

## Overview

- SLS Operation and RF-failures
- SLS Upgrades
   Teststand LINAC, replacement of main cavities, noise investigations

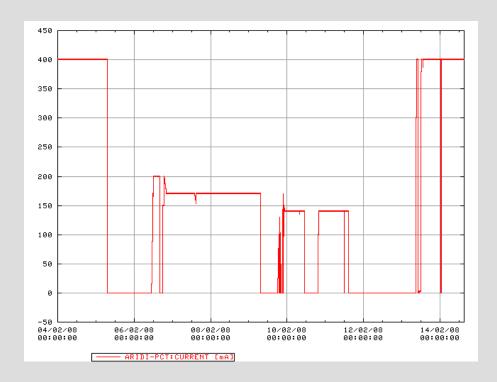
XFEL project: Status and Outlook





## Transformer failure

 Repair of 50kV transformer causes 1 week warm operation of S3HC at 170mA





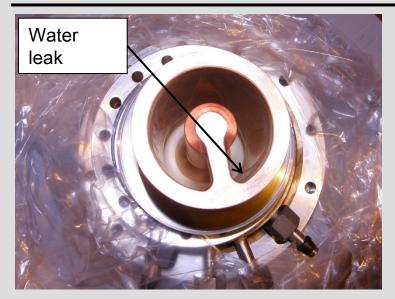


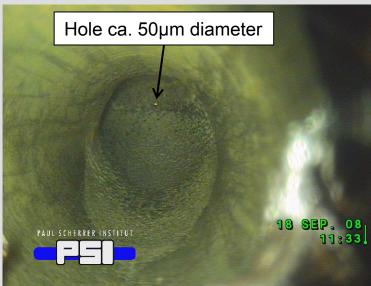
## Water Leaks 2008

Date	Part	Down time
18.5.	Cav. 3, demi. water, coupling flange	5h
16.6.	Cav. 4, demi. water, vac. pump flange	10h
11.8.	Cav. 3, demi. water, coupling flange	10h
14.9 18.9.	Booster, demi. water, coupler	92h

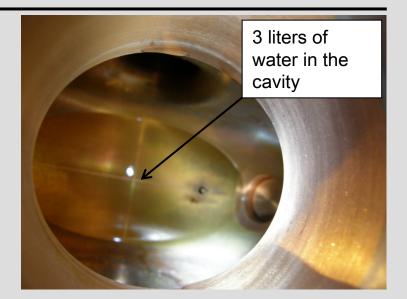


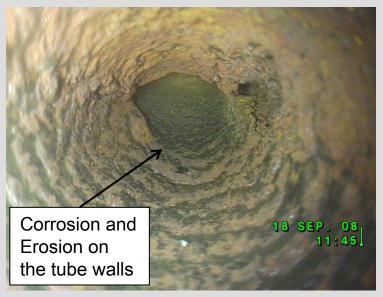
### **Booster Water Leak**





ESLS RF meeting, 1.-2. 10. 2008 @ Diamond Light Source





L. Stingelin PSI



## Water leaks

#### Reduction of water leaks in future?

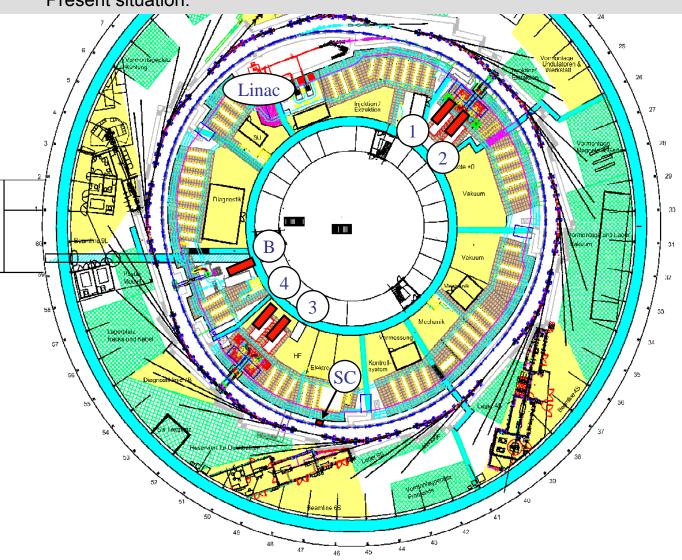
- Control of water quality in the coolingracks since 2004 with Polyflex 177 from Aquaflex.
  - Acidity value adjusted to pH = 8.5
- Reduction of flow rate in the demi-water circuit from about 7.5 m/s to 4.5 m/s





## Upgrade studies

#### Present situation:



#### Linac (100MeV) upgrade:

S-Band Teststand

#### Booster RF upgrade

- •Replacment by solidstate amplifier
- (M. Gaspar)
- Teststand for 500MHz

#### Storage ring RF upgrade

- •Replacement of the main cavities
- •Spare parts for the S3HC superconducting 3<sup>rd</sup> harmonic idle cavity





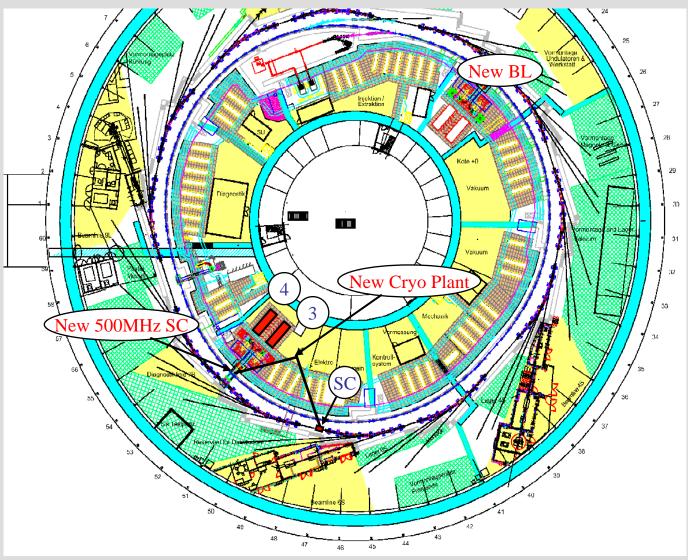
## S-Band Teststand

- Upgrade of the LINAC vacuum-, watercontrol system- and RF-infrastructure for power tests of S-band components.
- For XFEL S-band components (CTF-gun, maybe SLED, Structures).
- For SLS-LINAC spare parts.





#### Replacement of SR main cavities



- Replacement of 4 normal conducting cavities by one cryomodule?
- Vgap=2MV, Pb=240kW
- Combined cryo plant for S3HC and new superconducting cavity
- •Gives place for a new insertion device in the free straight section.
- CESR-Type cryomodule might fit in. Rescaled **SOLEIL-cavities?**
- Or better normal conducting cavities?





### Comparison of Upgrades Scenarios

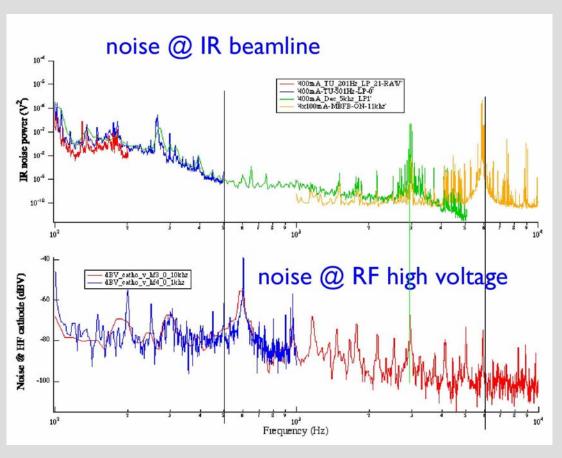
Super Conducting	Normal Conducting
Gives space for additional insertion device	Established and proven system
HOM damping	HOM tuning necessary, but HOM damping might also be possible
Reliability?	Redundancy
Less number of power rf-systems required	More electrical power required
Manpower?	More water cooling required



### Noise investigation in SR

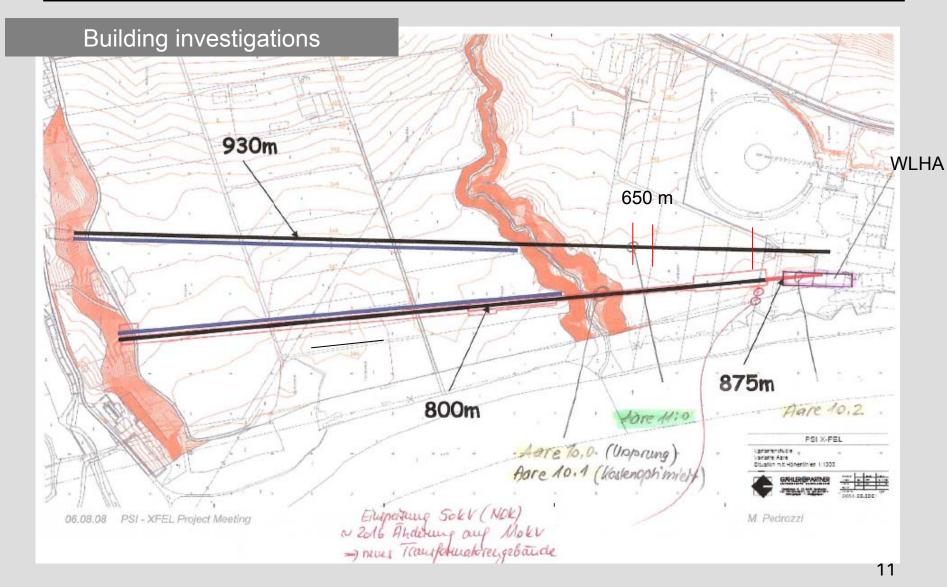
Infrared beamline has too much noise in the light spectrum.

Most of the peaks in the range 500 Hz to 10 kHz can be correlated to the noise in the 40kV anode high voltage supply.



- •Increase of Pulse Step Modulator (PSM) frequency shifted the 3kHz peak to 6kHz.
- •But since noise level higher, it did not help to solve the problem.
- Other solutions are under investigation, like: modification of the filter, or upgrade of the PSM-system.

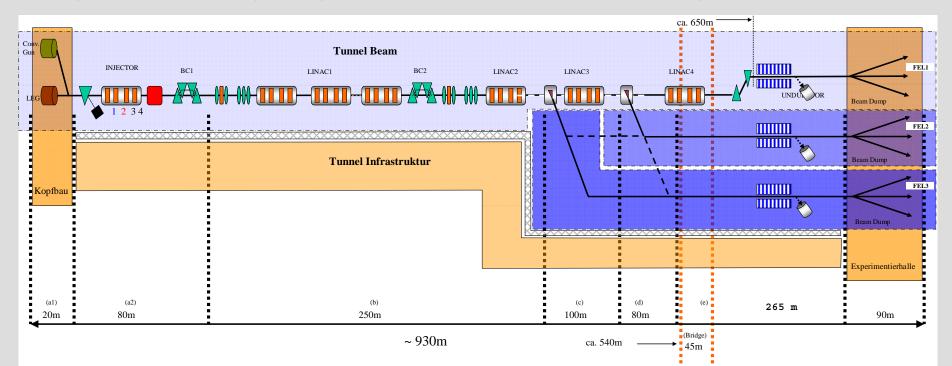


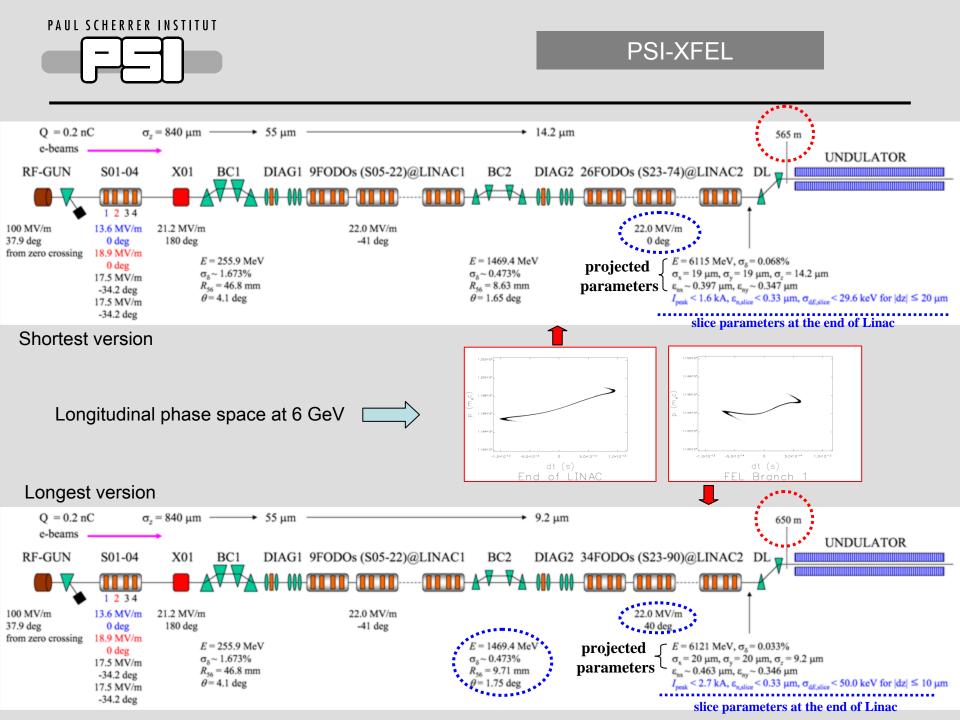


#### **Building investigations**

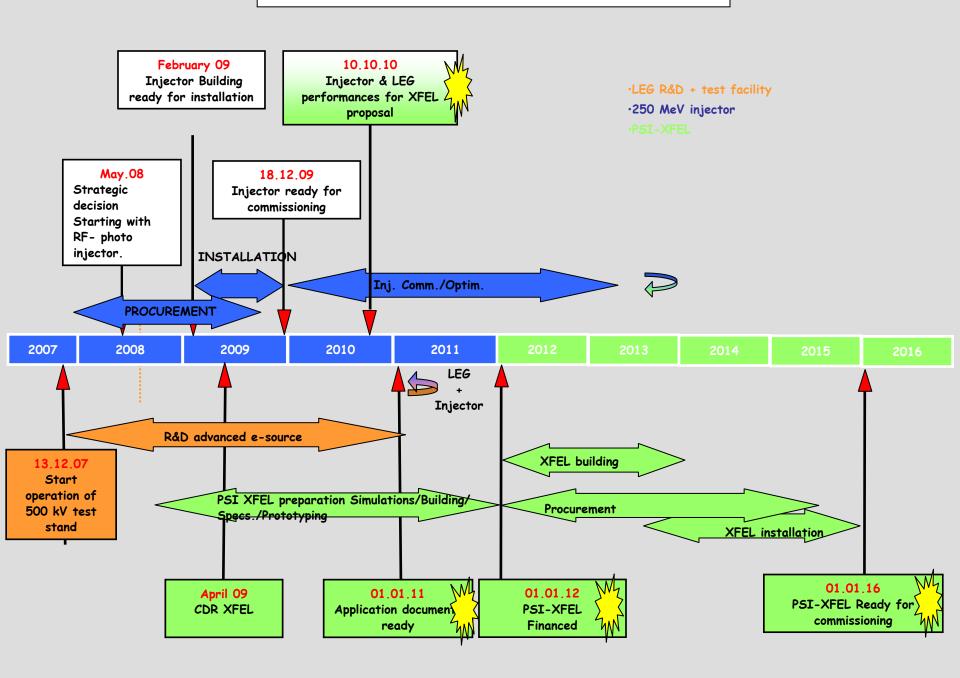
First investigations of building issues based on the design consideration here above

- Analysis of electrical power requirements (<7.9MW for the longest linac)</li>
- Analysis of the cooling requirements (85% water cooling with 30 °C,15 % air cooling)
- Specification of the tunnel cross section based on the equipment space requirements, transport during assembly, maintenance accessibility, regulations, costs...
- New tilted position of tunnel 930 m instead of 800.
- Bridge evaluation, civil engineering and costs (required specification for shielding)





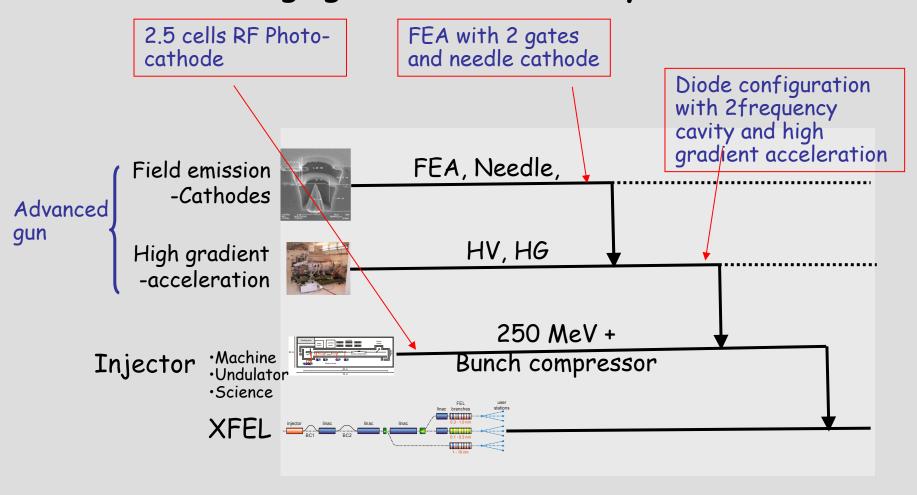
#### PSI- XFEL Constraints schedule





### Developement strategy

#### Parallel work merging in the FEL facility





#### Development strategy

#### FIELD EMISSION CATHODES / FEA and NEEDLE:

GOAL: ~5.5 A (0.2 nC - 36 ps) emission with small emittance and energy spread

ACTIONS: - Install 100 kV test stand with laser for FEA tests

- Reach the current for single gated array and Single Tip

-Optimize production of double gated array - Reach the current for double gated array

- Reach current and emittance for double gated array

- Combine FEA and pulser in the 4 MeV test stand.

FALLBACK: - Photo cathode with pulser, diode and 2-f cavity

#### PULSER WITH ACCELERATING DIODE:

GOAL: - 1 MV and 250 MV/m

ACTIONS: - Completion of gradient tests (material and surface treatment)

- Upgrading of the pulser to 1 MV

FALLBACK: - Re-optimization of the diode configuration according to maximum possible gradient and voltage



#### RF Systems 4 MeV test stand

#### 2 cell 1 frequency prototype

## Pre machined cavity body successfully brazed

#### Present situation

- Tuning and field balance adjusted by shortening the cells before last brazing
- Power splitter completed and measured
- Cavity and wave guide splitter assembled in OTLA clean room
- Adjustment final inner conductor coaxial coupler completed
- After last brazing at PSI and preassembly:
  - Frequency error at 40 Co: 57 kHz (2 Co)
  - Field balance 95%
  - Coupling factor 2
- RF tests August-October 2008 conditionning currently at 5MW (29.9.2008)

rocedure or in the state of the



- 2 frequency version:- Rf design completed mode separation ...- 1.5 cell version to be reconsidered in order to avoid deceleration
- Thermal analysis

J.-Y. Raguin, M. Bopp et al.



## 2-Frequency Cavity

GOAL: - 35 MV/m combined voltage

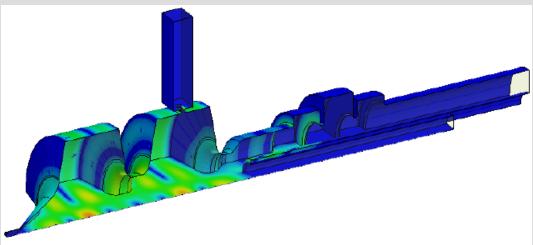
- independent tuning fundamental and third harmonic (temperature + rejection filter position)

**ACTIONS:** 

- Operation of the 1f prototype in the OBLA test stand (October 2008)

- Construction of the final 2-frequency cavity

- Test of the cavity in the OBLA test stand



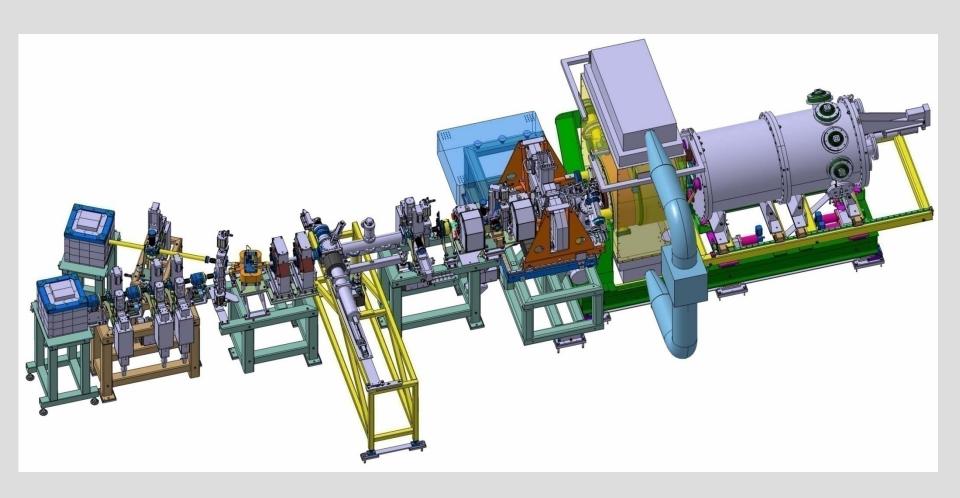
FALLBACK:

- 2 individual cavities (but less performing)

- Re-optimization of the initial linac section



#### RF Systems 4 MeV test stand

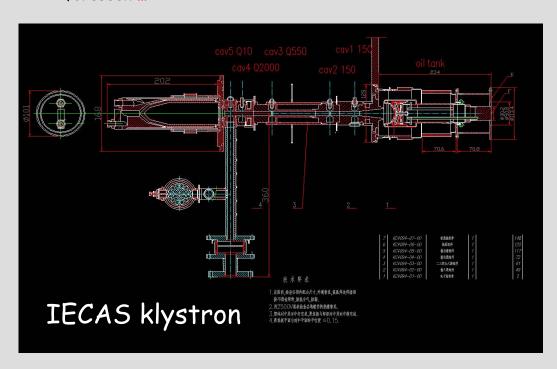




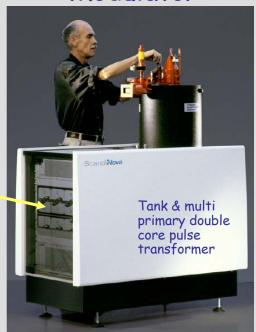
#### RF Systems 4 MeV test stand

#### Power systems 4.5 GHz - 4 MW

- First klystron power test in Bejing April ..
   Completed.
- Klystron delivered
- Modulator delivered
- Circulator and loads delivered
- Operation with 2 frequency cavity prototype foreseen ...



#### Modulator



IGBT switches

1.2 kV

- The company SCANDINOVA with solid state technology selected.

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#### Risk evaluation

#### Risks evaluation

- 1) Beam Dynamic, Target goal 1 MV pulser for stable operation (pulser upgrade)
- 2) High Gradient diode operation R&D (~90-100 MeV/m achieved routinely, 130 MV/m demonstrated but poor reproducibility at present)
- 3) Cathodes implementation with ultimate high gradient performances and 5.5 A not done (FEA, needle cathode, photocathode)
- 4) FEA R&D is progressing but requires more time (fabrication, current, homogeneity)
- 5) Two frequency Two cell cavity technology must be demonstrated

At present starting the 250 MeV injector operation with the advanced source could slow down both the gun development and the injector operation (beam studies).



#### Electron Source Development strategy

#### RF photo injector

One gun available as permanent loan from CERN. It will be used to start:

- 1. Test of low emittance beam transport gain experience with emittance compensation
- Consolidate photo cathode operation gain experience with laser and metallic cathode
- 3. Test bunch compression chicane explore full range compression ratio and investigate CSR
- 4. Study of Timing and synchronization
- 5. Diagnostic optimization slice and projected parameters, BPM, arrival time monitor
- 6. Machine stability studies

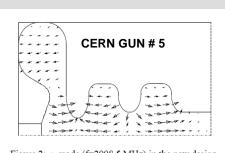


Figure 2:  $\pi$ -mode (f=2998.5 MHz) in the new design.



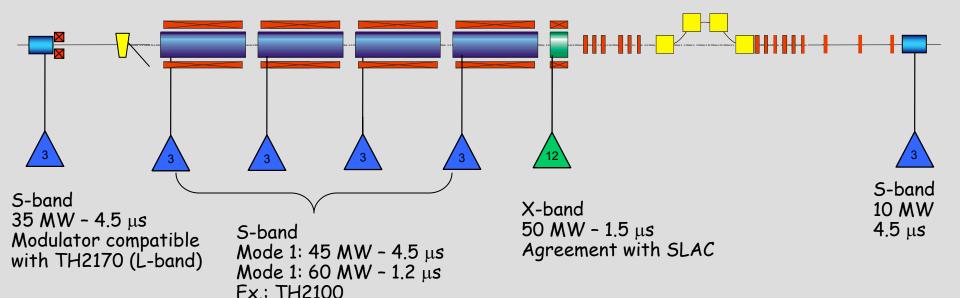
CTF GUN #5 from CERN

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#### 250 MeV Injector

#### RF systems starting configuration



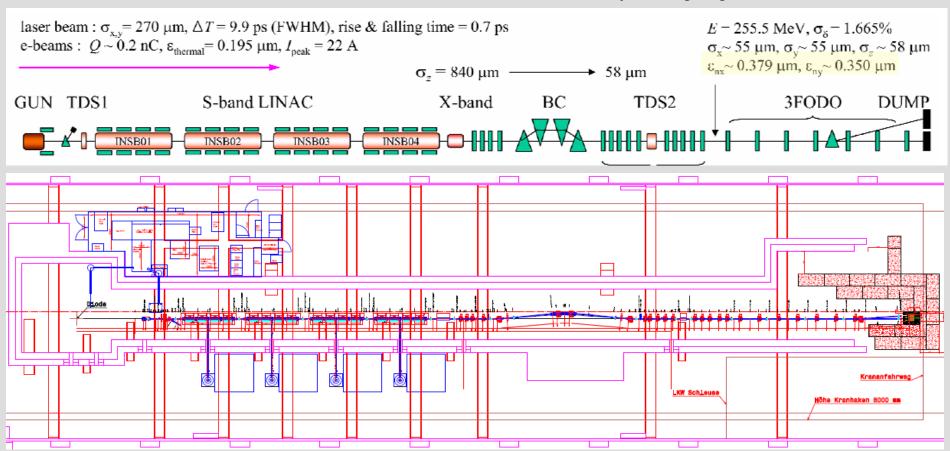


- Klystron call for tender published
- Modulator call for tender published
- RF-gun in house
- S-TW structure: RF design completed and verified by ACCEL
- · Deflecting cavity MOU (same as FERMI project)
- · X-band cavity (discussion with CERN, INFN-Frascati and ELETTRA)

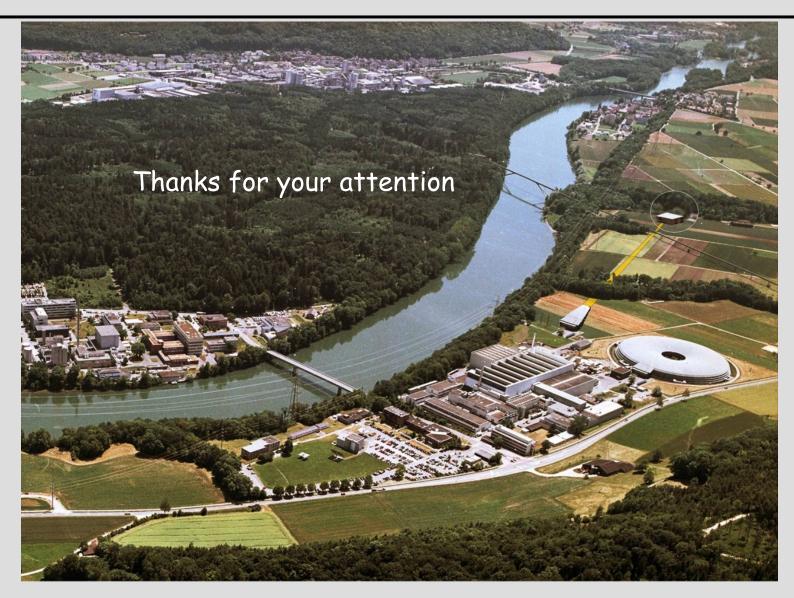
#### 250 MeV injector

#### Machine Layout with CTF gun

- Simulation completed
- Component positioning completed
- Beam dump specified
- Tolerance analysis on going









#### CONCEPT / LAYOUT

### Electron Source Development strategy

- OBLA will be kept as dedicated test stand for the advanced source:
- 1) High gradient R&D (>100 MV/m) with stable and reproducible gun operation
- 2) Systematic test of advance cathode technology (FEA, needle cathode) + implementation with high gradient operation, and beam characterization
- 3) 1 MV pulser upgrade and technology consolidation
- 4) RF LLE development

The complete 4 MeV test stand remains. This includes the pulser, the diagnostic line, the laser systems, the RF systems and the control systems.

• The 250' MEV injector will start with a S-band RF photo cathode

Both facilities will be operated in parallel

## The implementation of the advanced source in the injector must be planned from now

Space, transfer line, supports, vacuum components, RF and installation (possible implementation 1 Year after starting the injector with the RF photo cathode?)



#### WORK PROGRESS on High gradient operation

	<i>G</i> radient [MV/m]	Diode gap [mm]	Comments
Stainless Steel hand polished	70.	4	Routinely with laser
Stainless Steel hand polished	95	4	With laser better results
Stainless Steel hand polished	110/130	2.5	Without laser better results
TiVAl alloy	130	2.5	Without laser no sparks. (Irrecoverable spark at 140 MV/m)
Cu diamond turned (5nm roughness)	40	4	With laser stable. (Breakdown at 41 MV/m)
Nb	65	5	Vacuum fired at 900 °C for 2 hours and chemically buffered polished

#### Next steps:

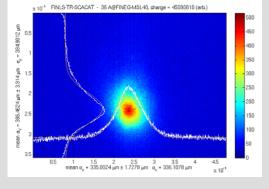
C. Gough

- Continue HG tests in OBLA
- New surface treatments (ex. Surface e-beam re-melting collaboration with Tomsk)

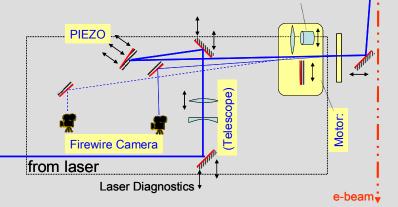
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#### CATHODES

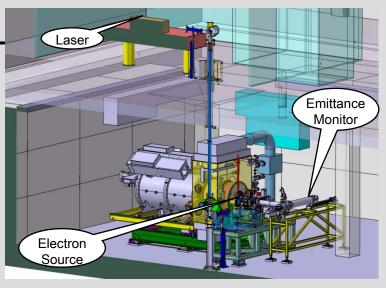
#### Photo cathodes



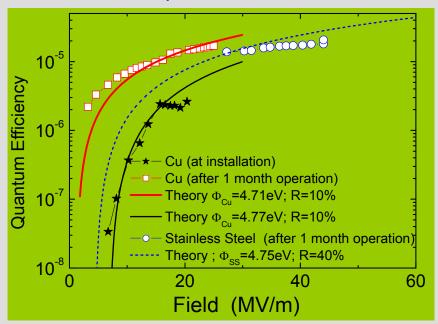
New: laser 10  $\mu$ m pointing stability



R. Ganter / C. Hauri

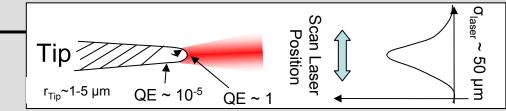


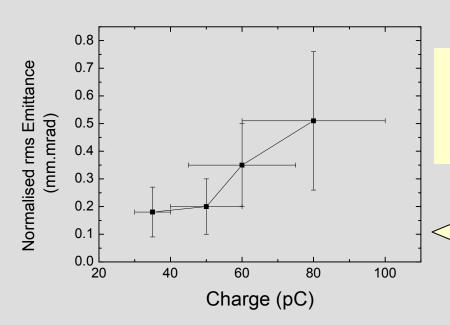
New: QE measurements



## PAUL SCHERRER INSTITUT Needle cathodes

#### **CATHODES**





#### Progress

- · Non-uniform QE-Verteilung: QE Apex >> QE Flanke
- Maximalstrom 2.9 A (140 pC)
- $\varepsilon_n$  ~0.2  $\mu$ m.rad (40 pC, Photo-Feldemission)

**Laser:** 6  $\mu$ J; 266 nm;  $\sigma_{t \, laser}$ =6.5 ps;

Voltage: 50 keV;

**Solenoid:** 35 mT < B<sub>Solenoid</sub> < 41 mT

R. Ganter

#### FLAC recommendations:

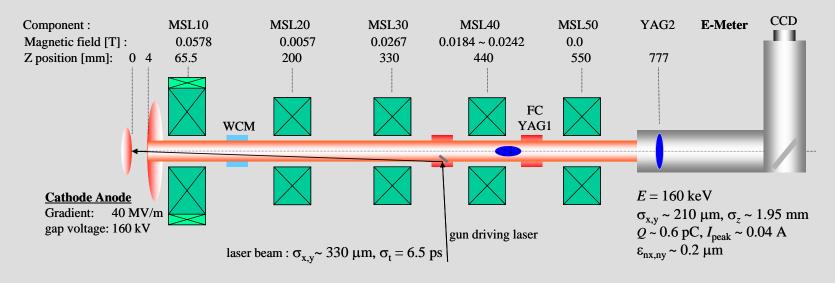
- (...) further development and investigations of this emission approach should be carried out with high priority.
- (...) It is not clear to FLAC how the implementation of the macro tip in the pulser will affect the field distribution and subsequently the emittance evolution in the diode gap. FLAC suggests that emittance simulations analog to the ones performed for the FEA should be carried out.

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#### **CATHODES**

## Photo cathodes thermal emittance

#### Solenoid scan at low charge



	Charge [pC]	Laser spot rms [mm] 6.5 ps rms pulse	HV [kV]	Thermal emi ttance [mm-mrad]
Cu diamond turned electrodes	0.6	0.33	40	~0.2
Stainless steel han d polished	0.6	0.3	50	~0.45

Y. Kim

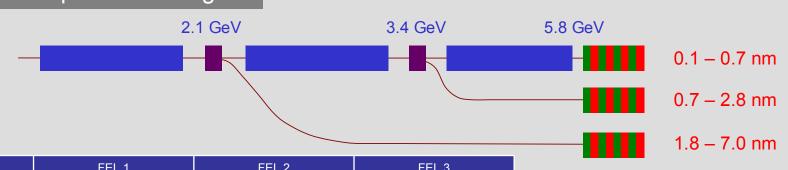


#### Machine layout

- First start to end simulation compatible with the CTF gun are available
  - Simulation based on the 250 MeV injector design with the CTF gun (FLAC recommendation)
  - The linac could be sensibly longer than initially expected, depends on the beam requirements at the undulator (energy chirp cancellation and not on the emittance)
  - Hard X rays FEL matched to the S2E simulation results (60 m undulator with some overhead)
- New optimization of the FEL concept
  - Soft X-ray undulator period changed to improve the tuning scheme
  - Seeding/slicing scheme under investigation



#### New FEL concept basic changes

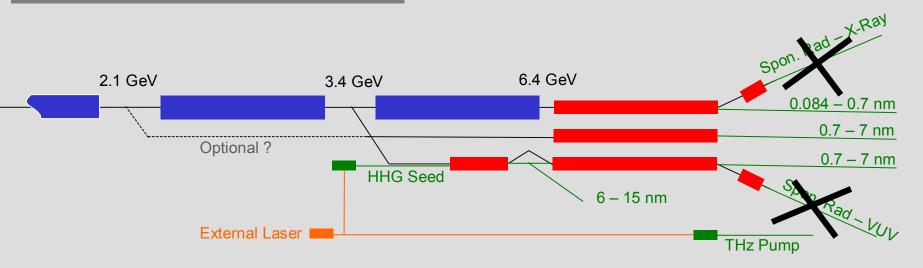


	FEL 1	FEL 2	FEL 3
Wavelength	0.1 – 0.7 nm	0.7 – 2.8 nm	1.8 – 7.0 nm
Beam Energy	2.2 - 5.8 GeV	3.4 GeV	2.1 GeV
Period Length	15 mm	40 mm	40 mm
K-Value	1.2	1.0 – 3.2	1.0 – 3.2
Und. Type	In-vac Cryo	APPLE	APPLE
Tuning	Energy	Gap	Gap

- •Linac is fixed till second extraction point at 3.4 GeV. Rest of Linac is used for energy tuning of hard X-ray FEL (FEL 1).
- •FEL Operation is decoupled from other FEL beamlines.
- •Wavelength range is roughly defined by available optics, resulting in one hard X-ray and two VUV beam lines
- •Module length is 4m to allow for lower beta-function of 10 m in the VUV beamlines.
- •FEL 2 and FEL 3 are using the same undulator type. Modules can be exchange among the beam lines and only one type of spare module is needed for the VUV FELs.
- •Requirement of minimum gap of 6.5 mm is achieved for VUV beamlines.
- •VUV beamlines have a tuning range of a factor 4. Extraction energy can be optimized to change wavelength range (e.g. 3.7/2.4 GeV for a VUV range from 0.6-6 nm)



#### New FEL extended concept



- •One 60 m X-ray FEL beam line, planar, tuned by energy.
- •Two 60 m VUV FEL beam lines, APPLE-type, tuned by undulator gap with 2 selectable electron beam energies.
- •Long wavelength undulators for seeding purpose or SASE FEL.
- •HHG source for seeding.
- •THz Pump source (Plasma injector + dipole radiator).
- •Extending beam energy range to reach 14.4 keV photon energy.
- •Short pulse with chirped pulse and slicing, low charge operation and/or emittance spoiler slit in bunch compressor.

# PAUL SCHERRER INSTITUT CONCEPT / LAYOUT

#### CONCEPT / LAYOUT

## Injector start baseline

