OPAL Status – pre 1.1.6

Andreas Adelmann
for the OPAL development team:

Ch. Kraus (PSI), Y. Ineichen (PSI/IBM), S.Russell (LANL) Y. Bi and J.Yang (CIAE)

with contribution of H. Guo & B. Oswald (FEMAXX)

On felsim:

```
module load opal-1.1.5
~adelmann/bin/opal-pre1.1.6
```

On Rosa (CSCS):

```
export PATH=~adelmann/bin:$PATH
```

Content

- Why OPAL – What is OPAL
- New Features (1.1.5 & 1.1.6)
- Recap Validation Strategy
- OPAL – FEMAXX & Lola
- Future of OPAL Development in AMAS and around the World

OPAL is a tool for charged-particle optics in large accelerator structures and beam lines including 3D space charge

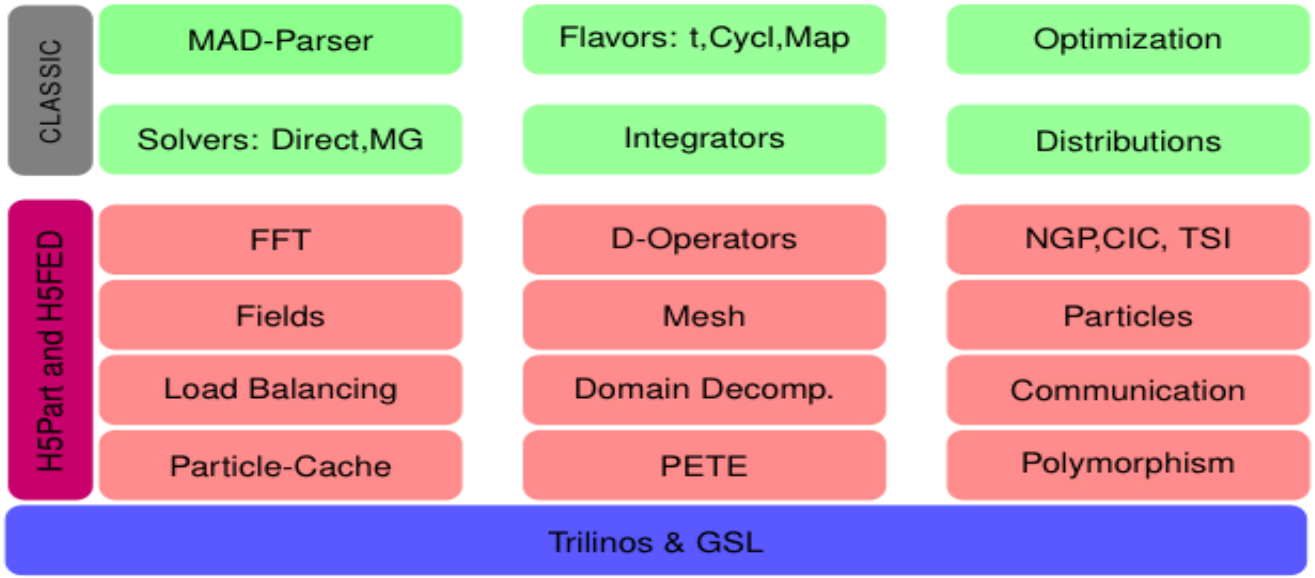
- OPAL is built from the ground up as a parallel application exemplifying the fact that HPC (High Performance Computing) is the third leg of science, complementing theory and the experiment. Hence OPAL enables the simulation of:
  - multi scale problems with O(n == real number of particles)
- OPAL runs on your laptop as well as on the largest HPC clusters
- OPAL uses the MAD language with extensions.
- OPAL (and all other used frameworks) are written in C++ using OO-techniques, hence OPAL is very easy to extend.
- Documentation is taken very seriously at both levels: source code and user manual http://amas.web.psi.ch/docs/index.html
- Regression tests running every day on the head of the repository

OPAL in a Nutshell cont.

OPAL is developed within an international collaboration including Los Alamos (LANL), China Institute of Atomic Energy (CIAE) and Tsinghua University, Beijing.
OPAL comes in 4 flavors:

- OPAL-t tracks particles which 3D space charge uses time as the independent variable, and can be used to model beamlines, guns, injectors and complete XFEL's but without the undulator.
- OPAL-cycl tracks particles which 3D space charge including neighboring turns in cyclotrons and ffags with time as the independent variable.
- OPAL-map tracks particles with 3D space charge using split operator techniques (not fully released yet).
- OPAL-envelope is based on the 3D-envelope equation i.e. a HOMDYN/BET like model (not fully released yet)

OPAL is based on several Frameworks



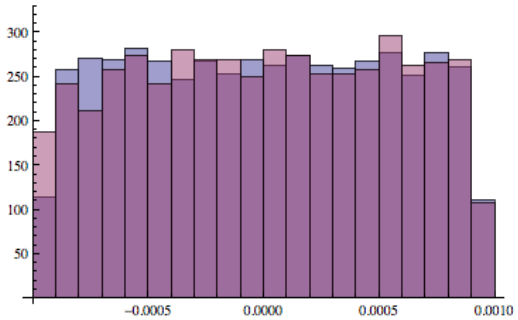
- **OPAL Object Oriented Parallel Accelerator Library**
- **IP^{2}L Independent Parallel Particle Layer**
- **Class Library for Accelerator Simulation System and Control**
- **H5PART and H5FED for parallel particle and field I/O (HDF5)**
- **Trilinos http://trilinos.sandia.gov/ & GNU Scientific Library**

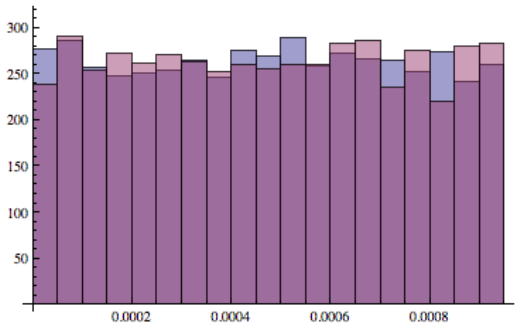
November 17, 2009 1 / 1

New Features -1

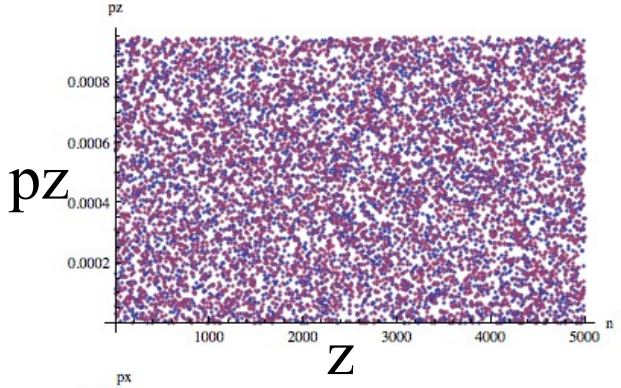
Thermal Emittance based on the Astra Model (CsTe) with A. Oppelt & B. Beutner

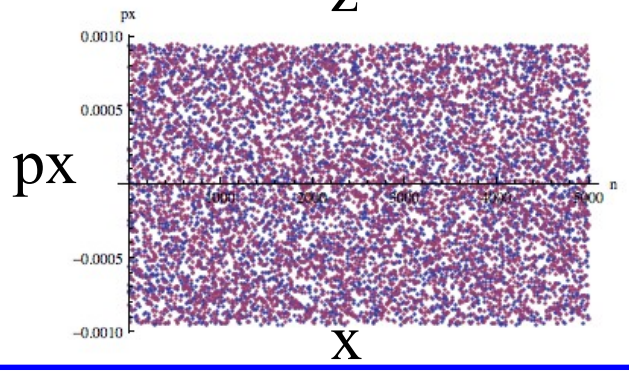
```
==>help, Distribution;
   +1 help, Distribution;
OPAL >
OPAL > The DISTRIBUTION statement defines data for the 6D particle distr.
Attributes:
OPAL >  string DISTRIBUTION    Distribution type: … GUNGAUSSFLATTOPTH ...
```





OPAL and ASTRA





Features 2 - Short Range Wakefields

Short Range Wakefields

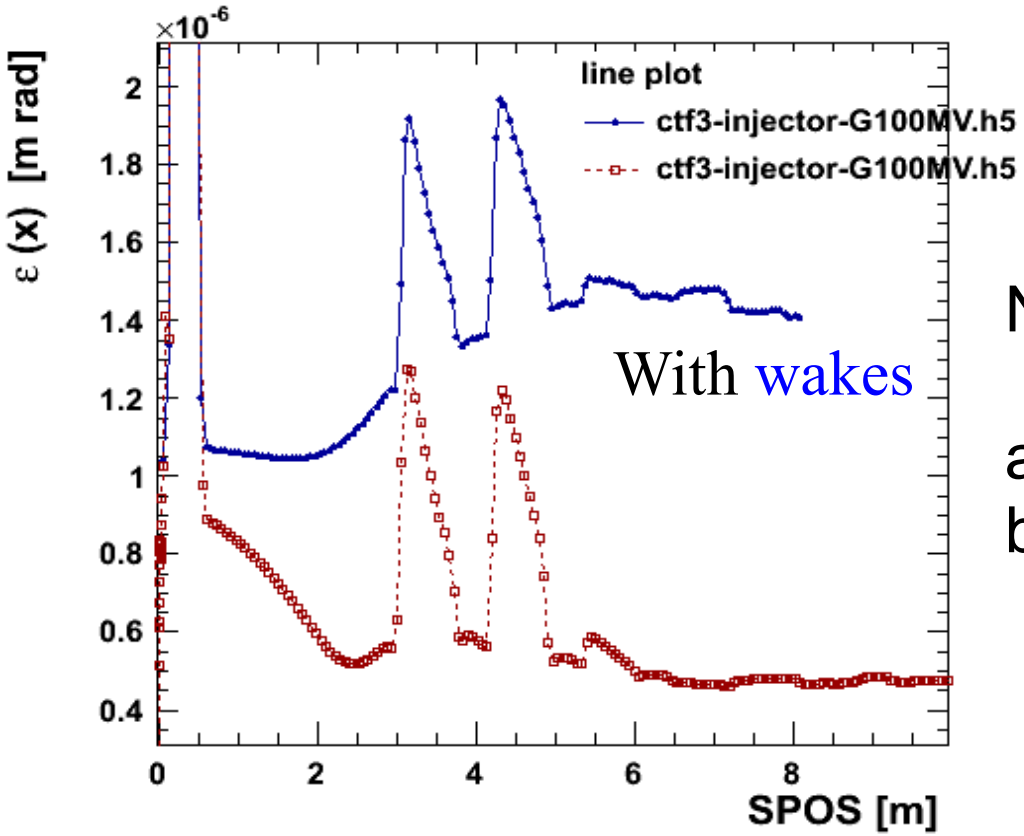
- SLAC-PUB-4169 (K.L.F Bane)
- our implementation passes analytic tests
- read in wake-potential from file

```
TWWAKE: Wake,TYPE="TRANSV-SHORT-RANGE", NBIN=32, CONST_LENGTH=false, CONDUCT="AC",
             Z0=376.991118, FORM="ROUND",RADIUS=0.00931,
            SIGMA=6.45337e7, TAU=2.70187e-14;



FINSB01_RAC: TravelingWave, L = 4.6, VOLT = 18.0, FMAPFN = "FINSB-RAC.T7",
                            ELEMEDGE = 2.95, NUMCELLS = 132, MODE = 1/3, ACCURACY = 39,
                            FREQ = 2997.924, LAG = -61.651178784 / 360.0, WAKEF=TWWAKE;
```

Please consult the online manual for more details concerning parameters

Features 2 - Short Range Wakefields cont.

(old) CTF 3 version (Yujong/S. Russel Dec 2008) up to 160 MeV



Note:

a) not optimized with wakes
b) the purpose is to show/test the wake calculations

New Feature 3 - SA-AMG PCG

Iterative Space-Charge Solver (SA-AMG PCG)

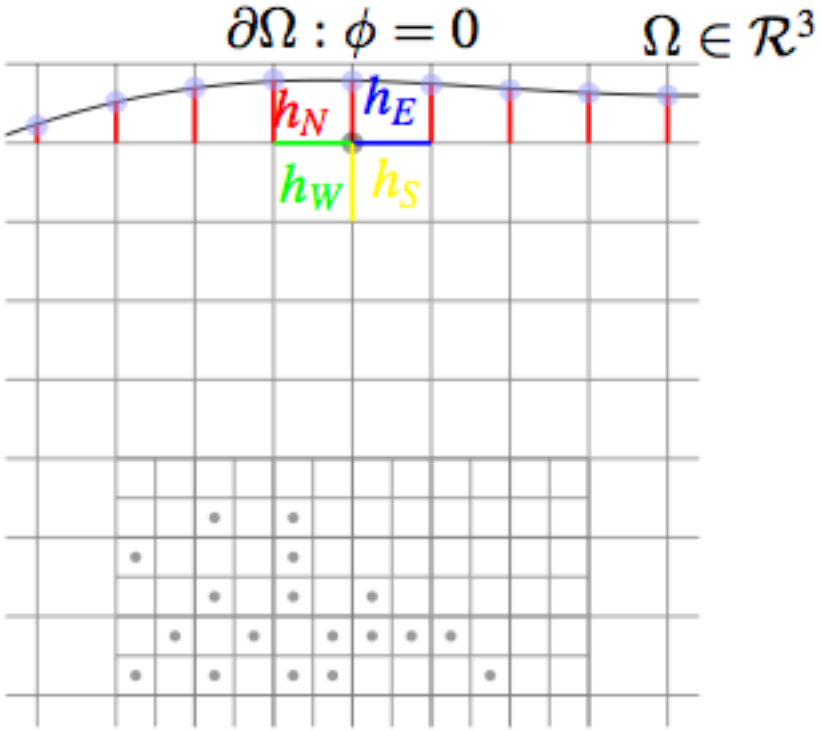
- improving approximation of space-charge forces by taking into account realistic beam pipe boundaries
- currently support for cylindrical shaped beam pipes
- in the (near) future: support arbitrary domains specified

```
GME: GEOMETRY,    LENGTH=1, S=0.0, A=0.001, B=0.001;

Fs: FIELDSOLVER, FSTYPE=MG, MX=32, MY=32, MT=64, PARFFTX=false, PARFFTY=false,
                 PARFFTT=true, BCFFTX=open, BCFFTY=open, BCFFTT=open, BBOXINCR=3,
                 GEOMETRY="GME", ITSOLVER="CG", INTERPL="linear", TOL=1e-6,
                 MAXITERS=100;
```

arXiv:0907.4863 & the online manual for more details concerning parameters

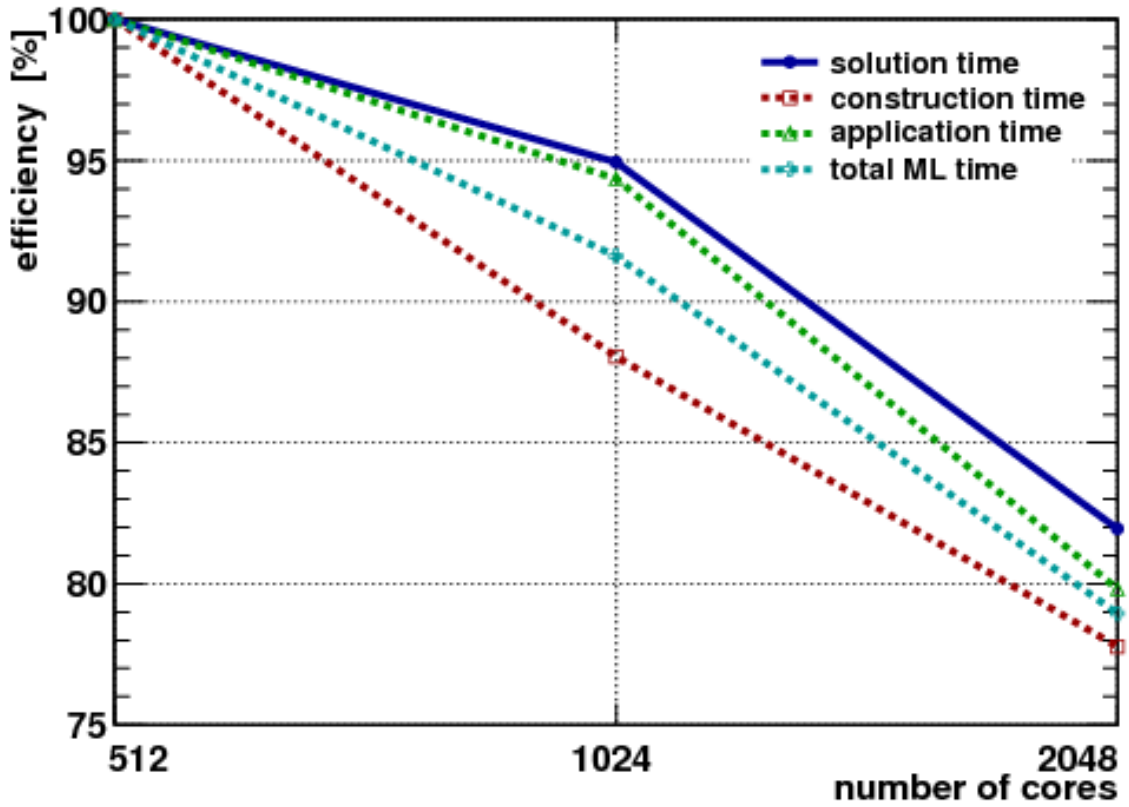
New Feature 3 - SA-AMG PCG cont.

Iterative Space-Charge Solver with arbitrary geometry (now



New Feature 3 - SA-AMG PCG cont.

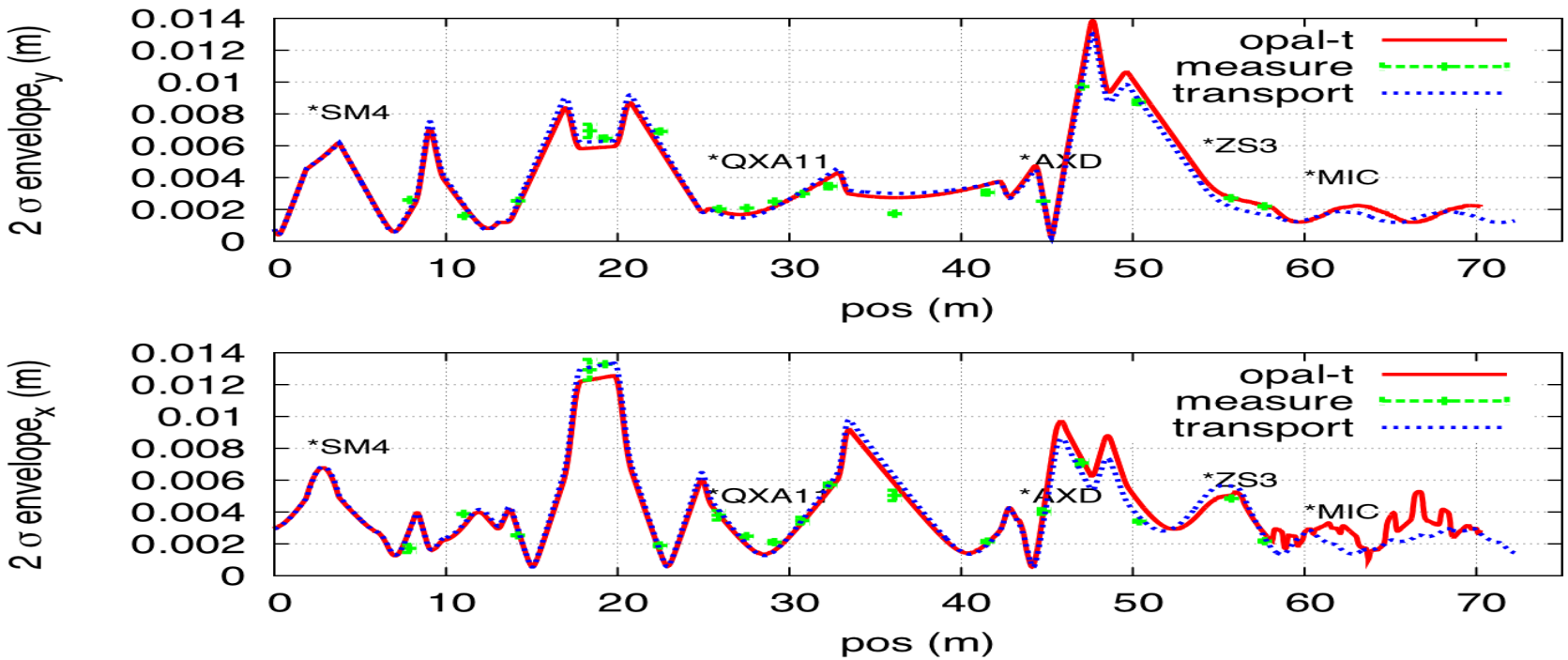
Iterative Space-Charge Solver: Parallel Efficiency on a 1024^3 grid



New Feature 4 – SBEND

72 MeV (p) line modeling (WIP, Y. Bi):

Measurement 30.4.2009
I=0.496 [mA]



New Feature 5 – SCAN mode

Scans within the OPAL lattice file

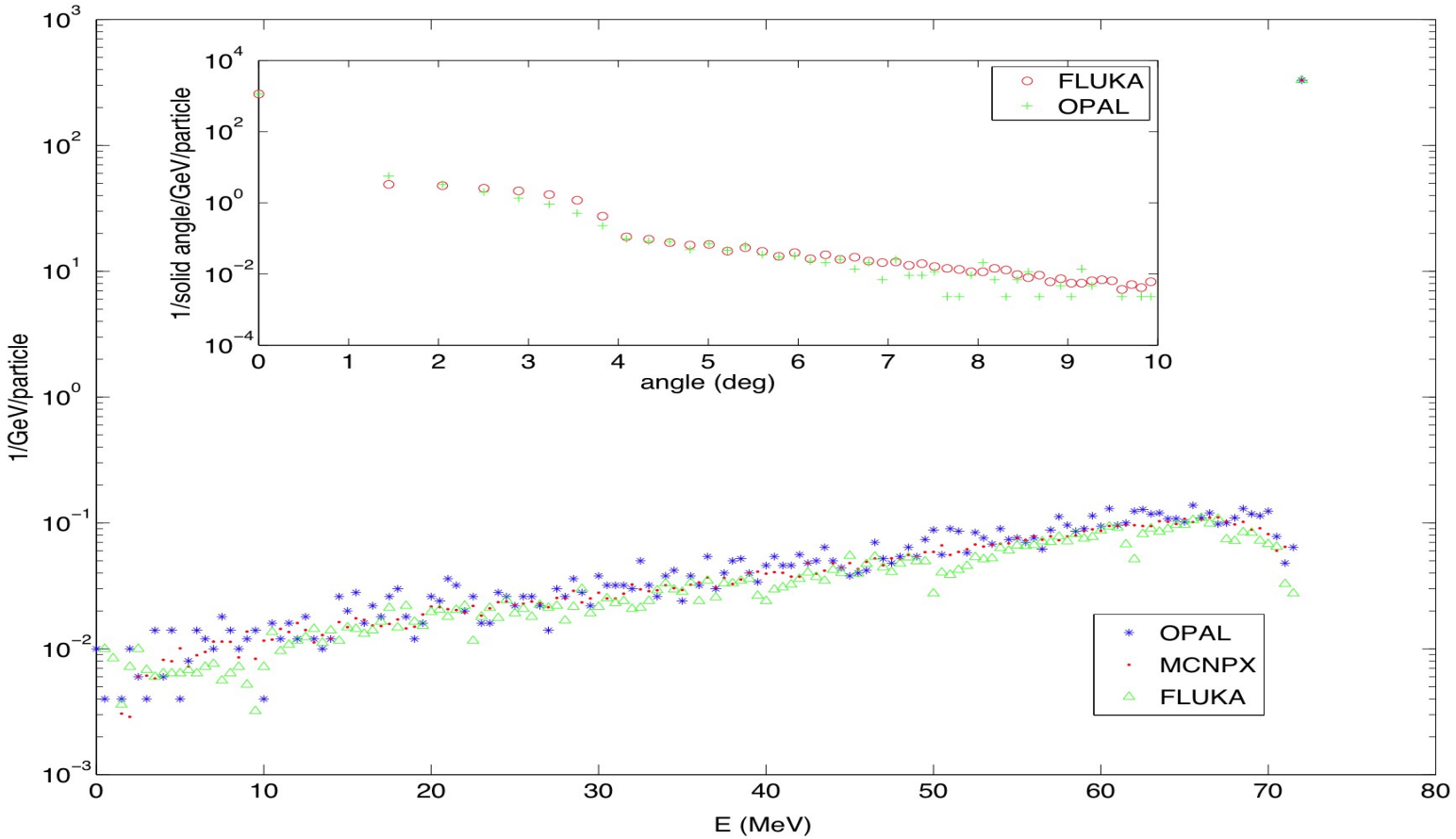
```
Option, SCAN=TRUE;
call,'IW2Elementsnew.in';

I=0;

WHILE (I < 200) {

 bphi := 49.0/180.8*PI;
 vol  := (-0.3 + (I*0.003));

 Buncher: RFCavity, L=0.437, VOLT=12.566*vol,  ....

 TRACK,line=IW2Line, beam=beam1, MAXSTEPS=12400, DT=5.0e-11;
  RUN, …
 ENDTRACK;

 SYSTEM,"mkdir -p Scan-" & STRING(I);
 SYSTEM,"mv  transferline-vscan.h5 Scan-" & STRING(I);
 I=EVAL(I+1.0);
}
```

New Feature 6 – Particle Matter interaction

p only at the moment, material: Cu,Al

- Energy loss -dE/dx (Bethe-Bloch)
- Coulomb scattering is treated as two independent events:
  - the multiple Coulomb scattering and
  - the large angle Rutherford scattering

New Feature 6 – Particle Matter interaction cont.

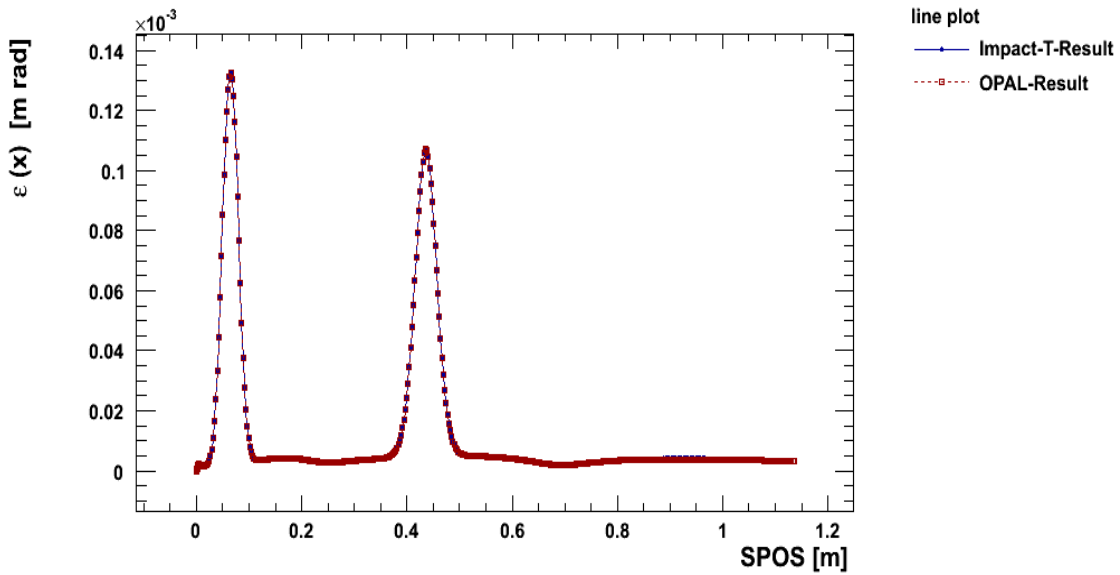


Recap Validation Strategy

Inductive reasoning

- IMPACT-T (PARMELA) & LCLS

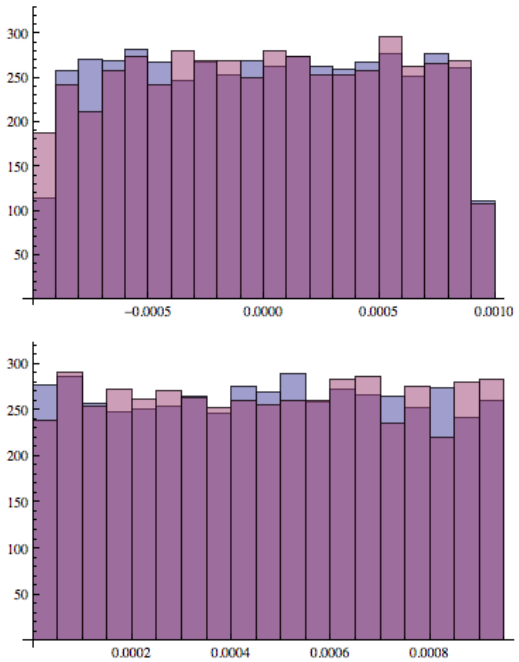
SLAC-PUB-11665 &
Phys. Rev. ST Accel. Beams 9, 044204 (2006).



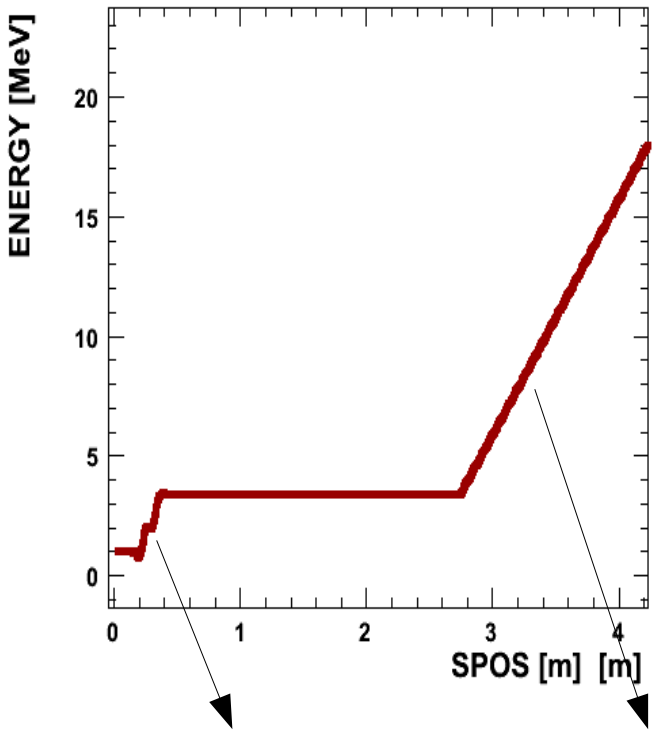
Code comparison

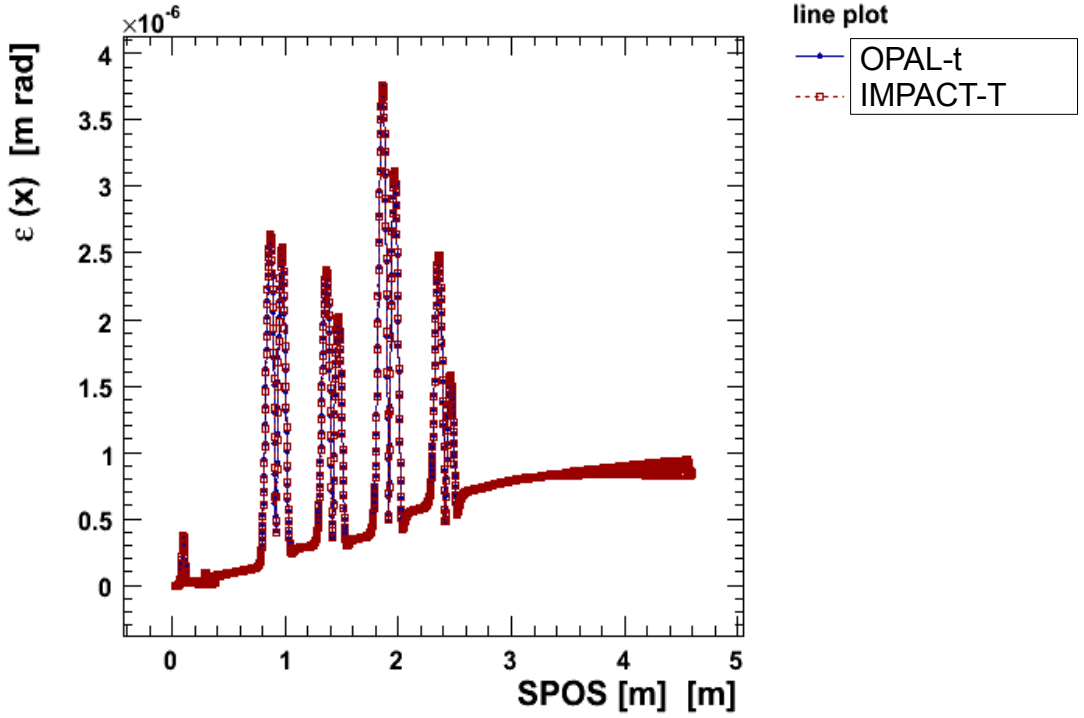
- OPAL & ASTRA

with A. Oppelt & B. Beutner



Recap Validation Strategy cont.



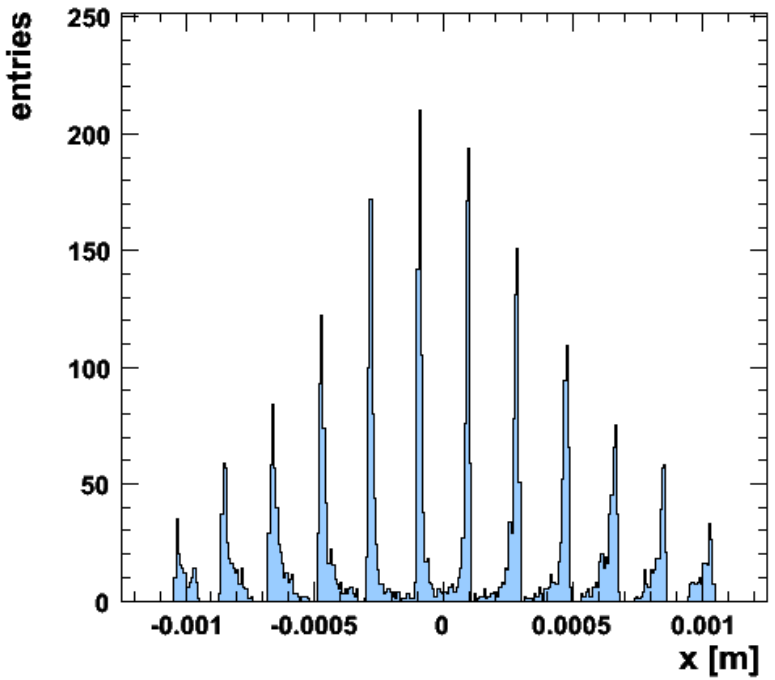


Standing wave Traveling wave

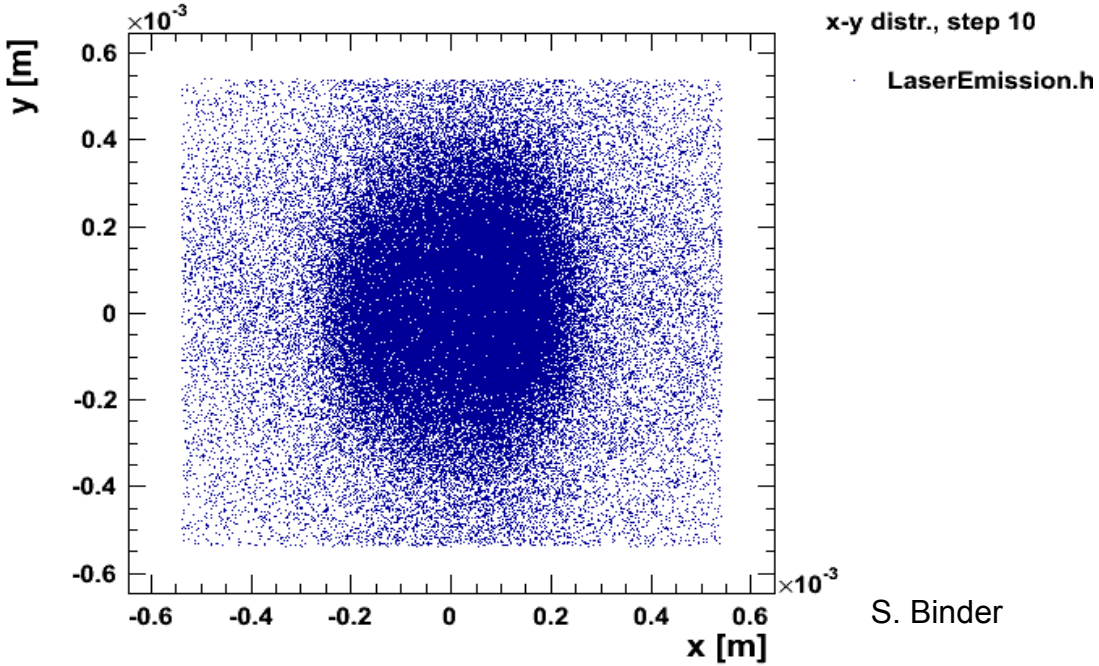
Implementation and tested by Yves Ineichen (summer student 2007)

Random Fun Features

Pepperpot & good statistics
→ compare model w. reality



Sample image on virtual cathode
→ better model of the reality

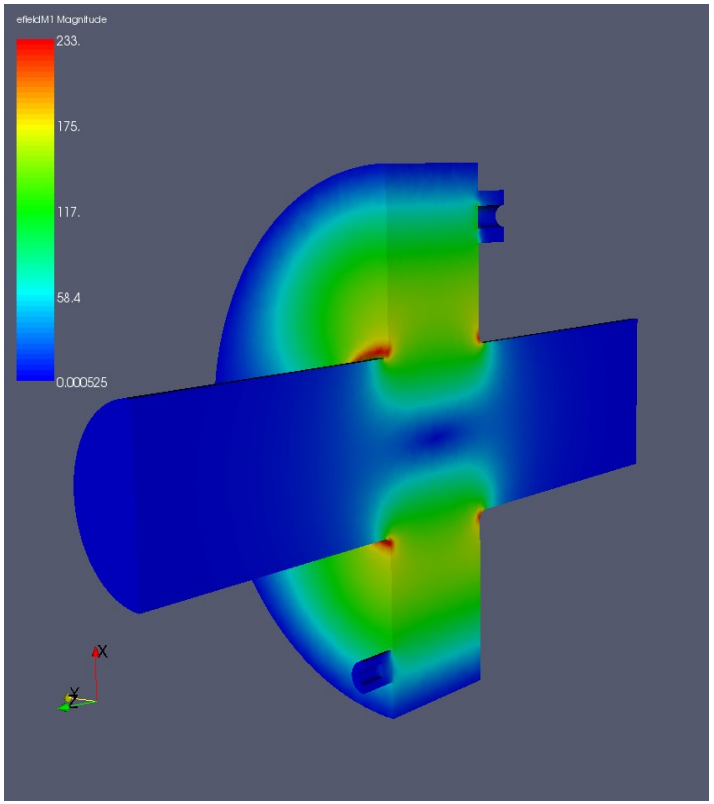


S. Binder

OPAL – FEMAXX & Lola

A Cartesian sampling routine had been implemented in FEMAXX. Tests are in progress. In this new routine, we use the library H5Part and H5Block, which are developed at PSI (AMAS/Scientific Computing) & LBNL.

Field computations of the Lola cavity on Rosa (CSCS) are done. The computation is based on quadratic elements. The design frequency of the desired mode in the Lola cavity is 2.997.9 (GHz). Accuracy 1..2 % w.r.t. HFSS.



Will enables us to do precise bd simulations in complicated (no symmetric) 3d em-fields.

More details will be given in a separate talk (G. Hua & B. Oswald)

OPAL Development in AMAS and around the World

- Los Alamos (S. Russel) code benchmarking and usage for LANL-FEL project if time i.e. funding permits
- CIAE (J. Yang & Y. Bi) development and usage of OPAL-cycl

- Multiobjective Optimization (Y. Ineichen) joint Ph.D project with IBM Ruschlikon, start 1.1.2010
- FEMAXX reader, unstructured boundaries, cut down on time to solution, integrating of ongoing Ph.D work, ...

Summary

- OPAL is a unique combination of
  - + “Level of detail” (1D CRS, 3D SC, Wakefields, #particle >, etc)
  - + easy to use (MAD-language, post processing H5PartROOT)
  - + parallel performance
- Active nat. & international development team
  - + full self consistent simulations (M. Wittberger & Ch. Kraus)
  - + multi objective optimization (Y. Ineichen)
  - + secondary effects on collimators & SBEND (Y.Bi)
  - + benchmarking & LANL-FEL design (S.Russel)
  - + PAC 2009, TU3PBC05, (J. Yang et al.)

Summary cont.

OPAL & 250 MeV Injector is a unique opportunity for taking up the challenge posed by nature …

i.e. comparing model/simulation with the real thing.

Summary cont.

OPAL has already taking up a challenge like this ...

PSI Ring Extraction
- production setup
- ~4.5 km simulation
- WIP: Y. Bi et al.