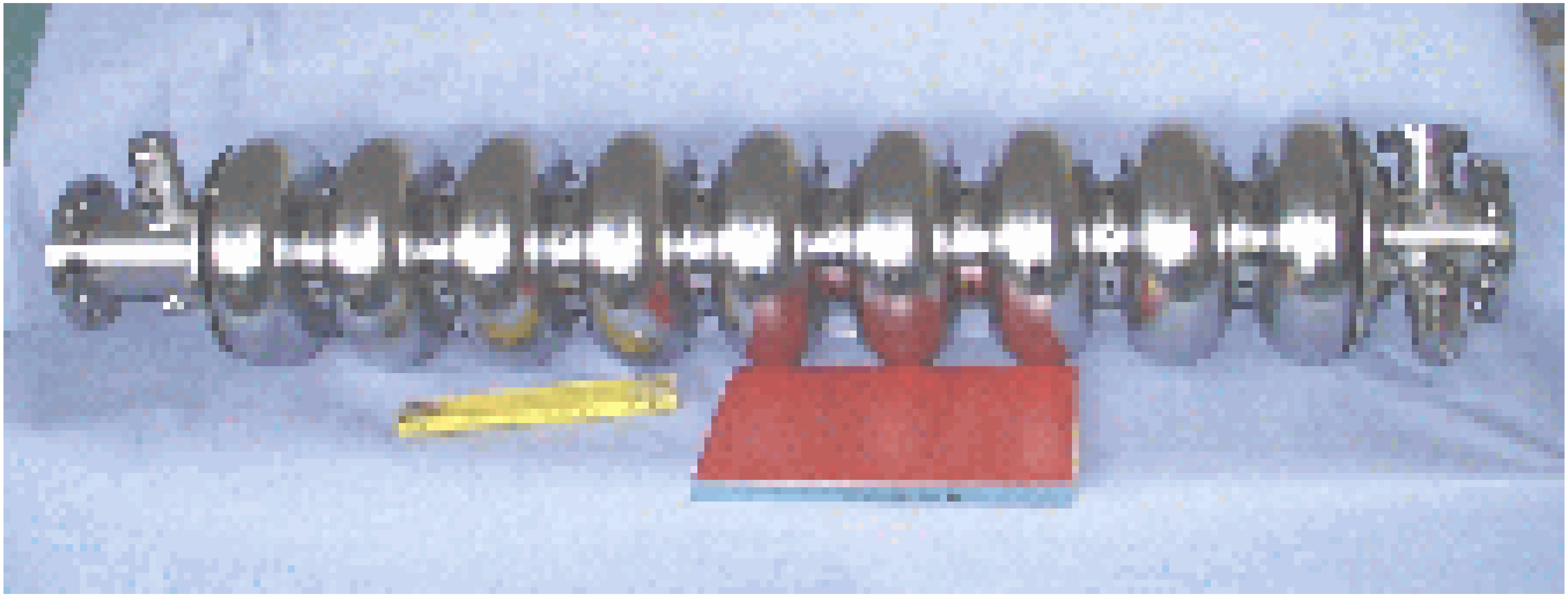


The FNPL experiment

- Electron source based on photo-electric effect
- Cesium Telluride cathode illuminated with a UV laser (λ~260 nm)
- E-field on cathode 35 MV/m
- Electron source designed for the TESLA linear collider unpolarized electrons source (in term of pulse format)



The FNPL experiment



- Beam energy boosted to 16 MeV with one superconducting TESLA cavity (soon we should have two of them and beam energy should approach the 50 MeV)

Research highlights

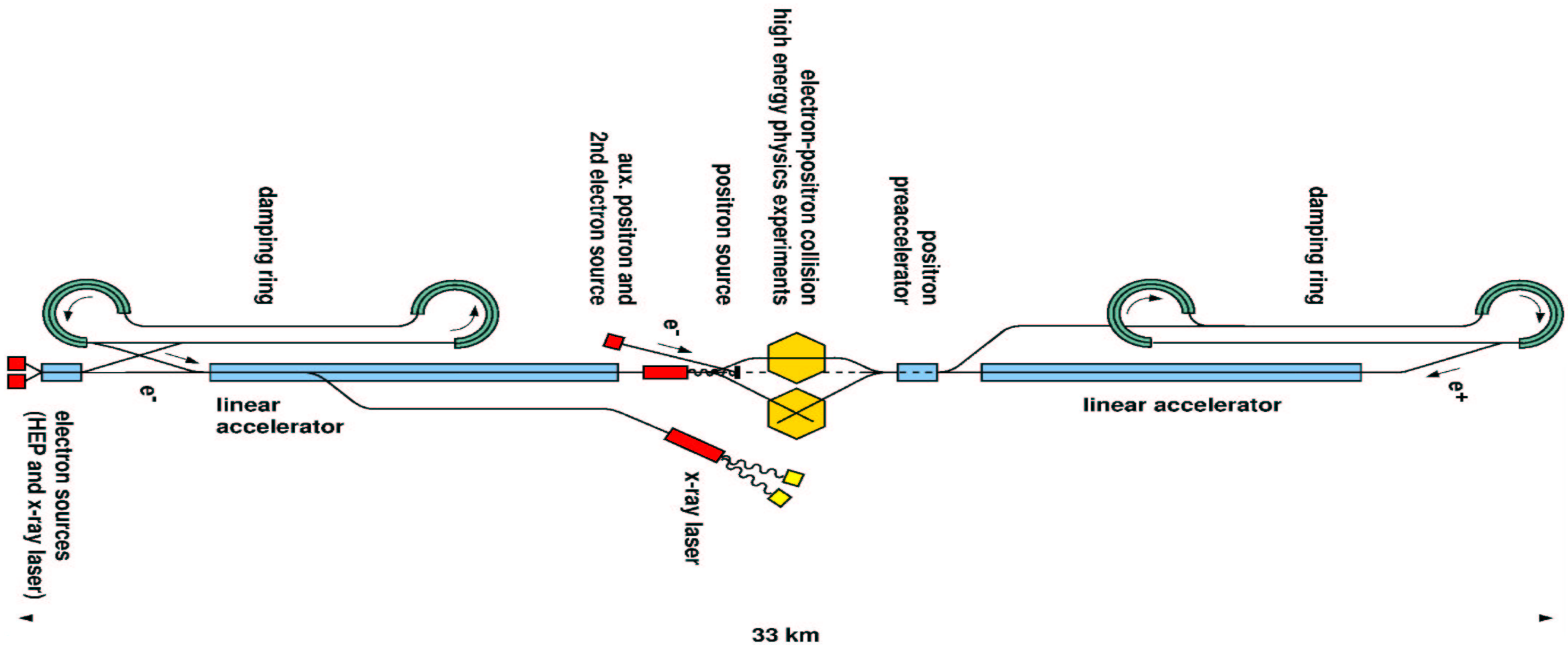
Several topics under investigation:

- Beam dynamics associated to high-brightness electron beams
- Flat beam experiment **(what I will "touch" today)**
- Plasma-based acceleration
- Electron source based on electron trapping at a plasma density transition
- R&D on electron beam diagnostics
- R&D toward laser acceleration of electrons

Applications of Flat beams

- All the proposed linear colliders rely on the generation of flat beams to be less sensitive to beamstrahlung at the IP

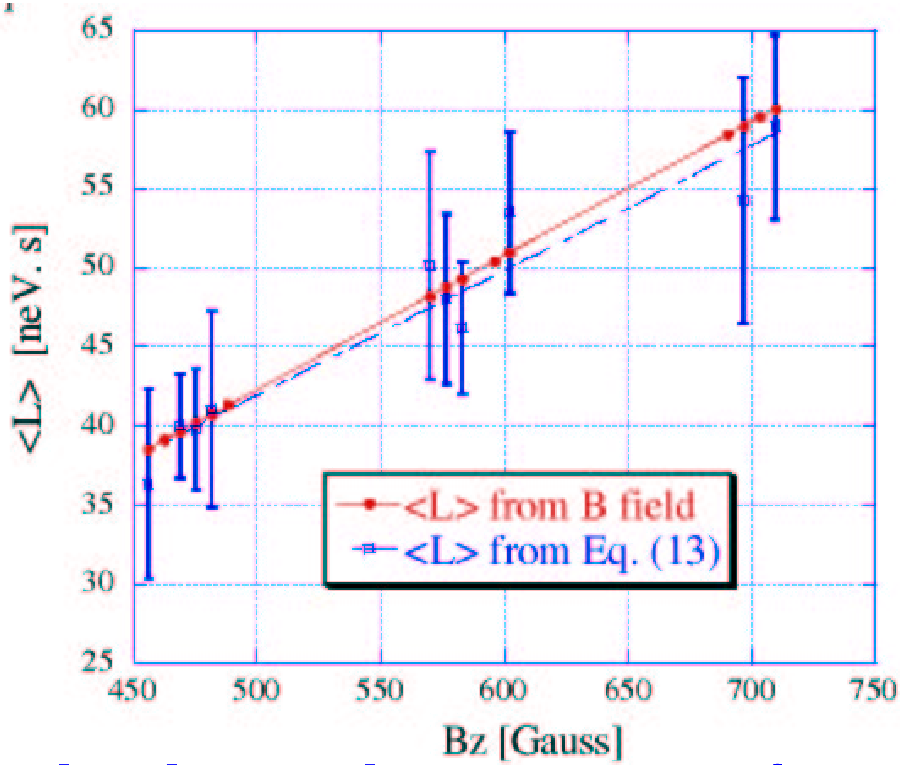
- Flat beam are usually achieved in damping rings (damping ring circumference for TESLA LC is 17 km!)

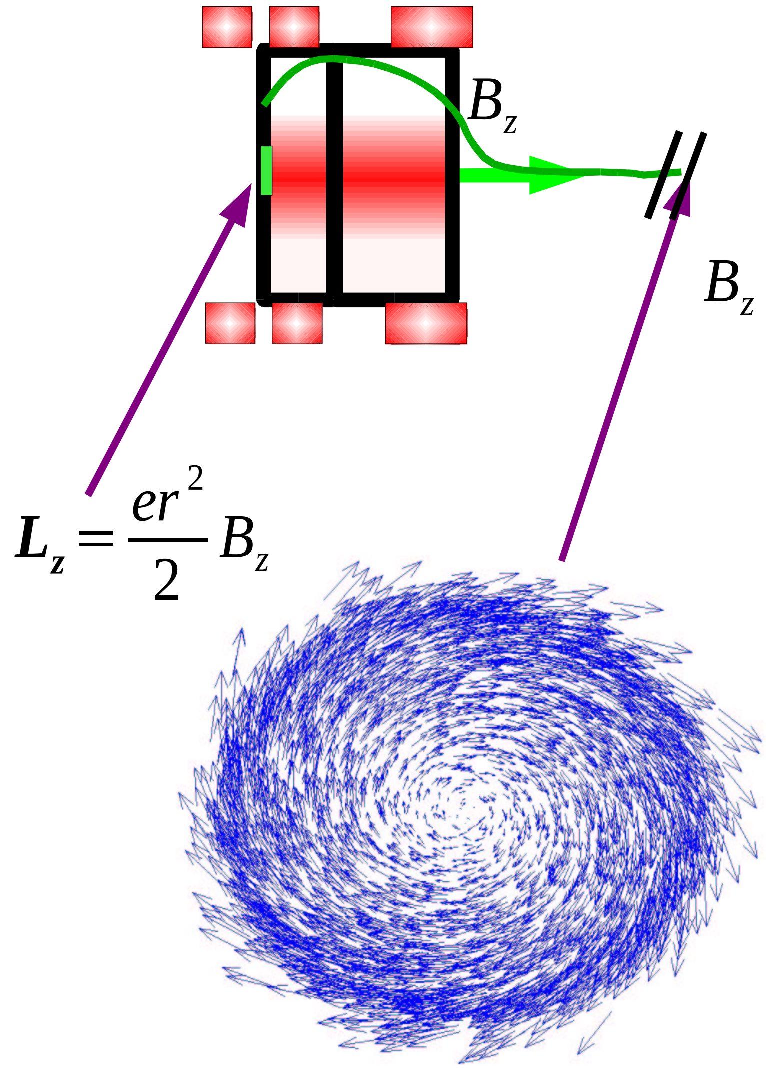


- A proposal for a ultra-short X-ray pulse linac-based light source at LBNL also require the use of flat beam

Photo-injector production of flat beams

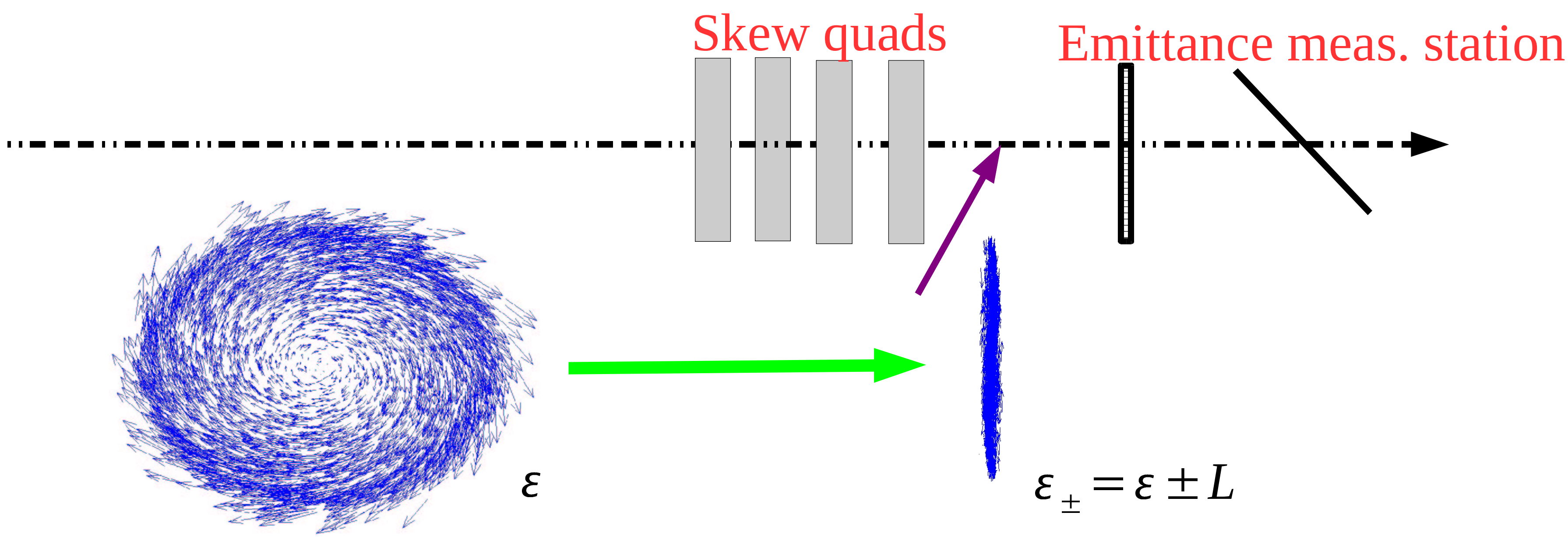
- An electron beam with an angular momentum $\boldsymbol{L} = \boldsymbol{r} \times \boldsymbol{p}$ by immersing the photo-cathode in a non-vanishing axial B-field.





- As the electron beam emerges from the magnetostatic field, in virtue of the conservation of canonical angular momentum, it acquires a kinetic angular momentum

Photo-injector production of flat beams

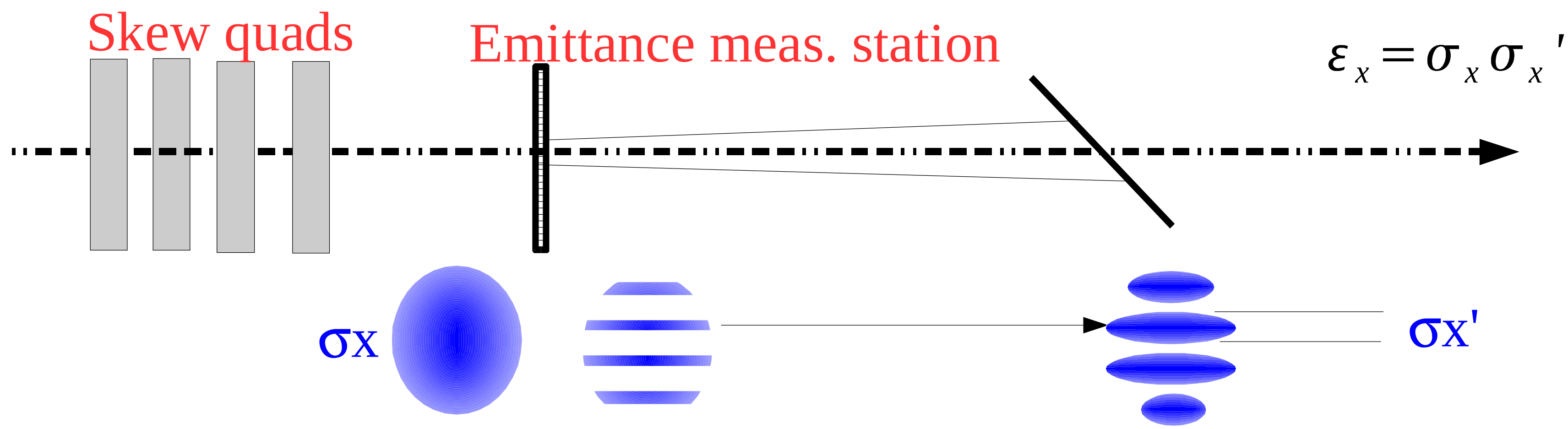


- A linear transformation using skew quadrupoles can be built to remove the angular momentum

- In such a process an incoming cylindrical symmetric beam (with equal transverse emittances) is transformed into a flat beam with emittance ratio given by:

$$\frac{\varepsilon_{+}}{\varepsilon_{-}} - 1 \propto B_z^2 \frac{\sigma_r^2}{\sigma_{r'}^2}$$

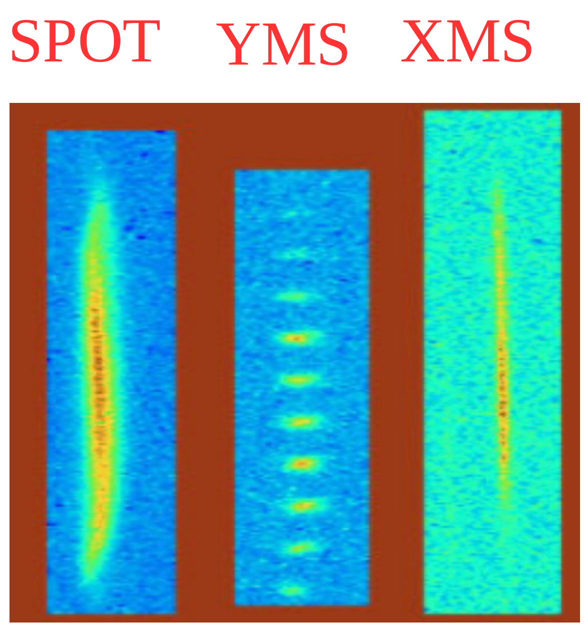
Photo-injector production of flat beams



- Downstream of the skew quadrupole channel, we have an emittance measu-rement station

- To date best emittance ratio achieved about 50 with smallest/largest emittance of ~1 and ~50 mm-mrad respectively

- Since few weeks we are studying the transformation itself



Summary

I just gave a BRIEF overview of our facility and some words on one on-going experiment, I hope in the future you will hear about these people on the following topics:

- R&D on polarized rf-gun (M. Huening, FNAL)
- Plasma wakefield acceleration of electron (N. Barov, NIU)
- Sub-picosecond bunch length measurement (D. Mihalcea, NIU)
- Flat beam studies (Y.-E. Sun, Chicago)
- Laser acceleration of electrons (R. Tikhoplav, Rochester)