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icBLM system overview Irena Dolenc Kittelmann ESS (BLM System Lead)

icBLM CDR1, CEA, France, 13/02/2019

Outline



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- ESS BLM
 - Reminder
 - L4 requirements

■ icBLM

- teams involved
- Interfaces
- Components overview
- Project timeline
- Procurement plan
- FW/SW development plan
- CDR1
 - charge

ESS BLM

Two BLM systems

icBLM

- Primary monitor in the high energy parts
- Detector: ionization chambers (ICs)
- nBLM
 - Primary monitor in the low energy parts
 - Detector: micromegas detectors

	Num. of devices				
Linac section	icB	LM		nBLM	
	comment	count	comment	count	
MEBT		/		2F+2S=4	
DTL	1/tank	$5 \times 1 = 5$	8/tank,2/end	$5 \times (4F + 4S) + 1F + 1S = 42$	
Σ		5		23F+23S=46	
Spoke	1/cryo,3/2q	13×4=52	1/2q, 1/cryo	13×(F+S)=26	
MB	1/cryo,3/2q	21×4=84		1F+1S=2	
HB	1/cryo,3/2q	9×4=36		1F+1S=2	
MEBT	3/2q	16×3=48		/	
A2T					
ramp	1/bend,3/2q	$6 \times 3 + 2 \times 1 = 20$		1F+1S=2	
to target	3/2q, 3/4rast.	$3 \times 3 + 2 \times 3 = 15$		2F+2S=4	
dump	1/mag.	6		/	
Σ		261		18F+18S=36	
$\Sigma\Sigma$		266		41F+41S=82	
$\Sigma\Sigma\Sigma$			•	348	





BLM L4 requirements



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#	Туре	Name	Description		
1	Beam loss	XXX beam loss measurement	The beam loss shall be measured in the XXX section.		Coverage
2	Beam loss	XXX beam loss measurement sensitivity	A beam current loss of 10 mW/m shall be detected.	\implies	Sensitivity, lower limit
3	General	XXX PBI damaging beam detection mitigation	Beam conditions that are potentially damaging to machine components shall be detected by the instrumentation and reported fast enough so that the conditions can be mitigated before damage occurs.		pper limit, esponse time, IP thresholds
4	General	XXX PBI peak current range	Proton beam instrumentation in the XXX section shall function over a peak beam current range of 3 mA to 65 mA.	Sys	tem
5	General	XXX PBI pulse length range.	Proton beam instrumentation in the XXX section shall function over a proton beam pulse length range of 5 µs to 2.980 ms.	all l	ctioning for beam modes
6	General	XXX PBI pulse-by pulse measurement update rate	Unless specifically stated, all instrumentation shall be able to perform the measurements and report the relevant PV data at a repetition rate of 14 Hz.		

Table 1: L4 PBI requirements [2] relevant for the BLM system. The 'XXX' refers to specific linac section and runs over all section from including MEBT on.

icBLM: teams involved



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LUT DMCS (ICS IK)

- FPGA FW design and implementation
- SW design and implementation



ESS BD

- System architecture, for example
 - Detectors & electronics
 - Detector and electronics layout
 - Mechanical support
 - Development of specifications and requirements
 - Spec. relevant for detector design
 - Def. of FW and SW functionality
 - Def. of data processing (FPGA algos)
 - Definition of monitoring variables and algos
 - Beam loss simulations: MC simulation of lost protons
- Installation
- System commissioning
- Coordination & project management

ESS ICS

• FW and SW support and integration

icBLM: teams involved



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LUT DMCS (ICS IK)

- W. Cichalewski (local coordinator)
- G. Jablonski (FW, SW)
- R. Kielbik (FW)
- W. Jalmuzna (FW)



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ESS BD

- T. Shea (section leader, interim BLM system lead)
- I. Dolenc Kittelmann (BLM system lead)
- K. Rosengren (FW, DOD)
- H. Kocevar (SW)
- J. Norin (bookkeeping: det. & el. layout, naming)
- S. Grishin (installation)
- C. Derrez (verification plan, QA, electronics)
- E. Bergman (cables, connectors, PPs)
- T. Grandsaert (mech.. Support & integration)

ESS ICS

- F. dos Santos Alves
- (S. Farina)
- (W. Fabianowski)

icBLM interfaces



Interfaces

- Infrastructure
 - Lang haul cables
 - Holes for mech. supports (rails along DTL)
- Vacuum
 - Detector mech. supports on LWUs
- Cryo
 - Detector mounting
- With MPS
 - FBIS (Fast Beam Interlock System)

icBLM: components

Detectors

- Parallel plate gas Ionisation Chambers (ICs) developed for the LHC BLM.
- Beam loss information based on ionisation current measurement of secondaries
- S. Grishin, "icBLM detectors"

Inner structure of the LCH BLM



3x3mm² beam, 220MeV on 1st insertion in 1st Spoke cavity, at 1mrad

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icBLM: components

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BEE – final selection

- IOxOS IFC1410 ICS standard platform
- Pico4, FMC digitizer (CAENels)
 - Modified COTS
 - 1MS/s, 20-bit ADC, 300kHz bandwidth
 - Dynamic range:
 - 0 500μA,
 - 0 10mA
- FBIS interface
 - Piggyback board on RTM, part of ICS standard platform (both still under development)
 - Temporary solution for test purposes: IOxOS DIO3118 FMC
- Low Latency Link
 - SFP+ on RTM
 - Temporary solution: existing RTM from IOxOS

icBLM: components

HV PS

- Provides:
 - Power the ICs (1.5kV) several ICs are daisy changed and connected to one HV ch
 - Modulation voltage for system HEALTH check.
- HV module (1ch):
 - ISEG DPr 40 305 24 5_CAB High Precision HV-PS
- Ethercat crate with
 - ethercat coupler,

BEE alternatives

- Digitiser: BLEDP card
 - Developed for CERN injector complex
- Processing board:
 - Struck SIS8300-KU (BLEDP)
 - DAMC-FMC25 (pico4)

icBLM project: time line

icBLM: FW/SW plan

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K. Rosengren, FW/SW development plan (See .xlsx file under the nBLM CDR3 material)

Procurement

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See .xlsx file under the icBLM CDR1 material for detailed view (procurement plan, installation time windows for MEBT and DTL1 detectors, system tests, SW and FW development plan)

icB	LM: procurement plan, installation time windo	ows for DTL1	icBLM				
10	neren Neren						
- put	internal second						
	Project Start Date	1/1/2019 (To	uesday)		Display W	wek 10	Week 10 Week 12 Week 13 Week 14 Week 15 Week 15 Week 15 Week 15 Week 16 Week 17 Week 16 Week 17 Week 16 Week 20 Week 30 Week 31 Week 32 Week 30 Week 3
	Project Lead						4 (Mar 2019) [11 Mar 2019] [21
-	1.92	1 .con 1	HAN 57195		Davis -	NOR WOR	
		cates -	646 STURT	LND		0.0	
1	Accelerator schedule - from TB28, 17.1.2019						
1.1	DTL1 installation - tank installation		Mon 8/19/19	Sun 915/19	28	0% 20	
13	NF 4 - max magazith 168 (1.3) RFO/MEBTIOTL1 RF Conditioning Window		Mpn 10/24/19	Sun 12/22/19	55	0% 40	
1.4	Beam Commissions: 1Sr to DTL1		Mon 12/16/19	Sun 3/22/20		0% 70	
2	icBLM installation time slots						
2.1	Detetors (short cables, PPs2, support) in tunnel						
2.1.1	DTL1 detectors (1 det)		Sat 9/07/19	Fil 9/13/19	7	0% 5	
2.2	Electronics in racks - installation time window					0	
2.2.5	DILT detectors (1 bit) NOTE: in SCI, only 2(3 of detectors rands for Stat and one (1 per 1 Will: detectors and		MD8 6/10/19	501 6/30/19	20	0% 15	
2.3	cables install, but not tested						
3	icBLM reviews						
2.1	POR .	1	MDR 7/10/17	168 //11/1/		0076 2	
4	Detectors (285)		1000 2 12 13	1104 2112 12		0.6 1	
4.1	Procurrement (production and QA tests)	ESS BI	Wed 7/15/14	Man 7/03/17	1083	102% 774	
4.2	Acceptance tests - 3 detectors	ESS BI	Fil 11/10/17	Sat 11/11/17	2 1	100% 1	
43	RFI - 3 det	1	Sun 11/12/17	Sun 11/12/17	1 1	102% 0	
4.4	Acceptance tests - 282 detectors (6 detectors per day) - resource problem	ESS BI	Wed 3/13/19	Sun 4/28/19	47	0% 33	
45	RFI - 282 det	/	Sun 4/28/19	Sun 4/28/19	1	0% 0	
5	Flattmirs	nas II	sat wo//19	PE M12/19		v.a 5	
5.1	CAENals, Picol					0	
5.1.1	Procurrement - 8 boards	ESS BI	Wed 8/08/18	Tue 10/30/18	64 3	0 00% 60	
5.1.2	QA tests - 8 boards (time window) - unclear end date (integration on Ifc140 issues)	ESS BI	Tue 1/15/19	Tue 2/12/19	28	50% 21	
5.1.3	RF1 - 8 boards	1	Wed 2/13/19	Wed 2/13/19	- 1	0% 1	
5.1.6	procurrent process preparation	ESS BI	Thu 2/14/19	Wed 3/13/19	28	0% 20	
5.1.5	Procurement - 92 boards	ESS BI	Thu 3/14/19	Wed 6/05/19	54	0% 60	
517	Un tests - siz boards (5 per day) - resource problem DDI - 62 hourds	Loo Bi	Thu 6/05/19	Fil 6/21/19	15	0% 12	
5.18	Installation for DTL (1 det)	ESS BLOW/TO	Mon 6/10/19	Sun 6/30/19	21	0% 15	
5.2	Crates						
521	procurement by ICS, availability unclera (on response from ICS)	ESS ICS					
5.3.2	Installation for DTL1 det time winodw	ESS BI (WUT)	Mon 6/10/19	Sun 6/30/19	21	0% 15	
5.3	Short signal cables, connect. & PPs - rack side						
5.3.1	final design - clear TBD	ESS BI	Tue 1/01/19	Wed 3/13/19	28	50% 52	
5.3.2	production/procurrent	ESS BI (WUT)	Thu 3/14/19	Wed 6/05/19	54	0% 60	
5.3.3	Installation for DTL1 det time winow	ESS BI (WUT)	Mon 6/10/19	Sun 6/30/19	21	0% 15	
5.4.1	short signal cases, connect, a case supports - detector side	E55 B	The 2154/10	West 3/13/19	28	0% 20	
5.4.2	PP (or cable support?) design and integration to 3D model - lack of recurces	ESS BI	Thu 2/14/19	Wed 4/10/19	56	0% 40	
5.4.3	procurrent process preparation	ESS BI	Thu 4/11/19	Wed 5/00/19	28	0% 20	
5.4.6	procurement/production	ESS BI	Thu 5/09/19	Wed 7/31/19	54	0% 60	
5.4.5	an .	1	Thu 8/01/19	Thu &/01/19	- 1	0% 1	
5.4.0	Installation for DTL1 det time windw	ESS BI	Sat 9/07/19	Fil 9/13/19	7	0% 5	
5.51	Long signal cases, connectors	ESS Infrastructure					
	ready for connection in DTL1 - dates unclear, this what is in P6 now; though pulling	ESS Infrastructure	Max Granes	Man 1015010			
**2	cables is the current focus, so changes likely	6.00 mmm.020.09	aux) 9/30/19	NAL 10/14/19		5/A 11	
5.61	w vs system (sets)	555 B	The Distant	Mine STOTIAL			
5.62	Procurement	ESS BI	Thu 2/20/19	Wed 5/22/119	- 14	0% 60	
5.63	QA Test	ESS BI	Thu 5/23/19	Wed 5/29/19	7	0% 5	
5.6.4	#P	1	Thu 5/30/19	Thu 5/30/19	- 1	0% 1	
5.6.5	Installation for DTL1 det time winodw	ESS BI (WUT)	Mon 6/10/19	Sun 6/30/19	21	0% 15	
5.7	Short IW cable connections (dalay chain) - detector side						
675	procurrent - orgoing Installation for 70% d data and encoded	ESS Infrastructure					
5.8	Etherset crate & modules	ware intractive		-	_	-	
5.81	procurement by ICS - availability unclear	ESS ICS					
5.8.2	Installation for DTL1 det time window	ESS BI (WUT)	Mon 6/10/19	Sun 6/30/19	21	0% 15	
5.9	Short cables in Ethercat crate connections - rack side						
5.81	procurment process preparation	ESS BI	Thu 2/14/19	Wed 2/27/19	54	0% 10	
5.82	procurement/production	ESS BI	Thu 2/28/19	Wed 3/13/19	54	0% 10	
5.8.3	RFI Installation for PTI 4 dat. Since whether	/	Thu 3/14/19	Thu 3/14/19	1	0% 1	
6	Detector mechanical surrout	wara BE (WUT)	Mpn 6/10/19	sun ecau/19	20	v.e 15	
6.1	for DTL1 detector						
6.1.1	Design & integration - resource problem	ESS BI	Thu 2/14/19	Wed 4/10/19	56	0% 40	
6.1.2	procurrent process preparation	ESS BI	Thu 4/11/19	Wed 4/24/19	54	0% 10	
6.1.2	Procurement	ESS BI	Thu 4/25/19	Wed 7/17/19	54	0% 60	
6.1.6	encomment as once 1 (1 GB) - exact dates to be contrasted with infrastructure, here assumed installation invariant with data-tive	ESS Billinfrastucture	Sat 9/07/19	Fil 9/13/19	7	0% 5	
7	System tests						
7.1	verocal integration tests - time windows in the lab.	ESS BLACSE TH	Set 601140	Di 8/23/10		0% =0	
7.1.2	tests after installation (with CE 1 dat) and connection short cables on detrains side	ESS BLOCK TH	Tue 10/15/19	Di 60/25/19		0% 9	

Procurement

- Detectors produced and delivered.
- Other lead times: no longer than 12 weeks
- For installation DTL1 (1 detector)
 - Almost all parts already available (detector, pico4) or expected in timed for planed installation time slots.
 - Note that electronics installation time window (crates, cards, short cables) pushed to as earlier date as possible to have it done before summer
 - Risks:
 - Availability of crates (ICS) unclear, but considered lower risk
 - Long and part of short cables available for installation (Infrastructure) dates unclear, but considered lower low risk
 - Some cabling details TBD (pin layouts, short signal connections on the rack side) – considered low risk
 - DTL detector support design and integration to 3d model lack of resources
 - Detector and support installation dates to be coordinated with Infrastructure

icBLM CDR1 - charge

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- Supporting documentation available on top of the agenda sicne Monday 5/2/2019: <u>https://indico.esss.lu.se/event/1173/</u>
- CDR1 Charge:
 - icBLM overall system.
 - Main focus: electronics.

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Back up material

ESS Beam Loss diagnostic tools

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- Total beam loss, microsecond measurement latency required for protection
 - BCM, icBLM (saturation, nBLM (current mode) → Interlock; Threshold/derivative term for fast protection
- > 1.6 milliamp lost for up to 200 μs
 - BCM, icBLM, nBLM -> Interlock; Damage model for protection
- ~ μC lost over 200 μs to many seconds (diffusion time)
 - icBLM, nBLM -> Interlock; Damage model for protection
- ~ "1 Watt/meter" radiation dose management
 - icBLM, nBLM -> alarm based on dose/activation plan

ESS BLM: Response time

- Required response time set in the past:
 - NC linac (MEBT-DTL): \sim 5 µs.
 - SC linac: ~10 μs.
 - Numbers based on a simplified melting time calculations, where a block of material (copper or stainless steel) is hit by a beam of protons with a uniform profile under perpendicular incidence angle, no cooling considered [9].
- Numbers re-checked with a Gaussian beam and update beam parameters:
 MEBT DTL
 - NC linac: calculated melting time values of 3-4µs imply even stronger demands on the response time (confirmed with a MC simulation as well).
 - SC linac: the 10µs requirement for response time fits well with the results of this calculations.

However: other damage mechanisms ma mandate even shorter response time SCL (discussed further).

ESS BLM: beam loss simulations

MC simulations for tracking of lost protons needed to determine

- Detector locations, system response time and dynamic range
- Expected particle fields, signals
- Initial MPS threshold settings at the startup and later adjustments
- Anticipated response of the system during fault studies to verify and calibrate the system response

Required inputs

- Ideally
 - Expected loss maps during normal operation
 - A list of accidental beam loss scenarios with loss maps
 - Elements to be protected, damage levels
- Large number of possible accidental scenarios: simplifications/assumptions needed

Simulation tool

- Geant4 simulation framework developed by the ESS neutron detector group
- Geant4 based ESS linac geometry created (current version: DTL HEBT)

ESS BLM: MC simulations - linac geo

Past studies

- Focused on DTL
- Tanks surrounded with "phantom detectors"
- Loss scenarios:
 - Accidental losses: scanned over various configurations of energy, beam size, hit angles and position along the DTL
 - Uniform loss, 1W/m loss
 - Nominal operation
- Studied:
 - Expected particle fields (type, energy, fluxes along the beam line)
 - Correlation between the loss location (center) and peak position in neutron hitmaps
 - Spread (RMS) of neutron hitmaps
 - Threshold energy to discriminate fast/slow neutrons

0 -1000

Hitmaps for det2

'detector" volume

- Tasks:
 - Support nBLM detector design, results used

integri meanx rmsx meany rmsy covxy covxy corxy xmin xmax ymin ymax

- As inputs to MC simulations to optimize detector design
- For signal estimations
- nBLM detector layout

Neutron hitmaps with $E_k > 0.5$ MeV cut: difference between the hitmap mean and

Peak visible ~3.5m

0.000 projecton on z [mm]: x [mm]=[-610.0,610.0], bins=[0,999] (o=True, u=Tru $54.75 - .3238.43 \pm 4.003$ Sim2-9: loc. loss at the beginning of the DTL5 (histogram normalized per *number of primaries):* hitmap mean=-2.76m 0.0000 *Gauss fit mean* = -3.56m0.00004 0.0000 0.00000

-3000-2000

4000

DTL5-det1: incoming hitmap zx (neutrons-EkLimited1) $Ek_{c}=0.07MeV$

z [mm]

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Current focus

- Cold linac
- Loss scenarios:
 - Scanned over various for various configurations of energy, beam size, hit angles and position along the cryo modules or quads
 - Uniform loss, 1W/m loss
 - Nominal operation
- Tasks:
 - Expected particle fields (type, energy, fluxes along the beam line)
 - Estimate signals/rates
 - Correlation between loss location and peak in distributions (hitmaps, Edep) & spread
 - Starting point for further studies
 - Determination of loss location (loss pattern) from the measurements (ANNs?)
 - MPS Thresholds

Example: energy deposition summed over 4 center slices along x

- 220MeV protons,
- Beam center hits inside a Spk cryo: on 1st insertion in 1st Spoke cavity

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Theta=1mrad

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Example:

- 220MeV protons
- Hit center inside Spk cryo at 1st insertion in 1st Spk cavity (z=1650mm)
- Theta=1mrad

<u>Plots:</u>

- Phi vs Z for particles at r=752mm from the beam axis
- Particle types (n, gamma, e-,...)

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Example:

- 220MeV protons
- Hit at: 1st insertion in Spk cavity
- Theta=1mrad
- Pencil beam

<u>Plots:</u> hits at r=752mm from beam axis

 Neutron and photon energy along the beam line

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Example:

- 220MeV protons
- Hit at: 1st insertion in 1st Spk cavity
- Theta=1mrad
- 3x3mm² beam

<u>Plots:</u> hits at r=752mm from beam axis

 Neutron and photon energy along the beam line

ESS BLM: detector layout (MEBT-MB)

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ESS BLM: detector layout (HB - end)

