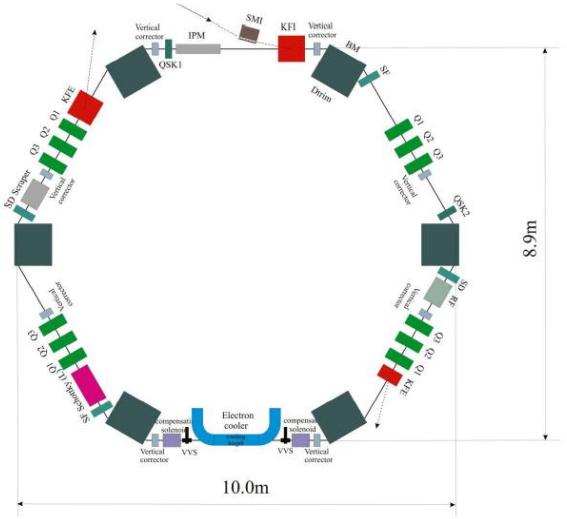
Radio-Frequency (RF) & Schottky diagnostics WP for ELENA



Maria Elena Angoletta, BE/RF
on behalf of the CERN RF group

First ELENA construction meeting
CERN, 28-29 September 2011

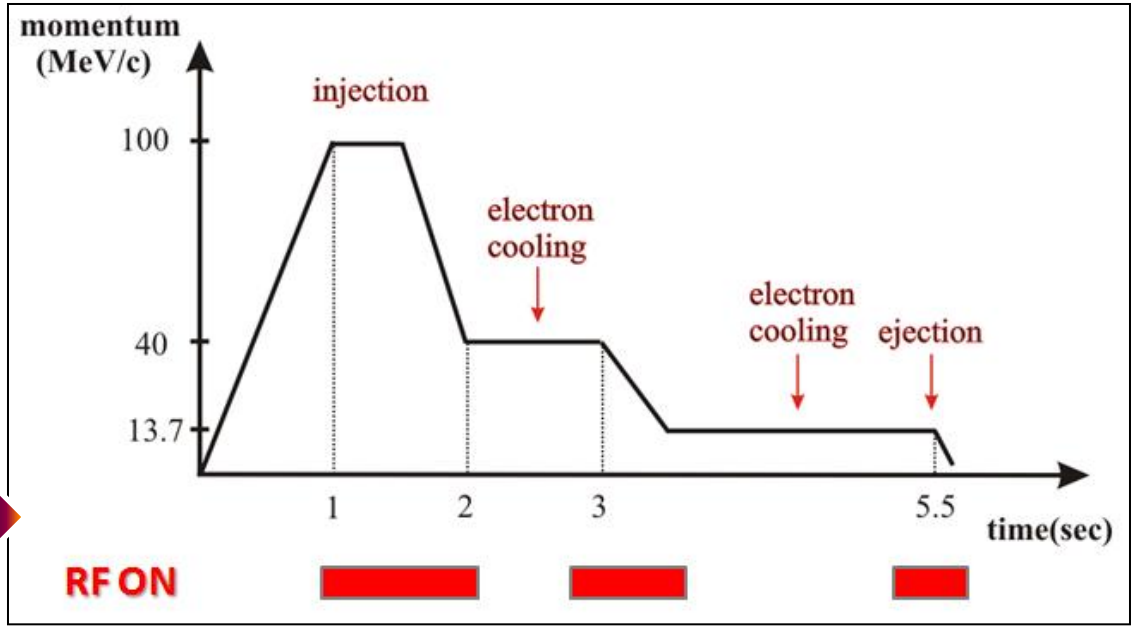
Outline

1. What
2. How
3. Possible external contributions
4. Conclusions
5. References

1. What: RF

Actions: beam capture, deceleration & synchronisation (inj + extr).

Qualitative ELENA cycle & RF actions.



Components:

- **Schottky Longitudinal Pick-ups (LPUs)** : based on AD LPUs design
- **Cavity**
- **Low-level RF (LLRF)**

} From CERN injectors' RF consolidation

1. What: Schottky diagnostics

Actions: beam parameters calculation on whole ELENA cycle

- Debunched beam: Schottky scans (**Np**, **Δp/p**, **<p>**, **averaged spectra**)
- Bunched beam: **Np** + bunch length from RF currents

Main components:

- Signal detection: **Schottky LPUs** (same as for RF part)
- Real-time digital signal processing: **LLRF hardware**

- Based on AD Schottky diagnostics
  - ***Essential*** machine diagnostics, used for >10 year
  - Usage: machine/cooling monitoring, optimisation, debugging
- Included in RF WP as closely interlinked to LLRF

Outline

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2. How
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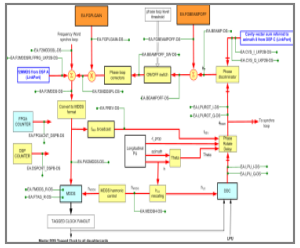
2. How: overview

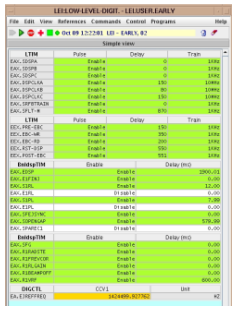
Controls

Local CR

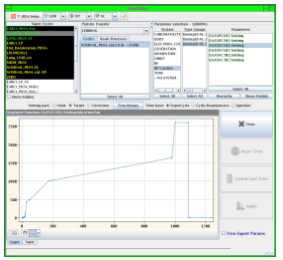
Ring



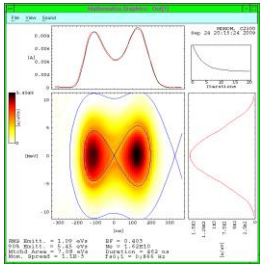
LLRF interface



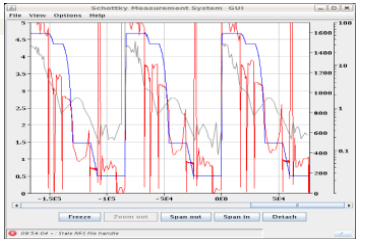
Working Set



Reference editor



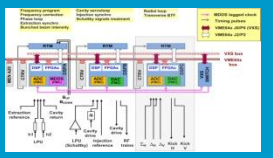
Tomoscope



Schottky diagnostics

OASIS

LLRF & DIAGNOSTIC DATA PROCESSING

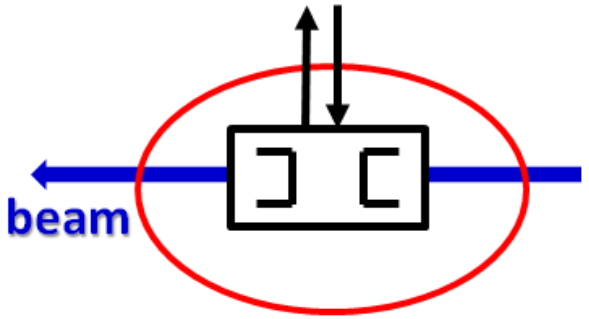


BTrain injection/ex references,

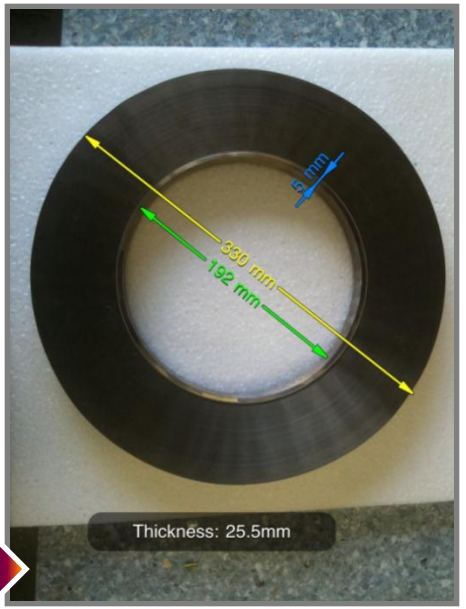
bear beam

LPUs

2. How: Cavity



- **Low-voltage broadband cavity + ampli**
  - BW: 145 kHz → 1.06 MHz
  - Controlled voltage range: 0.7 mV → 11 V
    - NB: > 80 dB dynamic range, challenging for LLRF !!!
- **Material**: ferrite vs. magnetic-alloy (Finemet)
- **Finemet** is the likely choice
  - Important item in injectors HLRF renovation
  - Finemet (***FT3M***) cavity deployed in CERN's LEIR **[1]**.
  - Low-loss Finemet (***FT3L***) **[2]** cavity will be tested in CERN's PSB.
  - Collaboration with MedAustron on HLRF.



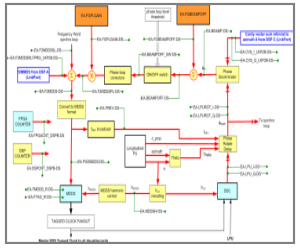
Finemet ring (courtesy G. Kotzian, MedAustron).

2. How: overview

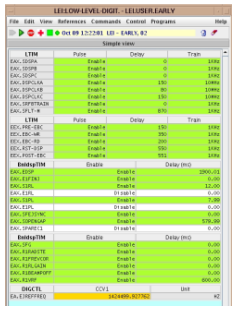
Controls

Local CR

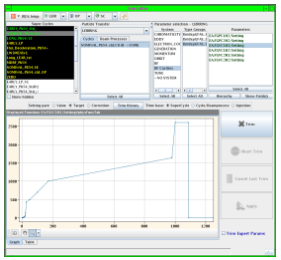
Ring



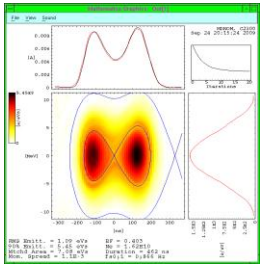
LLRF interface



Working Set



Reference editor



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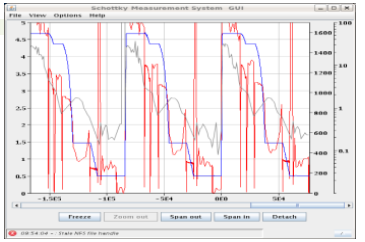
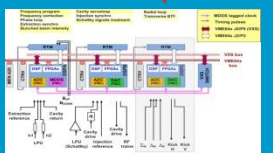


Schottky diagnostics

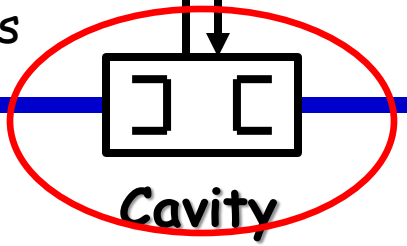
OASIS

LLRF & DIAGNOSTIC DATA PROCESSING



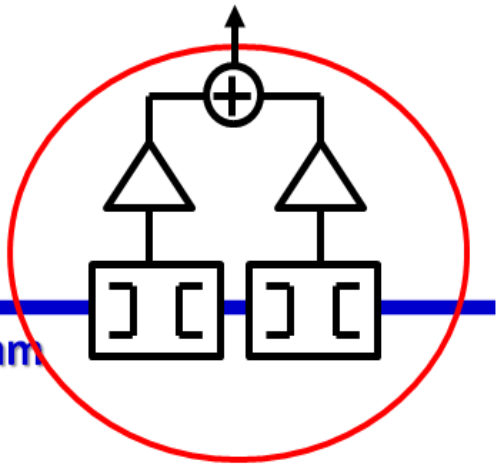
BTrain, injection/extraction references, timings

beam

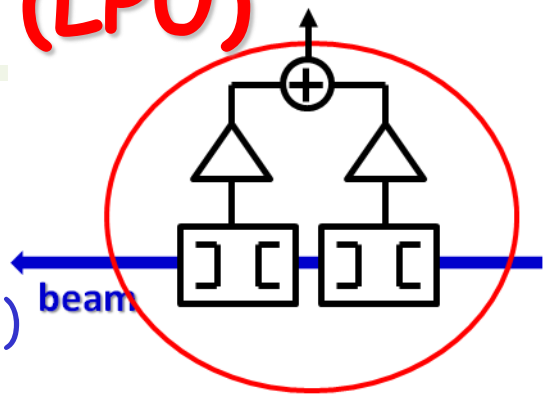


Cavity

beam



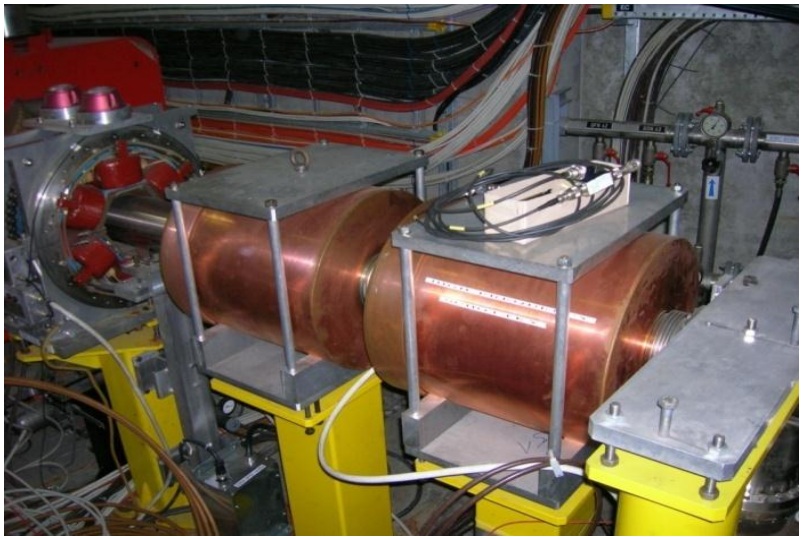
2. How: Longitudinal Pick-Up (LPU)



- **Usage**:
  - Beam phase loop in LLRF
  - Longitudinal Schottky scans (if noise low enough)
- ***Non-trivial* development based on AD LPU [3]**
  - BW : 20 kHz → 20 MHz.
  - 2 separate LPUs (HF + LF) + head amplifier
  - Summing unit in local CR
- Space limitations + components obsolescence

  → re-design likely needed.

LPU (LF + HF) currently installed in the AD ➡

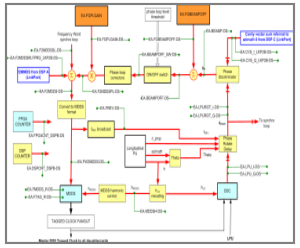


2. How: overview

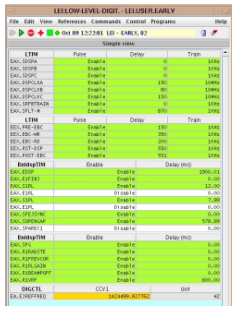
Controls

Local CR

Ring



LLRF interface



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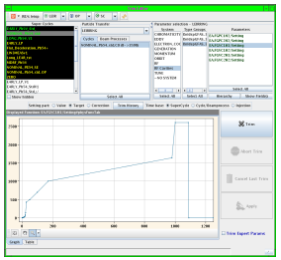

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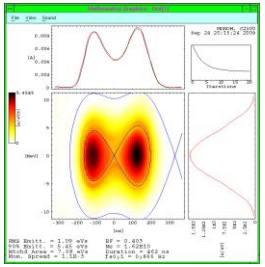
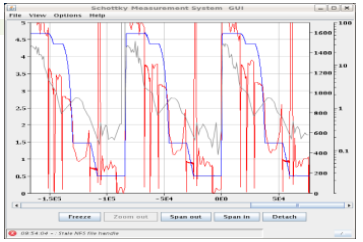
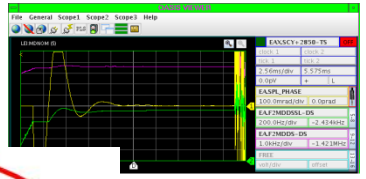


Tomoscope

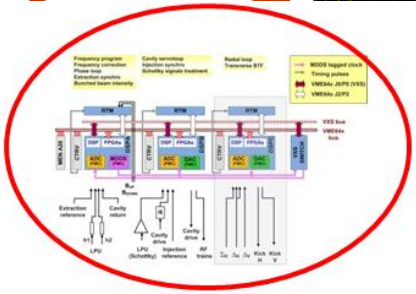


Schottky diagnostics



OASIS

LLRF & DIAGNOSTIC DATA PROCESSIN



BTrain, injection/extraction references, timings

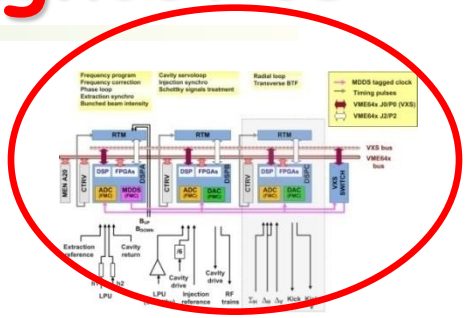
beam

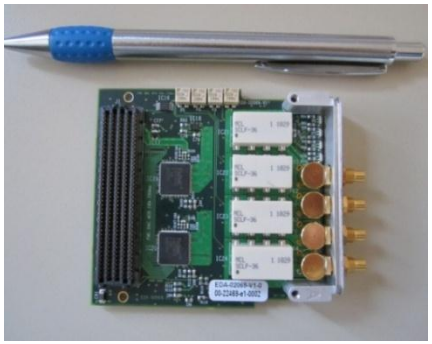
Cavity

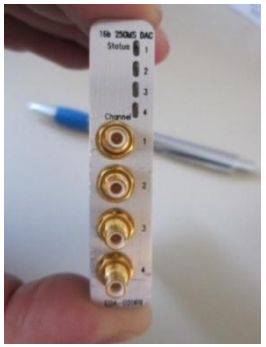
LPUs

2. How: LLRF & Schottky diagnostics

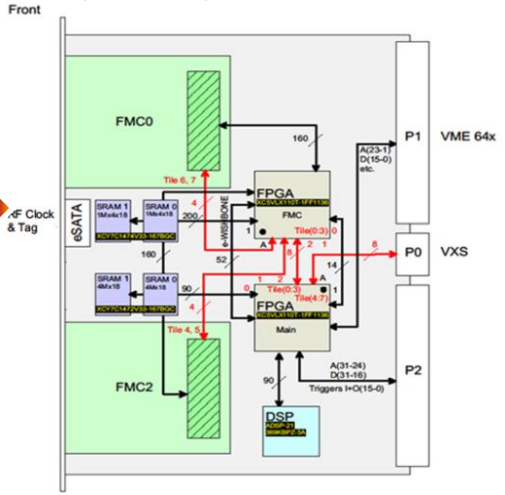
- ***State-of-the-art*** digital h/w + signal processing
  - CERN RF new standard for Meyrin injectors
  - Evolution of CERN's LEIR system **[4]**
  - Backplane: VME Switched Serial (VXS)
  - Motherboard: 2 x Virtex5 FPGAs + SharcDSP 400MHz
  - Daughtercards: FPGA Mezzanine Card Standard (FMC)





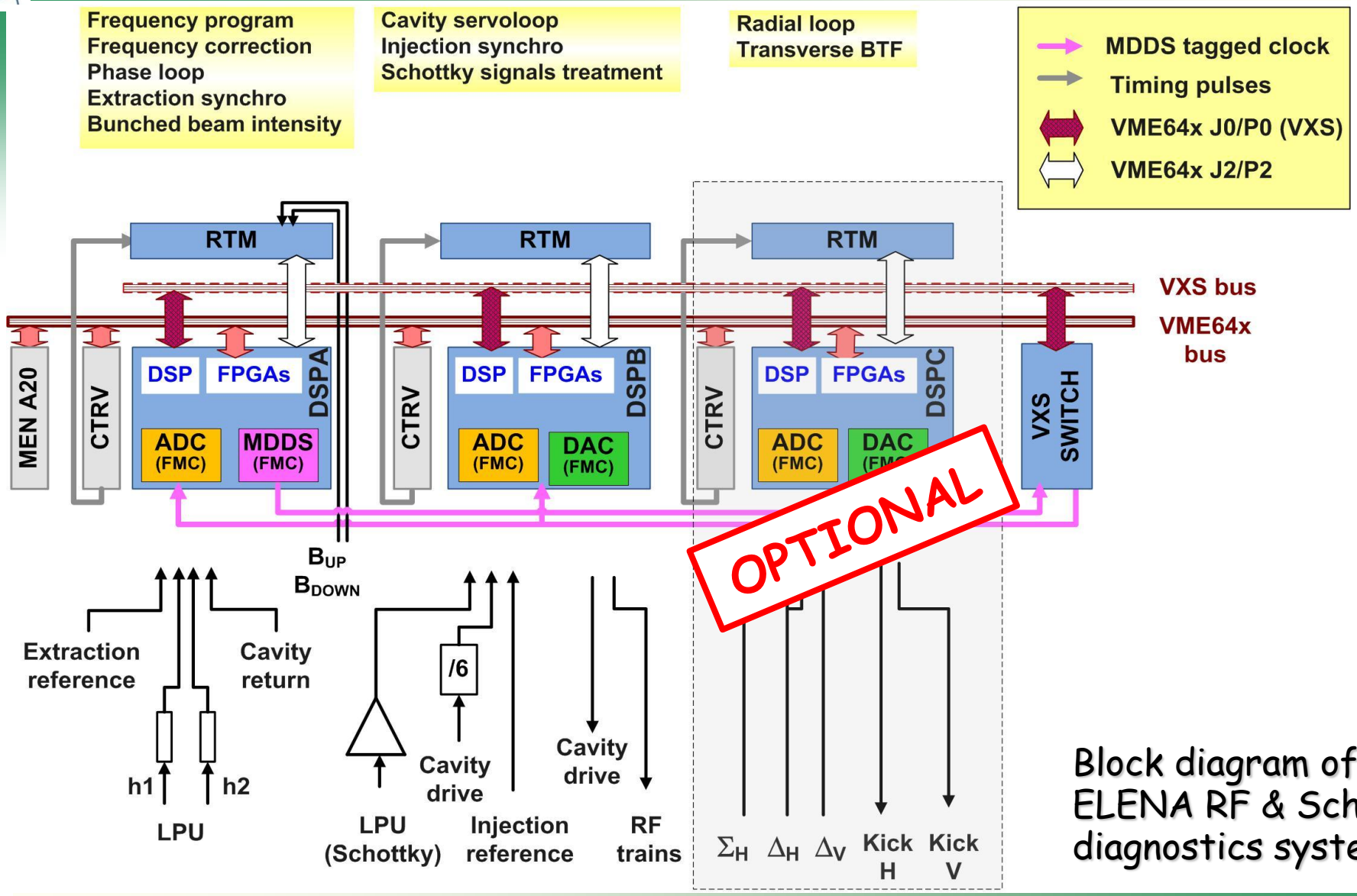


Some schematics & pictures of new h/w



- H/w + part of code (DSP, FPGA) from RF injectors consolidation **[5]**.
- Diagnostics: precise data processing specs from AD experience **[6]**.

2. How: LLRF & Schottky diagnostics



Block diagram of the ELENA RF & Schottky diagnostics system.

Outline

1. What
2. How
3. **Possible external contributions**
4. Conclusions
5. References

3. Possible external contributions

1. Cavity

Item	Description	Material [kCHF]	Personnel [FTE]
Low voltage broadband cavity and amplifier			
Cavity LF	Loaded ferrite/finemet cavity	60	0.2
Power Amplifier	~20 W if 4A15 ferrites used	5	

- No outsourcing required

2. Schottky Longitudinal PU

Item	Description	Material [kCHF]	Personnel [FTE]
Low noise pick-ups for bunch lengths, RF intensity, beam phase loop and long. Schottky			
PU LF (4A15 ferr.)	Low frequency pick-up (0.02 - 5 MHz	60	0.2
PU HF (4L2 ferr.) *)	High frequency pick-up (0.3 - 25MHz)	30	0.2
PU electr.	Electronics PU's (head+sum)	10	0.2

- Estimates are for copy of existing AD Schottky LPU.
- Re-design likely needed.
- Possible external help (@CERN!)??

3. Possible external contributions – cont'd

3. LLRF

Item	Description	Material [kCHF]	Personnel [FTE]
Digital low level RF, incl. bunch beam intensity and Schottky diagnostics			
VXS crate	VME 64x with CPU	4.0	
CPU	MEN A20	2.5	
2 DSP mother boards	2 x (RTM+DSP)	8.0	
Timing	2 x CTRV VME modules	1.4	
Master DDS	1 x MDDS	1.2	
VXS Switch module	1	4.0	
Clock Fan-Out	1 x VME Clock Fan-out	1.0	
4 ch. Receiver	2 x 4 ch DDC daughter cards	4.0	
4 ch. Modulator	1 x 4 ch. SDDS daughter card	2.0	
Components ordering, hardware manufacturing, tests and commissioning			0.4

- Possible outsourcing @CERN & in collaboration with BE/RF.

3. Possible external contributions – cont'd

4. Digital signal processing

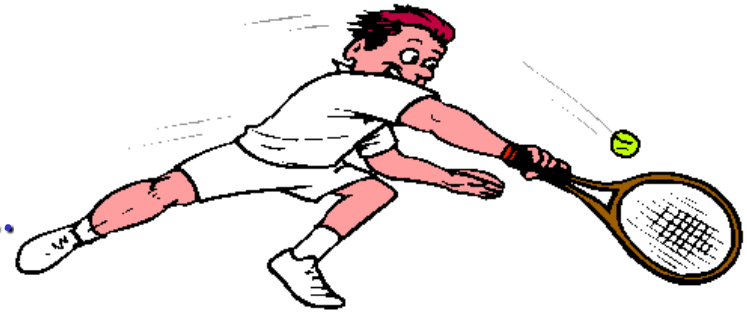
Item	Description	Material [kCHF]	Personnel [FTE]
Digital LLRF and Longitudinal Diagnostic Software			
Global system design	All 3 layers for the 3 main items below		0.2
FPGA, DSP, FESA, Appl.	Digital LLRF Software integration (DSP, RTT,App)		0.5
FPGA, DSP, FESA, Appl.	Longit. Bunched beam intensity and Schottky		0.8
FPGA, DSP, FESA, Appl.	Transverse BTF and Radial loop		0.6
Global system integration, commissioning with beam and setup			0.4
Diagnostic specific application (as for AD), provided by OP?			0.3

- DSP + FPGA development (~0.5 FTE): possible outsourcing @CERN & in collaboration with BE/RF.
- Diagnostic-specific application (~0.3 FTE): possible outsourcing @CERN & in collaboration with BE/RF.

4. Conclusions

- ELENA project will profit from RF injectors consolidation (HLRF + LLRF).
- AD experience:
  - Invaluable starting point for new developments
  - Enables precise specs for digital signal processing
- Tight manpower:
  - External collaborations welcome!
  - Identified areas for possible external contributions.

… Now the ball is in your court…



5. References

[1] R. Garoby, M. Haase, P. Maesen, M. Paoluzzi, C. Rossi, C. Ohmori (KEK), ***"The LEIR RF System"***, PAC05, Knoxville, USA, May 2005.

[2] C. Ohmori et al., ***"Developments of Magnetic Alloy Cores with Higher Impedance for J-PARC Upgrade"***, IPAC01, Kyoto, 2010.

[3] C. Gonzales, F. Pedersen, ***"An ultra low-noise AC beam transformer for deceleration and diagnostics of low intensity beams"***, *PAC '99, NY, 1999.*

[4] M. E. Angoletta, J. Bento, A. Blas, E. Bracke, A. Butterworth, F. Dubouchet, A. Findlay. F. Pedersen, J. Sanchez-Quesada, ***"CERN'S LEIR Digital LLRF: System Overview and Operational Experience"***, IPAC 2010, Kyoto, 2010.

[5] M. E. Angoletta, A. Blas, A. Butterworth, A. Findlay, P. M. Leinonen, J. C. Molendijk, F. Pedersen, J. Sanchez-Quesada, M. Schokker, ***"CERN's PS Booster LLRF Renovation: Plans and Initial Beam Tests"***, IPAC 2010, Kyoto, 2010.

[6] M. E. Angoletta, V. Chohan, M. Ludwig, O. Marqversen, F. Pedersen, ***"The New Digital-Receiver-Based System for Antiproton Beam Diagnostics"***, PAC 2001, New York, 2001.