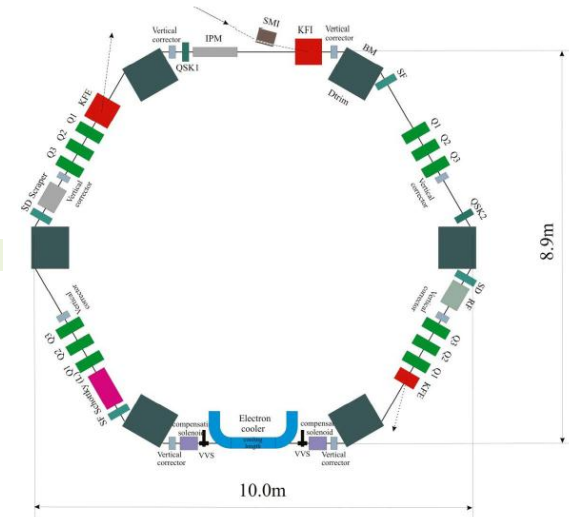


Radio-Frequency (RF) & Schottky diagnostics WP for ELENA

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

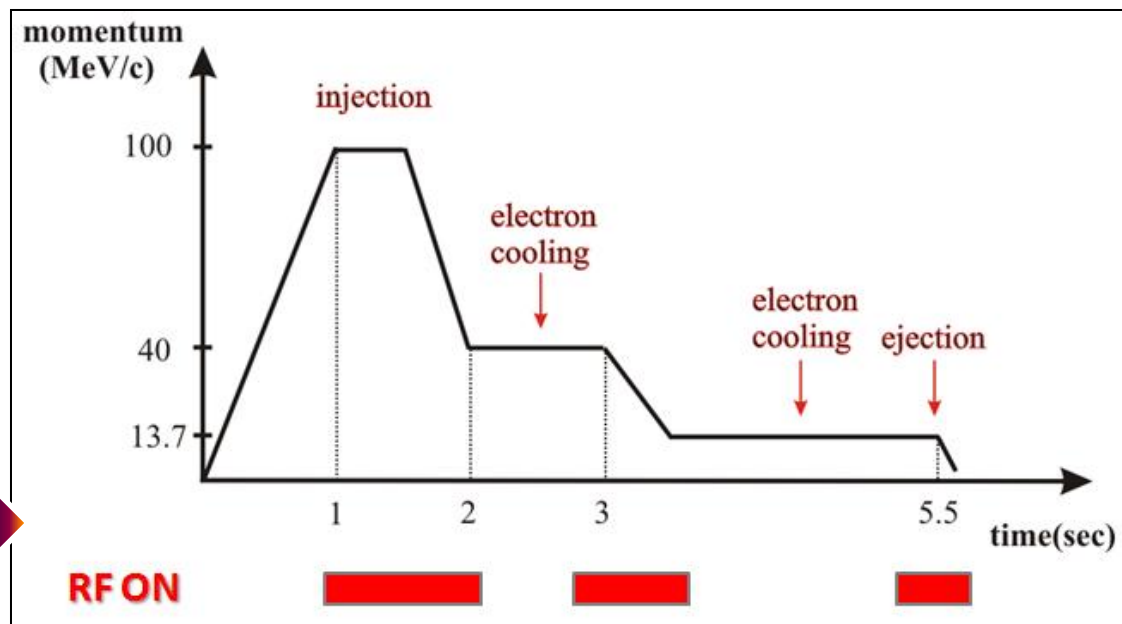
4. Conclusions

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 (N_p , $\Delta p/p$, $\langle p \rangle$, averaged spectra)
- Bunched beam: N_p + 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

1. What

2. How

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4. Conclusions

5. References

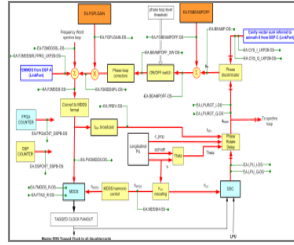


2. How: overview

Controls

Local CR

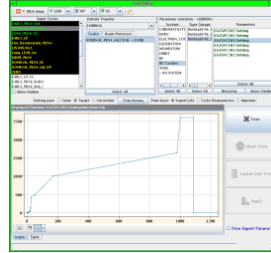
Ring



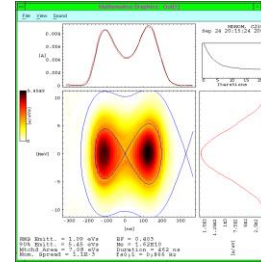
LLRF interface

LTW	Phase	Delay	Gain	Trigg
ECU_SOP1A	0.0000	0.0000	1.0000	0.0000
ECU_SOP1B	0.0000	0.0000	1.0000	0.0000
ECU_SOP1C	0.0000	0.0000	1.0000	0.0000
ECU_SOP1D	0.0000	0.0000	1.0000	0.0000
ECU_SOP1E	0.0000	0.0000	1.0000	0.0000
ECU_SOP1F	0.0000	0.0000	1.0000	0.0000
ECU_SOP1G	0.0000	0.0000	1.0000	0.0000
ECU_SOP1H	0.0000	0.0000	1.0000	0.0000
ECU_SOP1I	0.0000	0.0000	1.0000	0.0000
ECU_SOP1J	0.0000	0.0000	1.0000	0.0000
ECU_SOP1K	0.0000	0.0000	1.0000	0.0000
ECU_SOP1L	0.0000	0.0000	1.0000	0.0000
ECU_SOP1M	0.0000	0.0000	1.0000	0.0000
ECU_SOP1N	0.0000	0.0000	1.0000	0.0000
ECU_SOP1O	0.0000	0.0000	1.0000	0.0000
ECU_SOP1P	0.0000	0.0000	1.0000	0.0000
ECU_SOP1Q	0.0000	0.0000	1.0000	0.0000
ECU_SOP1R	0.0000	0.0000	1.0000	0.0000
ECU_SOP1S	0.0000	0.0000	1.0000	0.0000
ECU_SOP1T	0.0000	0.0000	1.0000	0.0000
ECU_SOP1U	0.0000	0.0000	1.0000	0.0000
ECU_SOP1V	0.0000	0.0000	1.0000	0.0000
ECU_SOP1W	0.0000	0.0000	1.0000	0.0000
ECU_SOP1X	0.0000	0.0000	1.0000	0.0000
ECU_SOP1Y	0.0000	0.0000	1.0000	0.0000
ECU_SOP1Z	0.0000	0.0000	1.0000	0.0000
ECU_SOP2A	0.0000	0.0000	1.0000	0.0000
ECU_SOP2B	0.0000	0.0000	1.0000	0.0000
ECU_SOP2C	0.0000	0.0000	1.0000	0.0000
ECU_SOP2D	0.0000	0.0000	1.0000	0.0000
ECU_SOP2E	0.0000	0.0000	1.0000	0.0000
ECU_SOP2F	0.0000	0.0000	1.0000	0.0000
ECU_SOP2G	0.0000	0.0000	1.0000	0.0000
ECU_SOP2H	0.0000	0.0000	1.0000	0.0000
ECU_SOP2I	0.0000	0.0000	1.0000	0.0000
ECU_SOP2J	0.0000	0.0000	1.0000	0.0000
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ECU_SOP2L	0.0000	0.0000	1.0000	0.0000
ECU_SOP2M	0.0000	0.0000	1.0000	0.0000
ECU_SOP2N	0.0000	0.0000	1.0000	0.0000
ECU_SOP2O	0.0000	0.0000	1.0000	0.0000
ECU_SOP2P	0.0000	0.0000	1.0000	0.0000
ECU_SOP2Q	0.0000	0.0000	1.0000	0.0000
ECU_SOP2R	0.0000	0.0000	1.0000	0.0000
ECU_SOP2S	0.0000	0.0000	1.0000	0.0000
ECU_SOP2T	0.0000	0.0000	1.0000	0.0000
ECU_SOP2U	0.0000	0.0000	1.0000	0.0000
ECU_SOP2V	0.0000	0.0000	1.0000	0.0000
ECU_SOP2W	0.0000	0.0000	1.0000	0.0000
ECU_SOP2X	0.0000	0.0000	1.0000	0.0000
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ECU_SOP2Z	0.0000	0.0000	1.0000	0.0000

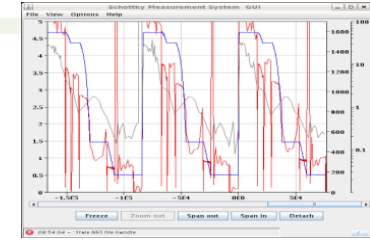
Working Set



Reference editor



Tomoscope



Schottky diagnostics

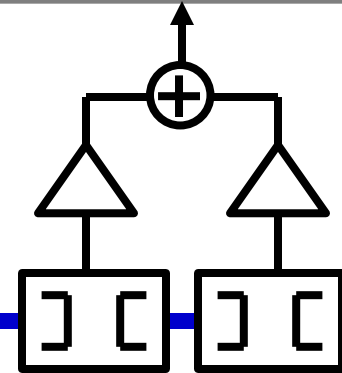
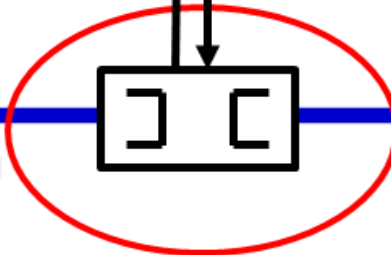


OASIS



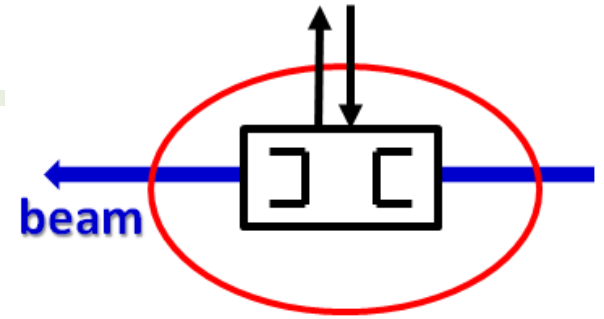
BTrain injection/ex references,

← bear beam



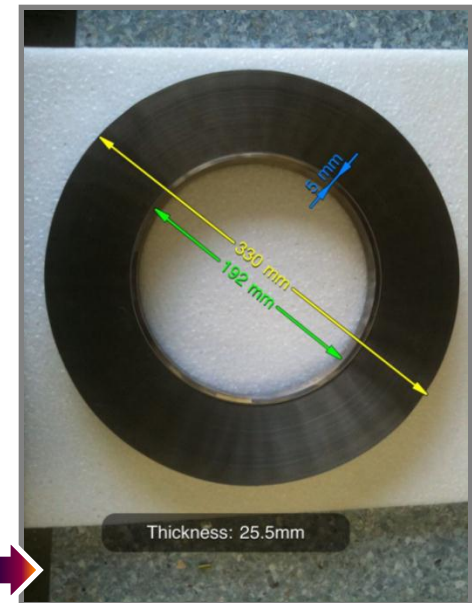
LPU's

2. How: Cavity



- ❖ Low-voltage broadband cavity + ampli
 - BW: 145 kHz \rightarrow 1.06 MHz
 - Controlled voltage range: 0.7 mV \rightarrow 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).



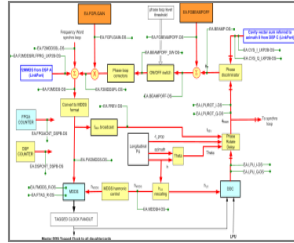


2. How: overview

Controls

Local CR

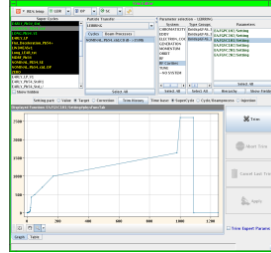
Ring



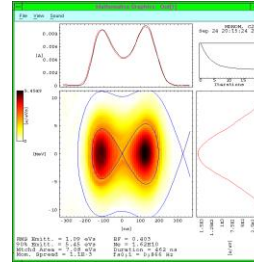
LLRF interface

LTW	Phase	Gain	Trk
EXC_SOP1A	0.0000	0.0000	0.0000
EXC_SOP1B	0.0000	0.0000	0.0000
EXC_SOP1C	0.0000	0.0000	0.0000
EXC_SOP1D	0.0000	0.0000	0.0000
EXC_SOP1E	0.0000	0.0000	0.0000
EXC_SOP1F	0.0000	0.0000	0.0000
EXC_SOP1G	0.0000	0.0000	0.0000
EXC_SOP1H	0.0000	0.0000	0.0000
EXC_SOP1I	0.0000	0.0000	0.0000
EXC_SOP1J	0.0000	0.0000	0.0000
EXC_SOP1K	0.0000	0.0000	0.0000
EXC_SOP1L	0.0000	0.0000	0.0000
EXC_SOP1M	0.0000	0.0000	0.0000
EXC_SOP1N	0.0000	0.0000	0.0000
EXC_SOP1O	0.0000	0.0000	0.0000
EXC_SOP1P	0.0000	0.0000	0.0000
EXC_SOP1Q	0.0000	0.0000	0.0000
EXC_SOP1R	0.0000	0.0000	0.0000
EXC_SOP1S	0.0000	0.0000	0.0000
EXC_SOP1T	0.0000	0.0000	0.0000
EXC_SOP1U	0.0000	0.0000	0.0000
EXC_SOP1V	0.0000	0.0000	0.0000
EXC_SOP1W	0.0000	0.0000	0.0000
EXC_SOP1X	0.0000	0.0000	0.0000
EXC_SOP1Y	0.0000	0.0000	0.0000
EXC_SOP1Z	0.0000	0.0000	0.0000
EXC_SOP2A	0.0000	0.0000	0.0000
EXC_SOP2B	0.0000	0.0000	0.0000
EXC_SOP2C	0.0000	0.0000	0.0000
EXC_SOP2D	0.0000	0.0000	0.0000
EXC_SOP2E	0.0000	0.0000	0.0000
EXC_SOP2F	0.0000	0.0000	0.0000
EXC_SOP2G	0.0000	0.0000	0.0000
EXC_SOP2H	0.0000	0.0000	0.0000
EXC_SOP2I	0.0000	0.0000	0.0000
EXC_SOP2J	0.0000	0.0000	0.0000
EXC_SOP2K	0.0000	0.0000	0.0000
EXC_SOP2L	0.0000	0.0000	0.0000
EXC_SOP2M	0.0000	0.0000	0.0000
EXC_SOP2N	0.0000	0.0000	0.0000
EXC_SOP2O	0.0000	0.0000	0.0000
EXC_SOP2P	0.0000	0.0000	0.0000
EXC_SOP2Q	0.0000	0.0000	0.0000
EXC_SOP2R	0.0000	0.0000	0.0000
EXC_SOP2S	0.0000	0.0000	0.0000
EXC_SOP2T	0.0000	0.0000	0.0000
EXC_SOP2U	0.0000	0.0000	0.0000
EXC_SOP2V	0.0000	0.0000	0.0000
EXC_SOP2W	0.0000	0.0000	0.0000
EXC_SOP2X	0.0000	0.0000	0.0000
EXC_SOP2Y	0.0000	0.0000	0.0000
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EXC_SOP3A	0.0000	0.0000	0.0000
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EXC_SOP3C	0.0000	0.0000	0.0000
EXC_SOP3D	0.0000	0.0000	0.0000
EXC_SOP3E	0.0000	0.0000	0.0000
EXC_SOP3F	0.0000	0.0000	0.0000
EXC_SOP3G	0.0000	0.0000	0.0000
EXC_SOP3H	0.0000	0.0000	0.0000
EXC_SOP3I	0.0000	0.0000	0.0000
EXC_SOP3J	0.0000	0.0000	0.0000
EXC_SOP3K	0.0000	0.0000	0.0000
EXC_SOP3L	0.0000	0.0000	0.0000
EXC_SOP3M	0.0000	0.0000	0.0000
EXC_SOP3N	0.0000	0.0000	0.0000
EXC_SOP3O	0.0000	0.0000	0.0000
EXC_SOP3P	0.0000	0.0000	0.0000
EXC_SOP3Q	0.0000	0.0000	0.0000
EXC_SOP3R	0.0000	0.0000	0.0000
EXC_SOP3S	0.0000	0.0000	0.0000
EXC_SOP3T	0.0000	0.0000	0.0000
EXC_SOP3U	0.0000	0.0000	0.0000
EXC_SOP3V	0.0000	0.0000	0.0000
EXC_SOP3W	0.0000	0.0000	0.0000
EXC_SOP3X	0.0000	0.0000	0.0000
EXC_SOP3Y	0.0000	0.0000	0.0000
EXC_SOP3Z	0.0000	0.0000	0.0000

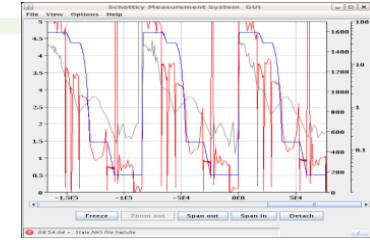
Working Set



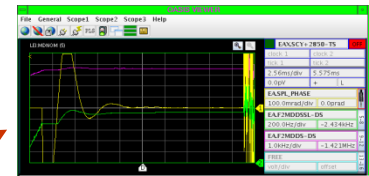
Reference editor



Tomoscope



Schottky diagnostics

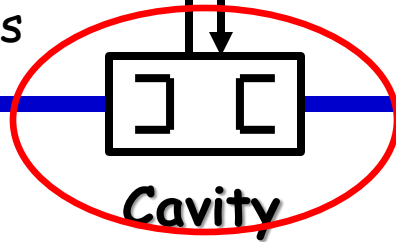


OASIS

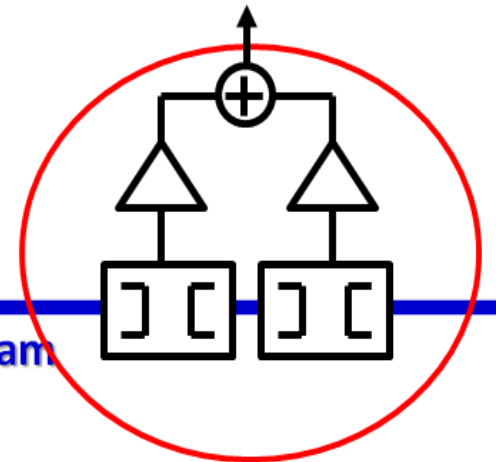


BTrain, injection/extraction references, timings

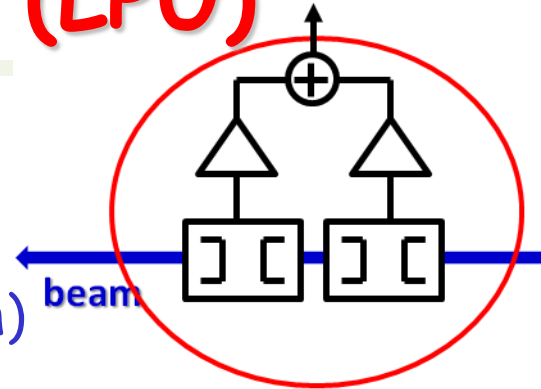
beam



beam



2. How: Longitudinal Pick-Up (LPU)



❖ Usage:

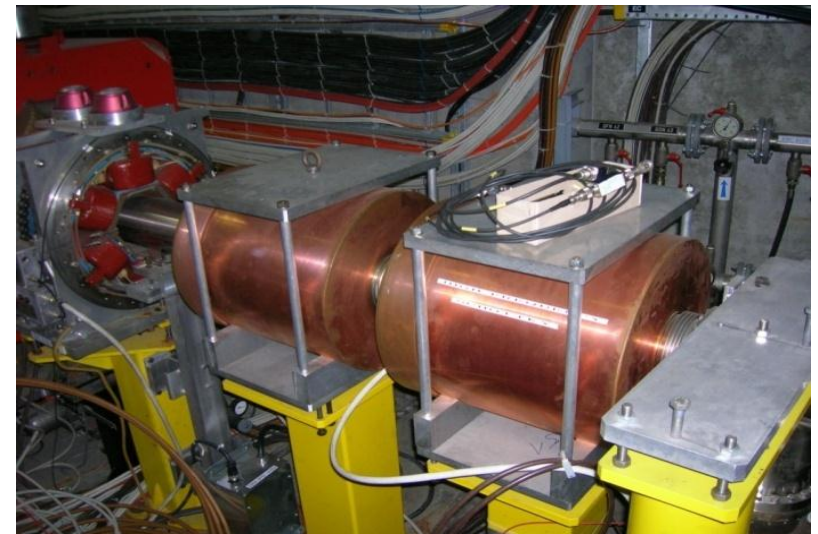
- Beam phase loop in LLRF
- Longitudinal Schottky scans (if noise low enough)

❖ 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 →



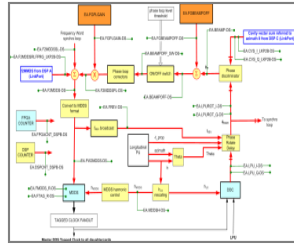


2. How: overview

Controls

Local CR

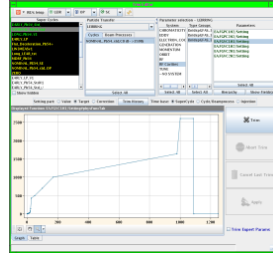
Ring



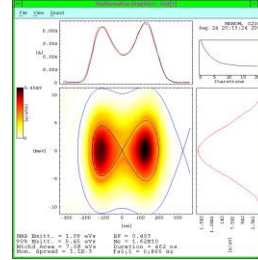
LLRF interface

LTW	Phase	Gain	Trk
ECU_SOP1	0.0000	0.0000	0.0000
ECU_SOP2	0.0000	0.0000	0.0000
ECU_SOP3	0.0000	0.0000	0.0000
ECU_SOP4	0.0000	0.0000	0.0000
ECU_SOP5	0.0000	0.0000	0.0000
ECU_SOP6	0.0000	0.0000	0.0000
ECU_SOP7	0.0000	0.0000	0.0000
ECU_SOP8	0.0000	0.0000	0.0000
ECU_SOP9	0.0000	0.0000	0.0000
ECU_SOP10	0.0000	0.0000	0.0000
ECU_SOP11	0.0000	0.0000	0.0000
ECU_SOP12	0.0000	0.0000	0.0000
ECU_SOP13	0.0000	0.0000	0.0000
ECU_SOP14	0.0000	0.0000	0.0000
ECU_SOP15	0.0000	0.0000	0.0000
ECU_SOP16	0.0000	0.0000	0.0000
ECU_SOP17	0.0000	0.0000	0.0000
ECU_SOP18	0.0000	0.0000	0.0000
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ECU_SOP20	0.0000	0.0000	0.0000
ECU_SOP21	0.0000	0.0000	0.0000
ECU_SOP22	0.0000	0.0000	0.0000
ECU_SOP23	0.0000	0.0000	0.0000
ECU_SOP24	0.0000	0.0000	0.0000
ECU_SOP25	0.0000	0.0000	0.0000
ECU_SOP26	0.0000	0.0000	0.0000
ECU_SOP27	0.0000	0.0000	0.0000
ECU_SOP28	0.0000	0.0000	0.0000
ECU_SOP29	0.0000	0.0000	0.0000
ECU_SOP30	0.0000	0.0000	0.0000
ECU_SOP31	0.0000	0.0000	0.0000
ECU_SOP32	0.0000	0.0000	0.0000
ECU_SOP33	0.0000	0.0000	0.0000
ECU_SOP34	0.0000	0.0000	0.0000
ECU_SOP35	0.0000	0.0000	0.0000
ECU_SOP36	0.0000	0.0000	0.0000
ECU_SOP37	0.0000	0.0000	0.0000
ECU_SOP38	0.0000	0.0000	0.0000
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ECU_SOP40	0.0000	0.0000	0.0000
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ECU_SOP42	0.0000	0.0000	0.0000
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ECU_SOP44	0.0000	0.0000	0.0000
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ECU_SOP46	0.0000	0.0000	0.0000
ECU_SOP47	0.0000	0.0000	0.0000
ECU_SOP48	0.0000	0.0000	0.0000
ECU_SOP49	0.0000	0.0000	0.0000
ECU_SOP50	0.0000	0.0000	0.0000
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ECU_SOP53	0.0000	0.0000	0.0000
ECU_SOP54	0.0000	0.0000	0.0000
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ECU_SOP58	0.0000	0.0000	0.0000
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ECU_SOP63	0.0000	0.0000	0.0000
ECU_SOP64	0.0000	0.0000	0.0000
ECU_SOP65	0.0000	0.0000	0.0000
ECU_SOP66	0.0000	0.0000	0.0000
ECU_SOP67	0.0000	0.0000	0.0000
ECU_SOP68	0.0000	0.0000	0.0000
ECU_SOP69	0.0000	0.0000	0.0000
ECU_SOP70	0.0000	0.0000	0.0000
ECU_SOP71	0.0000	0.0000	0.0000
ECU_SOP72	0.0000	0.0000	0.0000
ECU_SOP73	0.0000	0.0000	0.0000
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ECU_SOP86	0.0000	0.0000	0.0000
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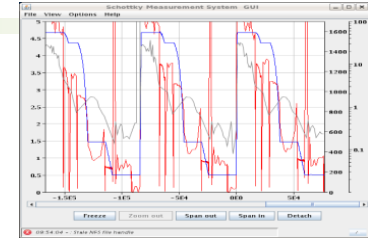
Working Set



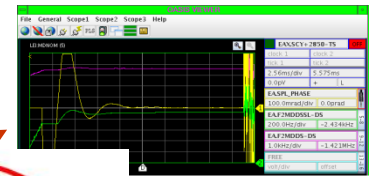
Reference editor



Tomoscope



Schottky diagnostics

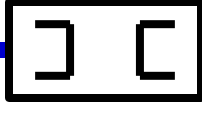


OASIS

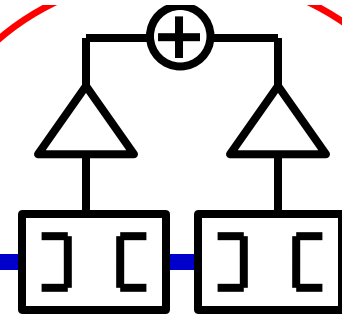
LLRF & DIAGNOSTIC DATA PROCESSING

BTrain, injection/extraction references, timings

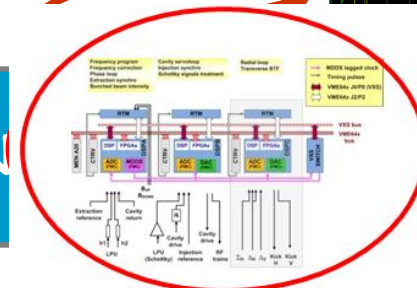
beam



Cavity



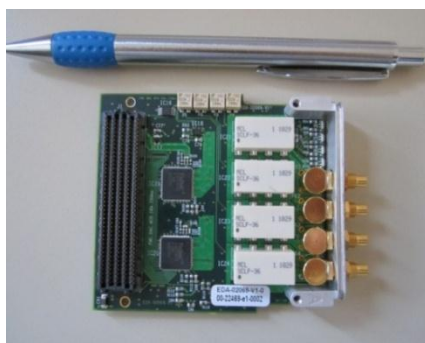
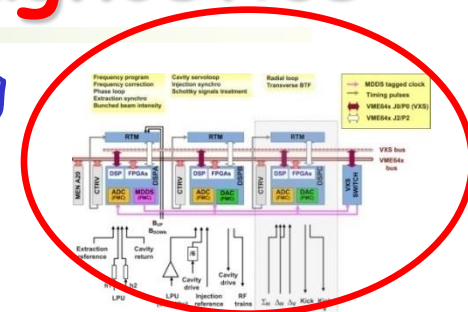
LPUs



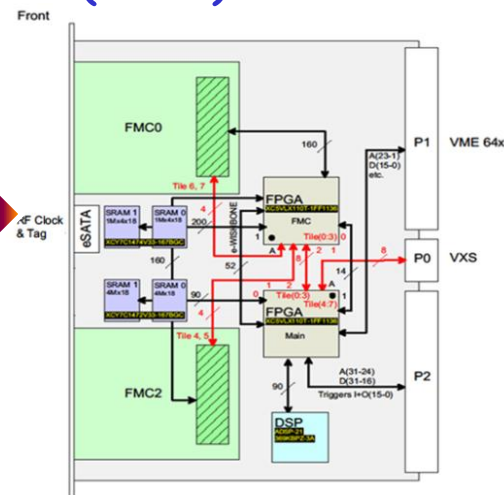
2. How: LLRF & Schottky diagnostics

❖ *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)

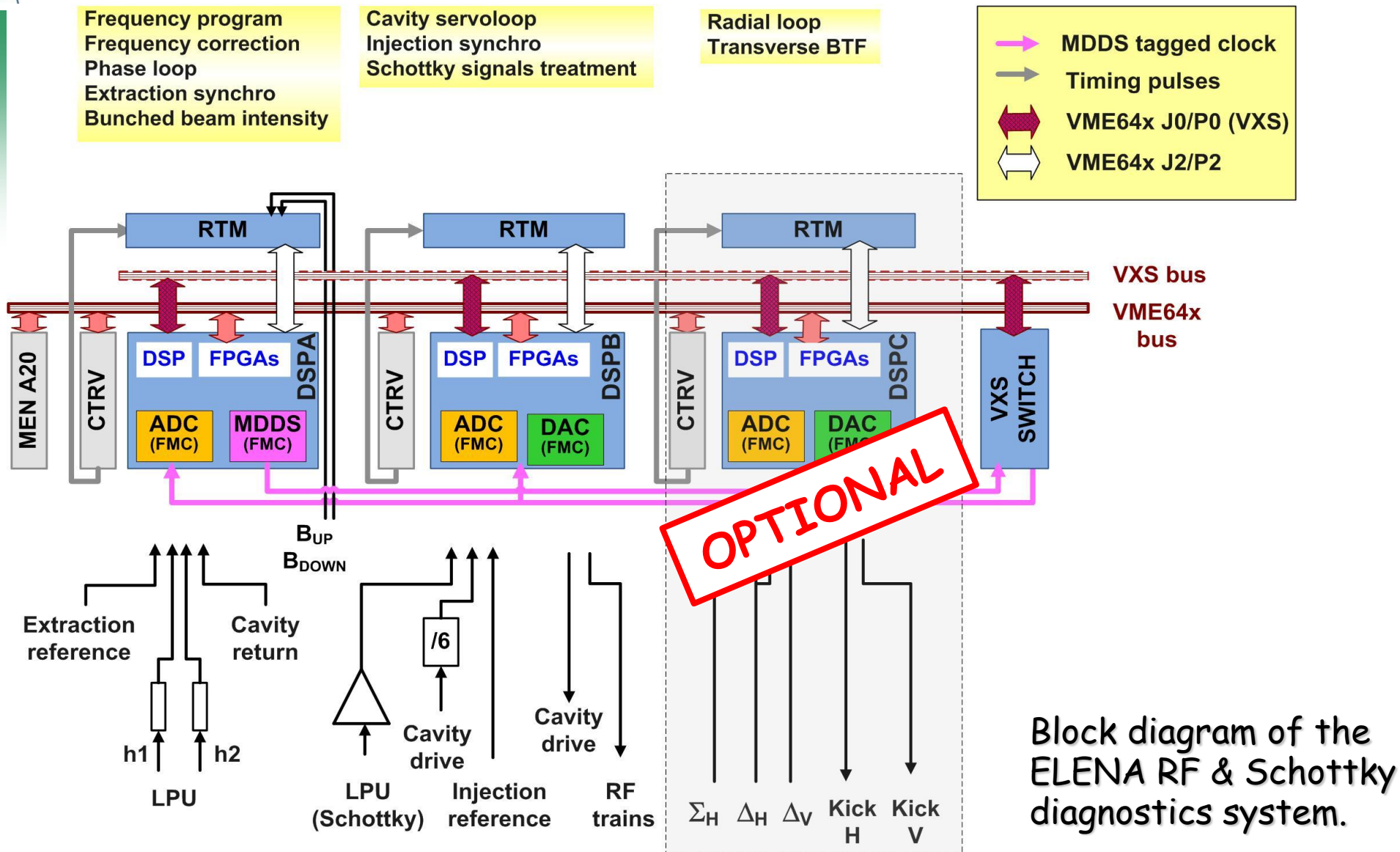


Some schematics & pictures of new h/w



- ❖ 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



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

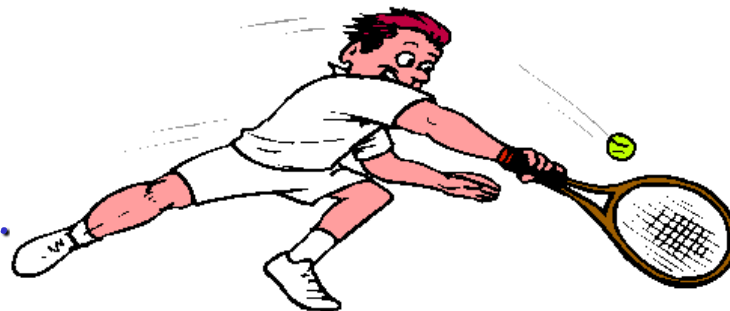
Item	Description	Material [kCHF]	Personnel [FTE]
Digital LLRF and Longitudinal Diagnostic Software			
Global system design	All 3 layers for the 3 main items below		0.2
FPGA, DSP, FESA, Appl.	Digital LLRF Software integration (DSP, RTT, App)		0.5
FPGA, DSP, FESA, Appl.	Longit. Bunched beam intensity and 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. Marquversen, F. Pedersen, "*The New Digital-Receiver-Based System for Antiproton Beam Diagnostics*", PAC 2001, New York, 2001.