Overview of xcode

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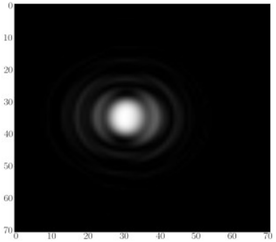
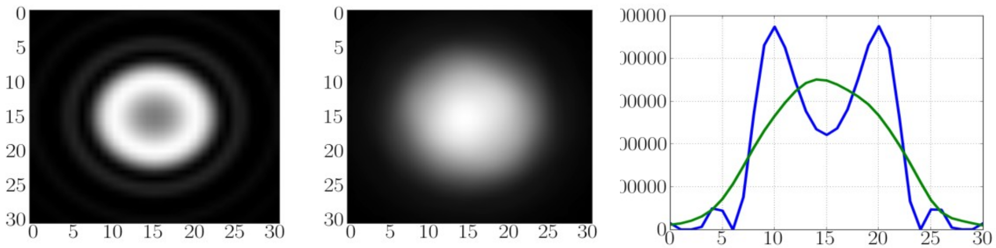
Original motivation: spontaneous radiation

- Need for diagnostics, power loads and potentially science cases
- Numerical methods well understood, single particle solver provided by O. Chubar (SRWlib)
- Issues for xfel.eu: long undulators, narrow UR bandwidth, need to account for: electron optics, emittance, energy spread

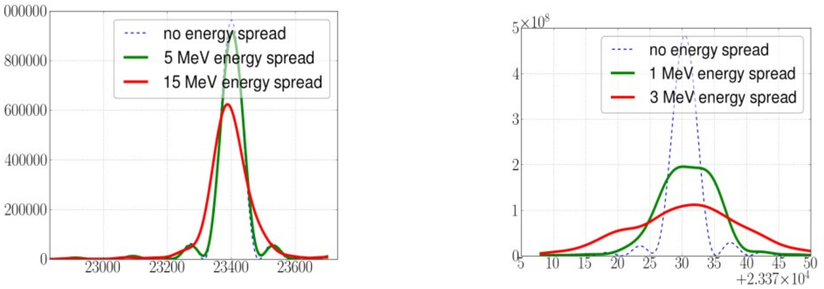
Effect of orbit distortion, flash



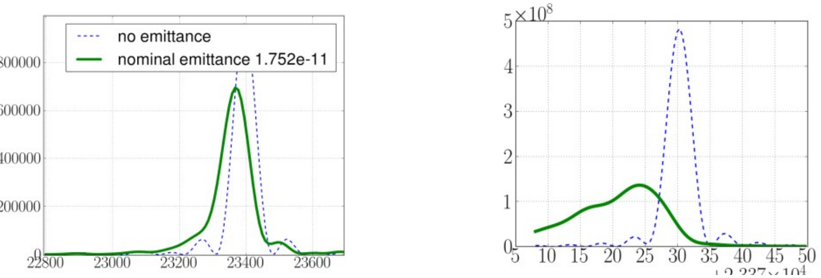
SASE1 (0.05nm), emittance effect on rad spot after mono



SASE1 (0.05nm), energy spread effect



SASE1, emittance effect

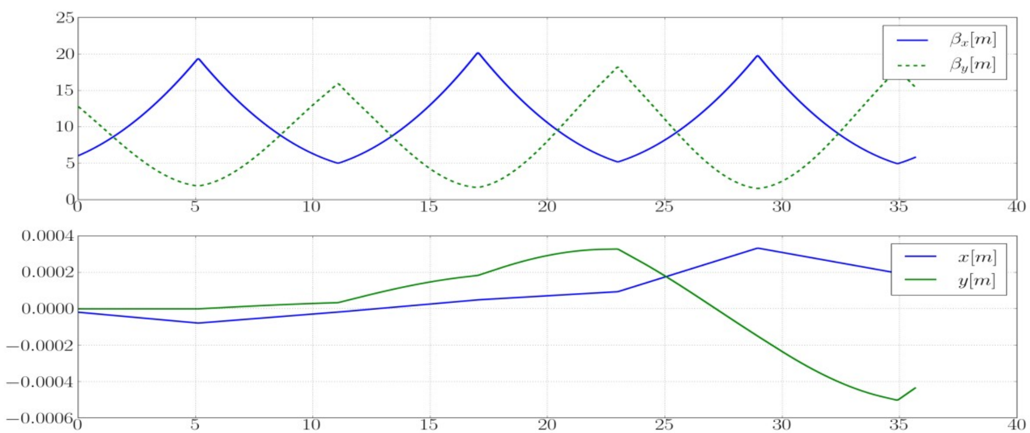


Along the way: need beam dynamics module

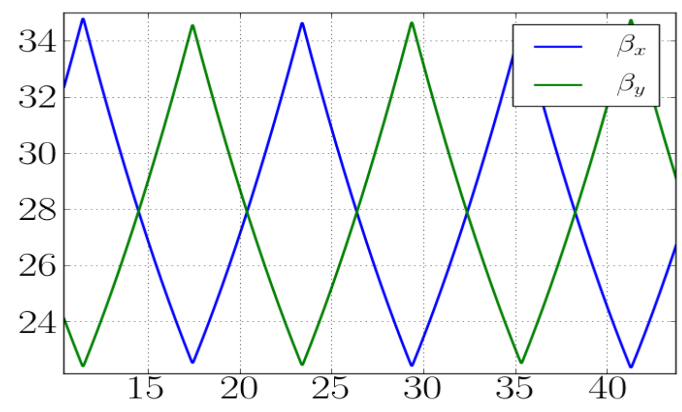
Need:

- Beam optics model to account for emittance effects
- Matching (not to rely on external optics)
- Alignment errors, beam jitter to see effect on SR
- Orbit correction and steering (bumps and the like, no DFS)

Flash-like optics, effect of misalignment



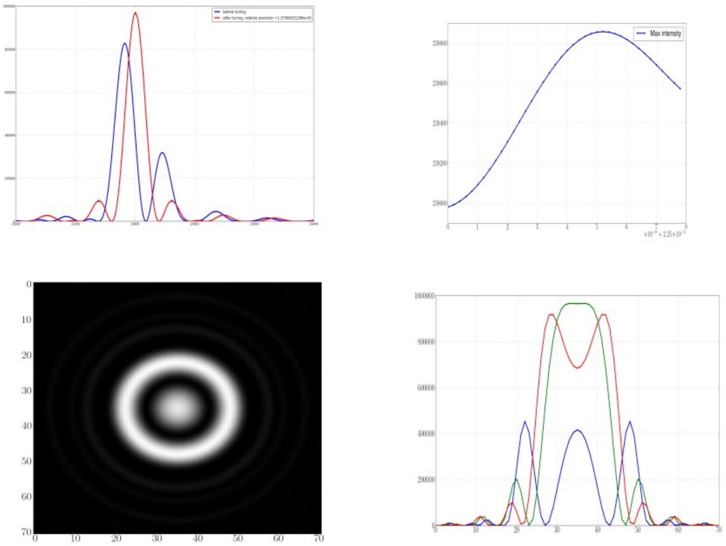
SASE3 optics

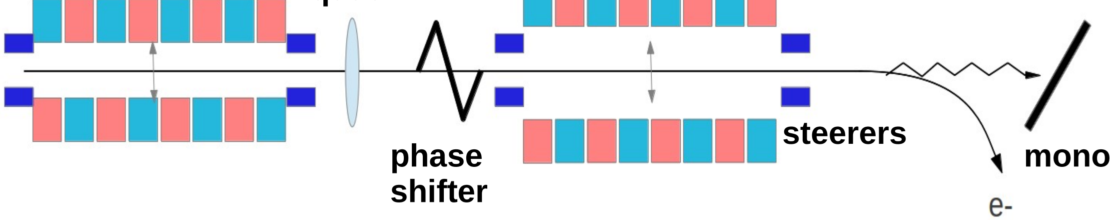


PBBA: need 'on-line tools'

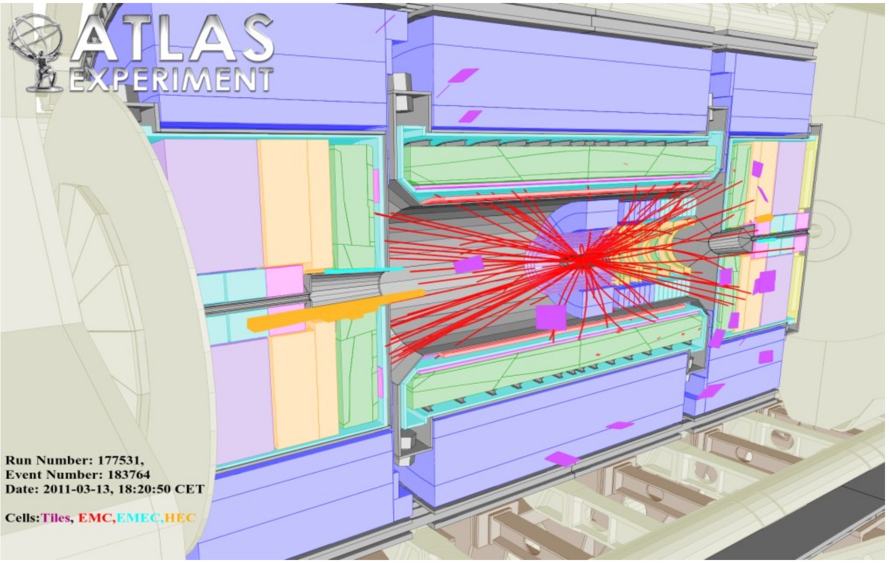
- Main motivation of SR is for diagnostics
- Tuning undulator K and phase shifter based on SR properties
- Any study cases should be easily transferrable to the control room

SR properies for various phase shifter strengthes





Emerging concept: software framework



E.g.: HEP, detector simulations (Geant4)

- Complex geometries
- Diverse physics
- Large collaborations
- On-line event displays

For accelerator physics some attempts are known. However, we would need something simple, with the following features:

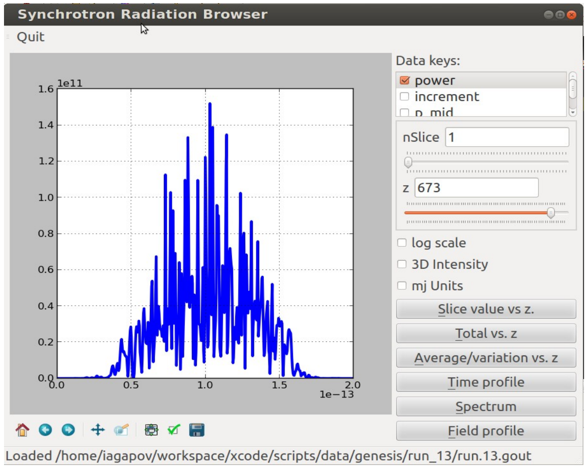
- Geometry: simple and extensible. MAD is not extensible, XML not simple. choose python. Can easily extend e-optics model to: aperture info, x-ray optics
- Scripting: python library the best choice
- Physics modules should be plugged in using the same model and IO
- Extension to on-line tools should be easy (Karabo is in python)
- Xframework supports these features, many are implemented, some tbd.

Xcode/xframework

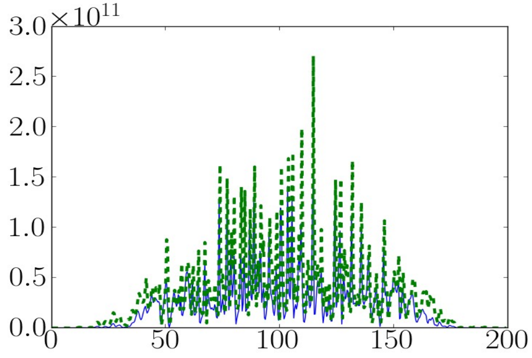
- 'xframework' refers to the common framework + integrated modules, the distribution incuding 3rd part codes (srw, genesis) is referred to as 'xcode'
- Open source https://code.google.com/p/xfel-xcode/
- SVN, unit tests, otherwise 'agile development'
- 1Yr in development

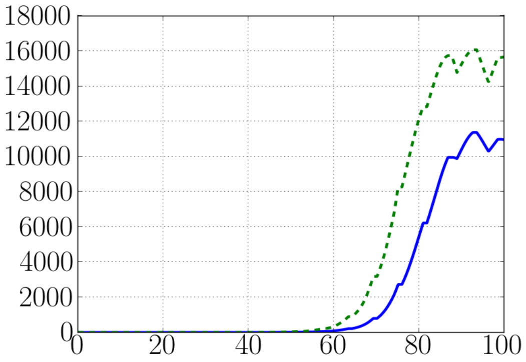
FEL simulations

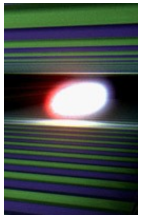
- Automatically generating genesis input from standard xframework decks, easy controls of run parameters
- Postprocessing tools for genesis: I/O and statistical analysis
- 1D python fel model
- Optimization routines and parameter scans (python)



Radiation parameters of SASE3, with postprocessing GUI (left)

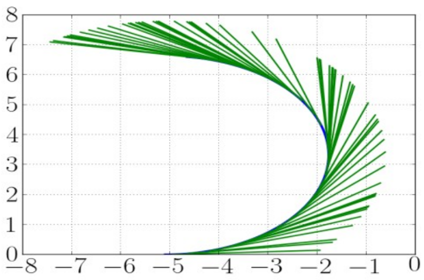


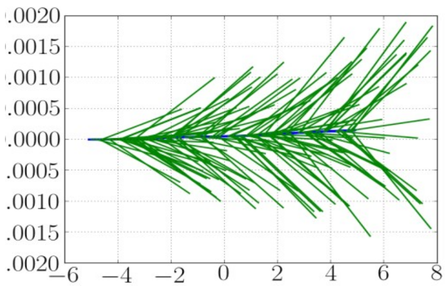


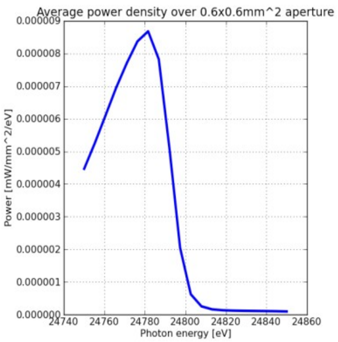


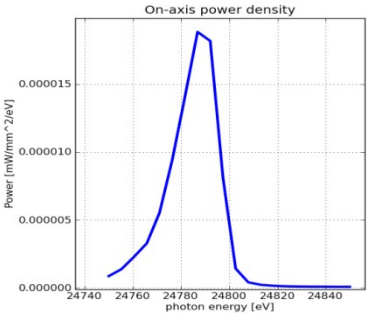
SR

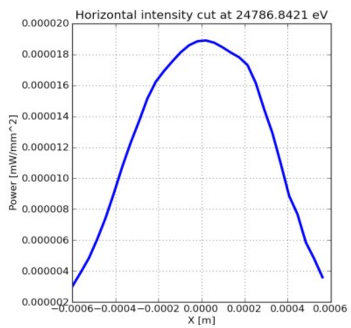
- SRW solver (O.Chubar and P.Elleaume, "Accurate and Efficient Computation of Synchrotron Radiation in the Near Field Region",EPAC-98)
- Based on the same e beamline model. Standard xframework components from which radiation can be caluclated: undulators with arbitrary polarization (analytical models and tabulated fields), quads, dipoles, sextupoles.
- Other solvers included (e.g. Monte-Carlo photon generator, bottom left)
- Solvers interchangeable
- Benchmarks are/have been done, as well as calculations for xfel with all effects (bottom right)
- SRW also allows for x-ray optics calculations. x-ray optic components (and particularly their placement) have not been standardized on xframework level,but direct access to appropriate srw functionality is always possible









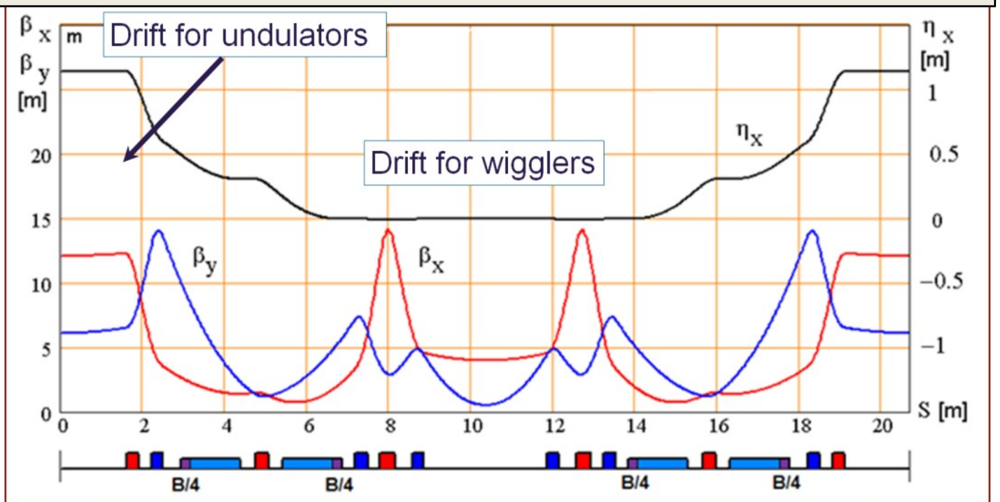


Beam optics

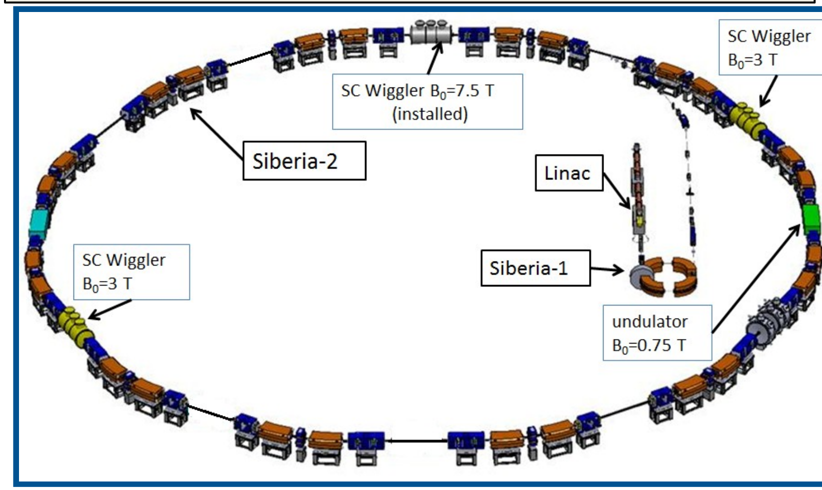
- Completely embeddable and extensible e optics module – not an optics code
- Standard optics calculations included in distribution as scripts
- Embeddable: call from any python code
- Extensible: user can define new elements, redefine transfer maps and attach any additional features to beam elements w/o changing the module
- Features beyond single-particle electron dynamics can be added as extensions (no collective effects so far)

Example of DA calculations @ Siberia2 (S.Tomin)

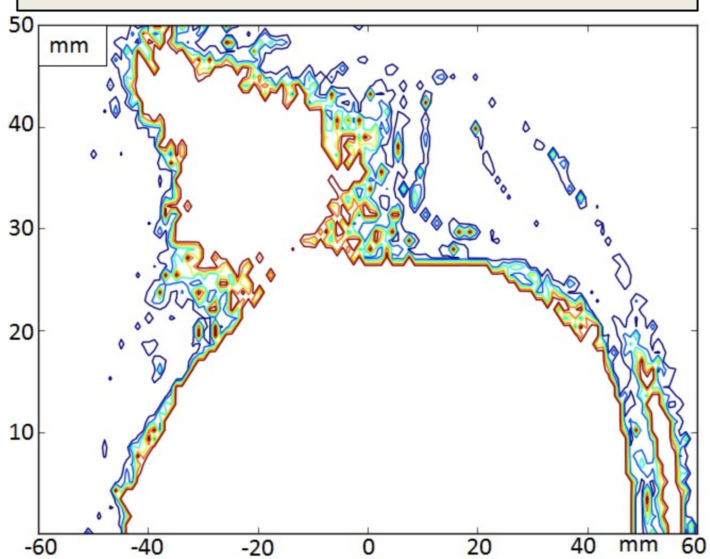
Optical functions of „standard“ structure (*εx=98 nm rad*)



Siberia-2 and proposed layout of insertion devices



DA without ID



Main parameters of IDs

	Wiggler	Wiggler	Undulator
B_{max}, T	7.5	3	0.75
λ_{period}, mm	164	44	7
Field decrease ($k_x=2\pi/\xi$), ξ - , m	0.8	0.8	0.5
N_{period}	10	34	300
ε_{crit} radiation/ ε_1 (W=2.5 ГэВ), keV	30.7	8-16.4	ε_1=2
Deflection parameters	115	12.3	0.5
Spectral range, keV	20-150	5-40	2-7

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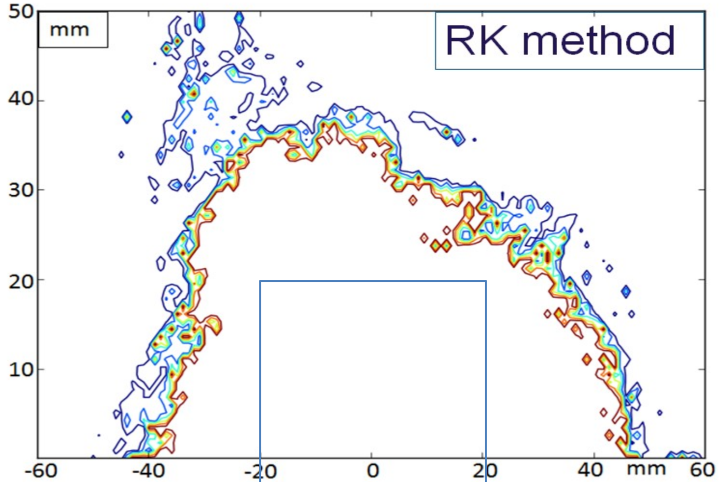
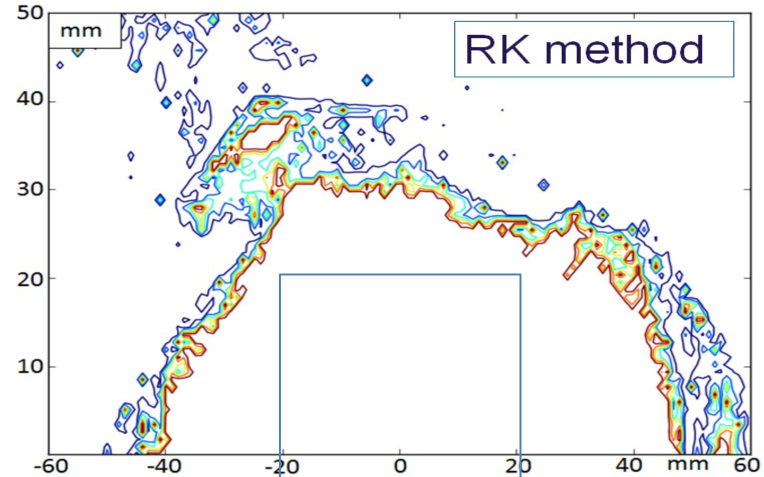
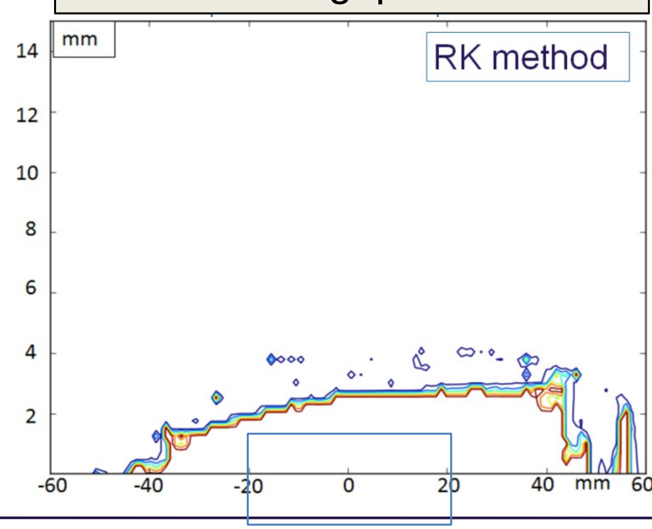
DA with 7.5 T wiggler



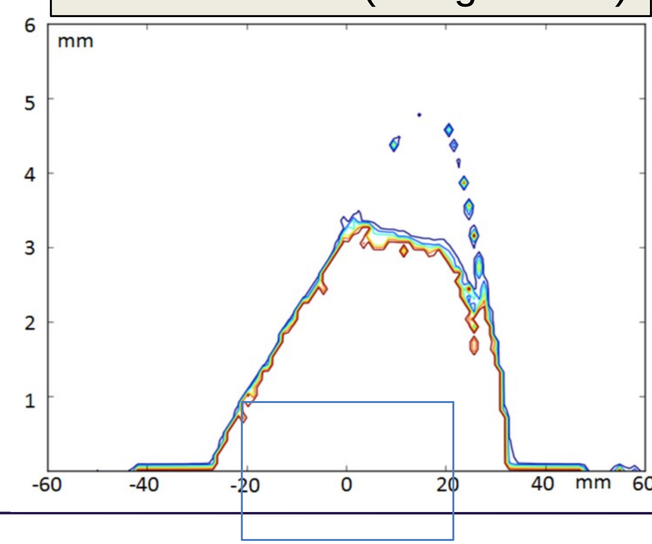
DA with single 3T wiggler



DA 2.5mm gap undulator



DA with all IDs (Runge-Kutta)

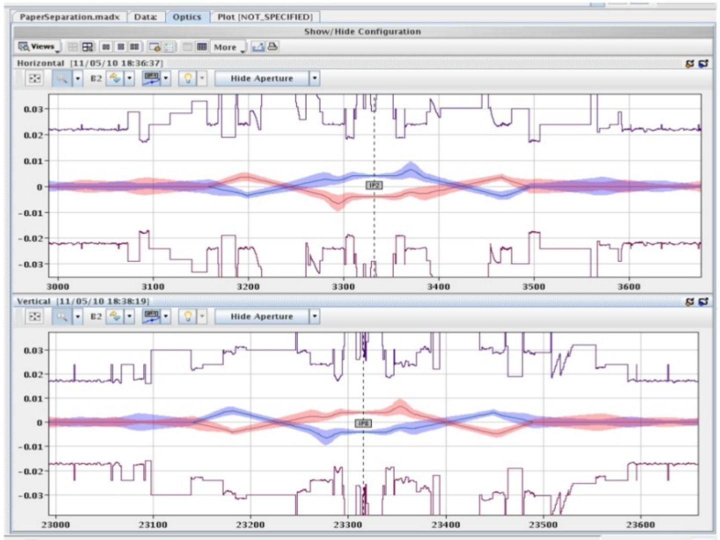


Radiation parameter database?

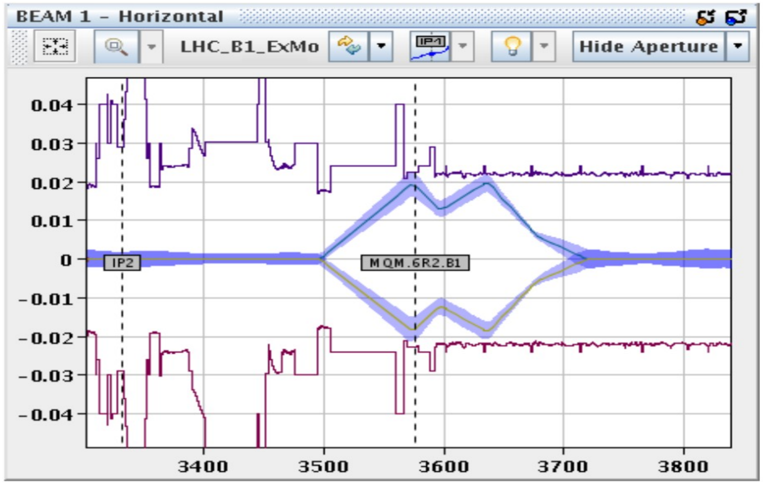
- Have python repos for SASE1/2/3 and FLASH undulator sections (derived from MAD), and partially undulator field maps
- Component XLS files translator prototype in place (Igor Zagorodnov)
- Simulation output dump on mass storage (dcache) + SQL index DB is foreseen (prototype in place)
- However: need to define the scope
- Motivation : communicating photon beam parameter to users
- These parameters can be corrected from operation experience
- With a bit of programming python functionality easily put on-line (e.g. https://www.djangoproject.com)
- Beyond simple parameter presentation, can potentially aim at correlation studies and data mining.

On-line tools

- OM (LHC): embedding mad-x into java control system (pic below). Successful for commissioning, however software complexity and support is an issue
- Machine Interface module in xframework allows for a 'flight simulator mode' of operation (TCP-based): alignment and tuning tools could be easily transferred to control room after switching from 'virtual' to 'real' mode. Similar things have been implemented in several labs already.
- Flight simulator mode requires data exchange protocol. Optics and other features can be more easily 'embedded' in python directly
- Scripting is a major advantage for scans etc. Python used at NSLSII too.



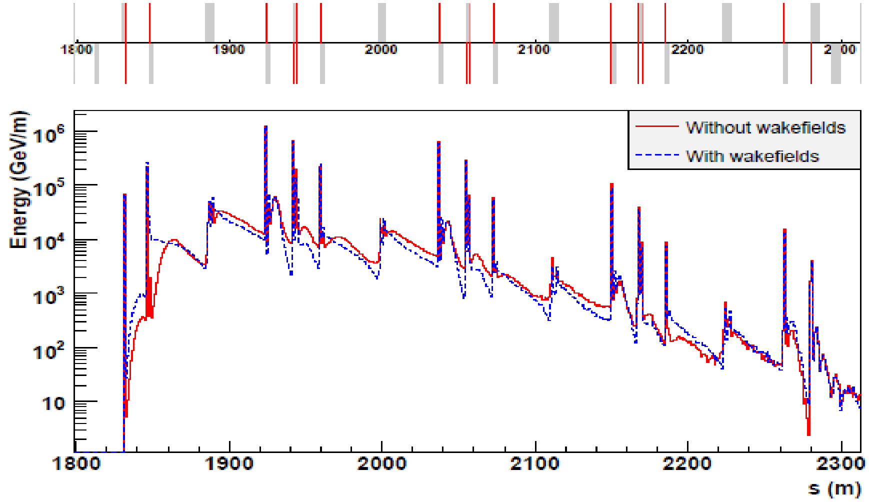
LHC OM beams at Ips



LHC OM Aperture scan

Pipelining/interleaving simulations

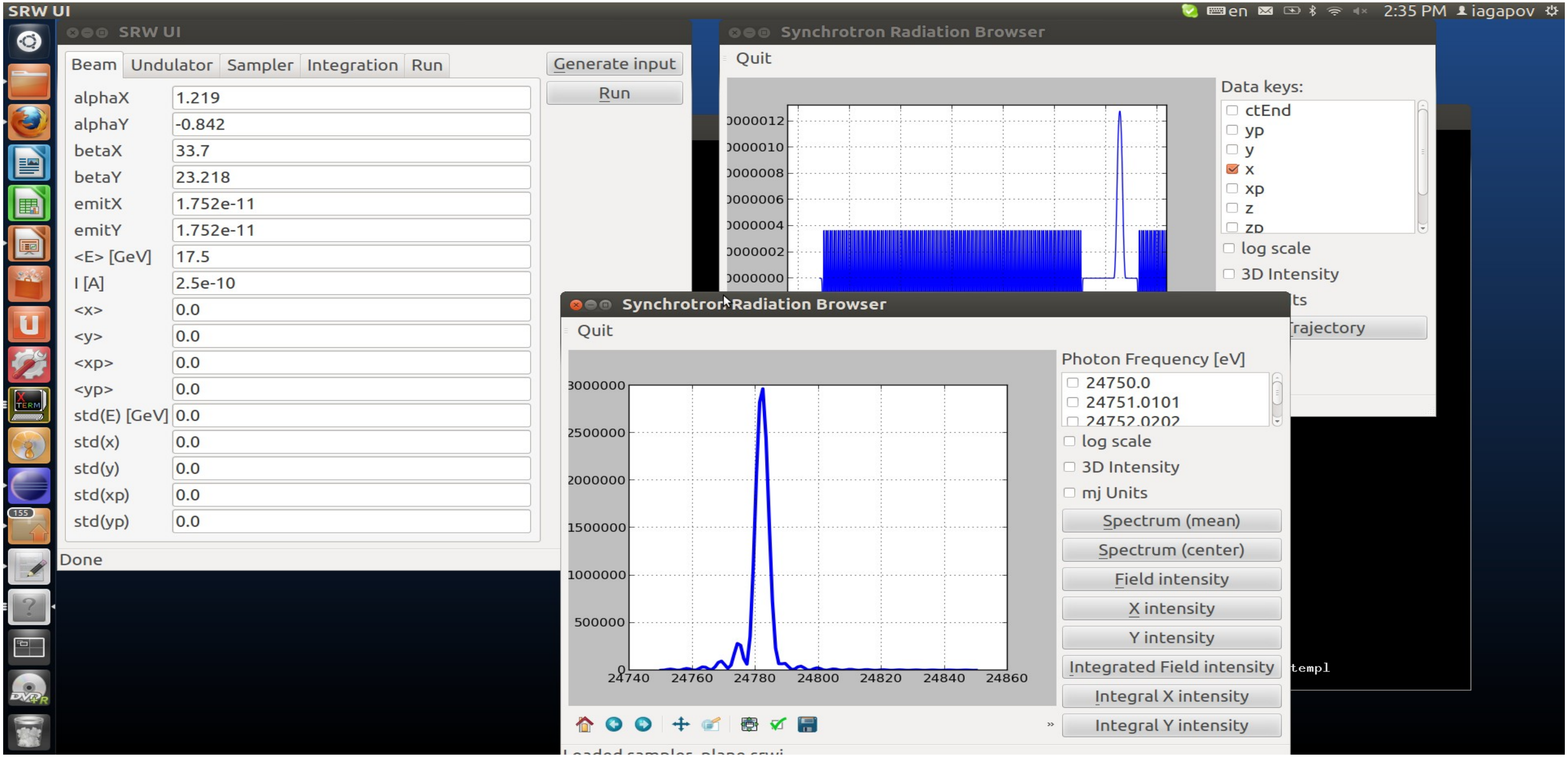
- LHC collimation: (SixTrack/FLUKA)
- CLIC Beam Delivery collimation: Wakefields + secondaries (BDSIM/PLACET)
- XFEL Beam Dynamics: space charge, CSR, wakefields, etc....
- Always reinventing protocols to exchange data between codes; different physics can be included only iteratively, not on small time steps
- Open python library can provide much simpler solution to the problem



From Tracking Studies of CLIC Collimation system
Agapov et al PRST-AB (2009)
Wakefields calculated with GdFidl, beam core tracked with PLACET and the halo with BDSIM. In this case wakefields Have negligible effect.

GUIs

- Integration of all functionality into user Qt interfaces easy, some prototypes for FEL and SR in place. Usable software is more of an issue.
- Would need extra software engineers to write GUIs properly



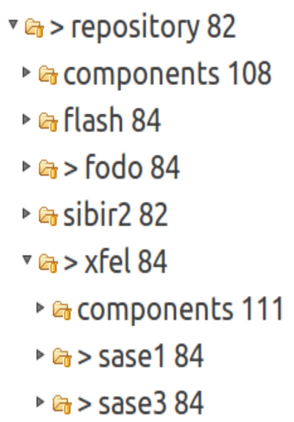
Input decks

- No parsing needed
- Current input decks are derived from official MAD decks and included in repo

```
beam = Beam()
beam.E = 17.5
beam.sigma_E = 0.001
beam.I = 2.5e-10
beam.emit_x = 1.752e-11
beam.emit_y = 1.752e-11
beam.beta_x = 33.7
beam.beta_y = 23.218
beam.alpha_x = 1.219
beam.alpha_y = -0.842

und = Undulator(nperiods=73, lperiod=0.068, Kx=0.0, id = "und")
d2 = Drift (l=0.45, id = "d2")
# phase shifter
b1 = RBend (l=0.0575, angle=0.0, id = "b1")
b2 = RBend (l=0.0575, angle=-0.0, id = "b2")
psu=(b1,b2,b2,b1)
# quads
qf = Quadrupole (l=0.1, id = "qf")
qd = Quadrupole (l=0.1, id = "qd")

cell_ps = (und, d2, qf, d2, und, d2, qd, d2)
sase3 = (und, d2, qd, d2) + 11*cell_ps
```



Embedding python is simple

- Twiss calculation

```
exec( open("../../repository/flash/flash.inp" ))
tw0 = Twiss(beam)
lat = MagneticLattice(flash_sase, beam.E)
tws=twiss(lat, tw0)
```

- Running a SR calculation and saving into hdf5

```
traj, int1 = srw.calculateSR_py(lat, beam, screen, runParameters)

dump = Dump()
dump.readme = 'test 1_1'
dump.index['beam'] = beam
dump.index['screen'] = screen
dump.index['intensity'] = int1
dump.index['trajectory'] = traj

xio = XIO('data/int_test_1_1.h5')
dump.dump(xio)
```

Summary and questions

- Have a python module supporting beam optics, SR, and FEL calculations
- However: development stage of many components is beta/prototype. To produce high quality software, will need to sync with the needs of other XFEL groups
- Some functionality is within our research needs, but many options are open:
- Interface to S2E?
- On-line tools?
- Parameter database?
- Additional beam physics?
- No entities beyond necessity
- Opportunity for information exchange from linac down to photon beamlines
- We are willing to collaborate and embrace new ideas