



Calculation of abort thresholds for the Beam Loss Monitoring System of the Large Hadron Collider at CERN

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Introduction

- **Master Threshold** → $T(E_{\text{beam}}, t)$
- **Applied Threshold** → $t(E_{\text{beam}}, t) = MF \times T(E_{\text{beam}}, t)$
- **Family** → Group of BLMs with same master threshold values
- Abort thresholds are independently sets for each BLM detector in the form of 12*32 (12 BLM RS * 32 LHC energy levels) table
- Threshold values are multiplied by a constant factor (ranges between 0 and 1; monitor factor) to account possible uncertainties and extra flexibility in tuning of dump levels
- More than 1.53 million critical parameters are calculated, stored in the database and send to the electronics to protect LHC equipment.

Abort Threshold Algorithm

Main Formula:

$$T(E_{\text{beam}}, \Delta t) = Q_{\text{BLM}}(E_{\text{beam}}) \cdot N_p(E_{\text{beam}}, \Delta t)$$

BLM signal per lost proton.

Parameters used:

Min.: 4

Max: 16 or more

Parameters used:

Min.: 14

Max: 28

Maximum number of lost protons.

Computed abort threshold table consists of **384** integer values (12 Integration time x 32 Energy).

Extended Formula (for particular families):

$$T(E_{\text{beam}}, \Delta t) = Q_{\text{BLM}}(E_{\text{beam}}) \cdot \frac{\Delta Q_{\text{critical}}(E_{\text{beam}}, \Delta t)}{\mathcal{E}(E_{\text{beam}}, \Delta t)}$$

Quench level

Parameters used:

Min.: 9

Max: 384

Parameters used:

Min.: 4

Max: 16 or more

Energy deposition in the coil

Abort Threshold Algorithm Corrections

- Corrections are applied to the basic thresholds for several reasons:
 - *Electronic maximum, filters, injection losses...*
 - *Differences between simulation and observations.*
- Corrections should (**MUST!**) be used with every calculation of thresholds.
- 10 algorithm corrections exists:
 - Scale correction: 1 parameter
 - RC correction: 1 parameter
 - IL correction: 3 parameters
 - Decrease Correction: 2 parameters
 - Ad-Hoc Factor Corrections: 44 parameters
 - Ad-Hoc Fix to RS Corrections: 44 parameters
 - Ad-Hoc Bits Corrections: 45 parameters
 - Off Bits Correction: 12 parameters
 - Min Bits Correction: 12 parameters
 - Max Bits Correction: 13 parameters

Current calculation approach

C++ and Root approach:

Configuration Files:

Element

ΔQ

BLM

Q_{blm}

LOSS

ϵ

Card File:

```

THRI.AR.B1.3_MQ.card ✖
Family = THRI.AR.B1.3_MQ
ElementType = ColdMagnet
ElementConf = DATA/COLD_MAGNET/MQ_v1
BLMConf = DATA/BLM/IC_MQ_B1.2_v3
LossConf = DATA/LOSS/MB_nominal_v3

[CorrectDecrease]
[CorrectMaxBits]

[AdHocCorrection]
Type=Factor
RS01 = 3
RS02 = 3
RS03 = 5
RS04 = 5
RS05 = 5
RS07 = 0.333333333333
RS08 = 0.333333333333
RS09 = 0.333333333333
RS10 = 0.333333333333
RS11 = 0.333333333333
RS12 = 0.333333333333

[CorrectDecrease]
[CorrectMaxBits]
    
```

Threshold File:

Threshold table
(12*32)



Algorithm corrections

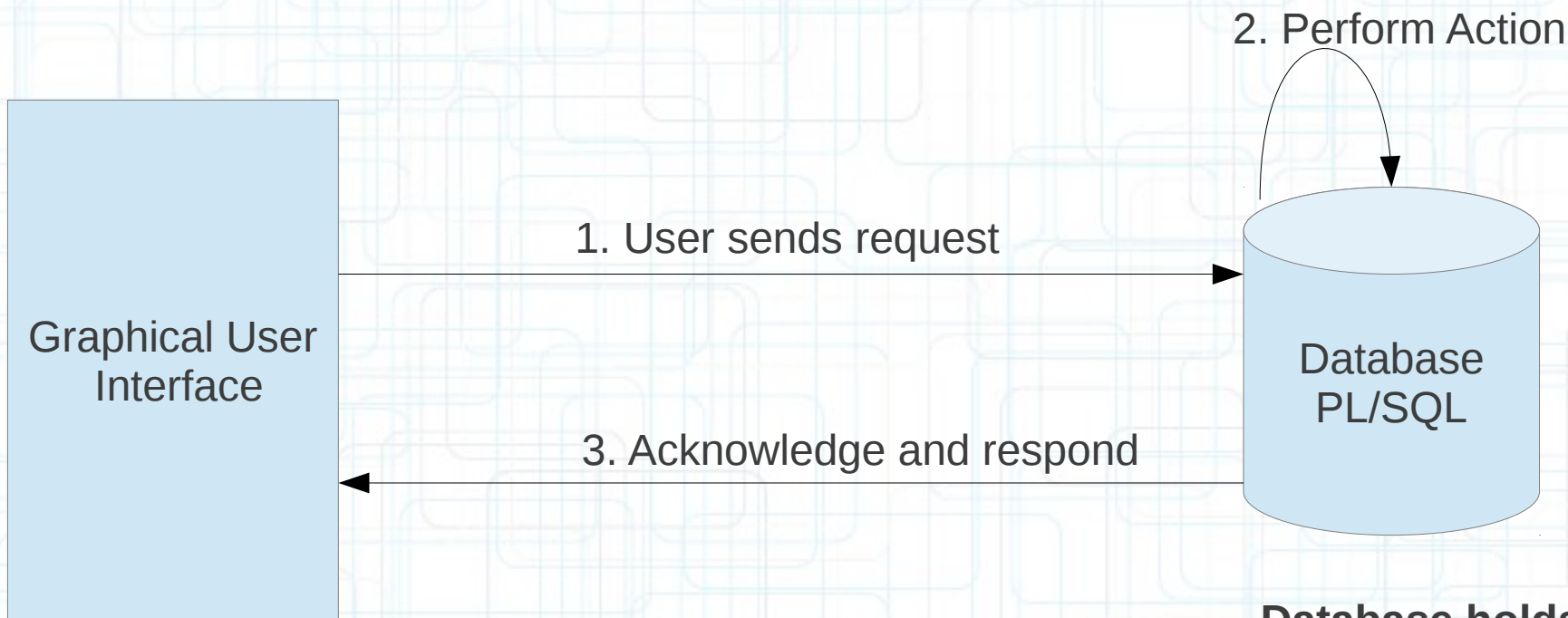
Procedure:

1. User types family name
2. User selects type of magnet
3. User specifies configuration files to be used
4. User applies needed algorithm corrections
5. Calculate thresholds
6. Generate threshold text file

Problems with current calculation approach

- **Change Management**
 - Who changed which thresholds? Why and when?
- **Storage**
 - Where to store all files?
- **Testing**
 - Not possible within threshold calculation application
- **Security**
 - No security mechanism (RBAC)
- **Usability**
 - Knowledge of C++/root is required

New automated database approach



Advantages:

- Data security and consistency
- Easy to track changes in thresholds
- Easy to calculate thresholds (Graphical User Interface)
- Testing of thresholds
- Security of system (RBAC)
- Separation of implementation and calculation of thresholds

Database holds:

- Thresholds
- Parametrisations
- List of all families
- Corrections

Security of new approach: Role-Based Access Control (RBAC)

- RBAC login system controls and grants rights to the user depending on the level of user's credentials
- Types of RBAC credentials:
 - MCS-BLM Piquet role: full access (r/w) in operational mode and development mode
 - MCS-BLM Expert role: full access (r/w) in development environment
 - MCS-BLM User role: read only (view) in operational mode
- Roles are controlled and assigned to the user by Bernd Dehning (BE-BI-BL)

New LHC/BLM threshold generator

Features:

- Parametrisation
 - View/plot algorithm param., Add/edit/remove corrections, Commit changes
 - Create new family from existing parametrisation
 - Monitor factor settings
- Testing
 - Master Threshold View + plotting data
 - Applied Threshold View + plotting data
 - Comparison of Independent families
- History
 - Summary view of number of changes in each family
 - Parametrisation history view by given date
- Generating reports
- Committing to final

Parametrisation: View

BASIC FLOW:

1. User selects Family
2. System displays algorithm parametrisations

Algorithm parameters are Read/Only (for user)

User ability:

- plot algorithm param.:
 - Qblm
 - Energy deposition
 - Quench margin

The screenshot shows a software interface for viewing and plotting algorithm parameters. On the left, a list of families is displayed, with 'THRI.DS.B1.1_MQM' selected. The right side of the interface is divided into several sections:

- Navigation:** Tabs for 'Parameterization', 'Testing', 'History', and 'Committing and Reports'. Below these are buttons for 'View', 'Add Family', and 'Monitor Factor'.
- Family Category:** A dropdown menu showing 'Cold Magnets 1'.
- Qblm Section:** A list of parameters including 'blmConvGy2C', 'blmConvBit2Gy', 'blmRespSlope', and 'blmRespOffSet'.
- E Section:** Parameters related to energy deposition, such as 'lossEdepThermalSlope' and 'lossEdepMaxSlope'.
- Q Section:** Parameters related to quench margin, such as 'mgEnliSlope' and 'mgQuiliSlope'.
- Plotting:** Buttons at the bottom for 'Plot Qblm', 'Plot Energy deposition', and 'Plot Quench margin'.

Parametrisation: Create new family

BASIC FLOW:

1. User types new family name
2. User selects family category
3. User selects conversion f.
4. User imports parametrisation (e.i.: Qblm, Edep, dQ) from one or more families.
5. Create family.
6. System saves to the DB.

- User is able to create a new family
- No changes to created family (algorithm param.) by user are allowed after committing to the DB.

Add new family

Family name:

Family category: Select category ▼

Conversion Factor

IC Gy/BITS

SEM A/(Gy/sec)

LIC

Import

Import from family

Parametrization Qblm ▼

VIEW

Qblm	Q	E
blmConvGy2C: 5.4e-5		
blmConvBit2Gy: 3.62e-9		
blmRespSlope: 40.1		
blmRespOffSet: 164.7		
blmCorrRS01: 0.4		
blmCorrRS02: 0.7		
blmCorrRS03: 1.0		
blmCorrRS04: 1.0		
blmCorrRS05: 1.0		
blmCorrRS06: 1.0		
blmCorrRS07: 1.0		
blmCorrRS08: 1.0		
blmCorrRS09: 1.0		
blmCorrRS10: 1.0		
blmCorrRS11: 1.0		
blmCorrRS12: 1.0		

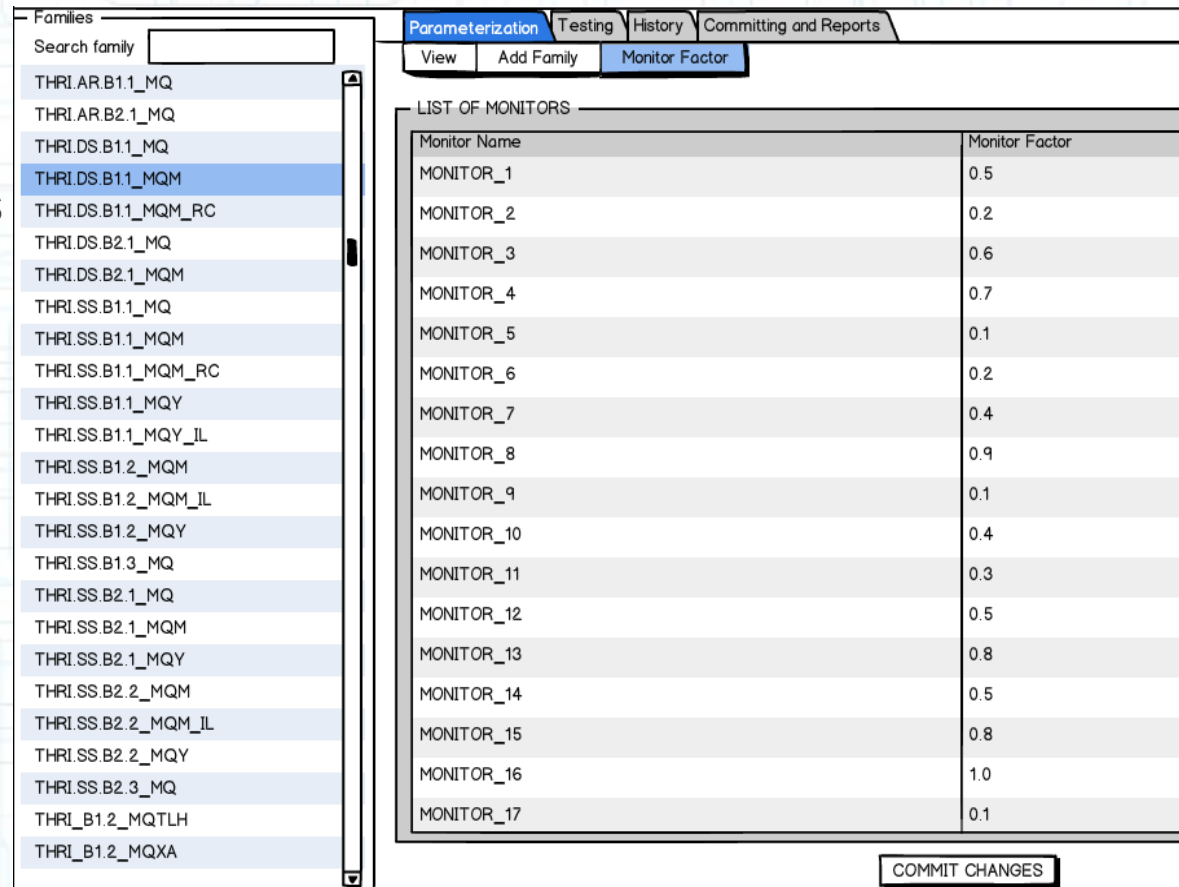
Parametrisation: Monitor Factor

BASIC FLOW:

1. User selects Family.
2. System displays monitors for a selected family.
3. User performs needed changes.
4. User commits changes.
5. System saves changes to the DB.

User ability:

- edit monitor factor values
- commit changes



The screenshot shows a web interface for configuring monitor factors. On the left, a list of families is displayed, with 'THRI.DS.B1.1_MQM' selected. On the right, a table titled 'LIST OF MONITORS' shows the current monitor factor for each monitor. A 'COMMIT CHANGES' button is located at the bottom right of the interface.

Monitor Name	Monitor Factor
MONITOR_1	0.5
MONITOR_2	0.2
MONITOR_3	0.6
MONITOR_4	0.7
MONITOR_5	0.1
MONITOR_6	0.2
MONITOR_7	0.4
MONITOR_8	0.9
MONITOR_9	0.1
MONITOR_10	0.4
MONITOR_11	0.3
MONITOR_12	0.5
MONITOR_13	0.8
MONITOR_14	0.5
MONITOR_15	0.8
MONITOR_16	1.0
MONITOR_17	0.1

Testing: Comparison of Independent Families

Parameterization **Testing** History Committing and Reports

Master Threshold Applied Threshold **Comparison of Independent Families**

Family: THRI.DS.B1_MQM Selected Families: THRI.SS.B2.1_MQM THRI.DS.B1_MQM

Current Select View: Master Threshold

Family: THRI.SS.B2.1_MQM
Monitor Factor: 0.4
Monitor_1
Monitor_2

Beam_POS	RS01	RS02	RS03	RS04	RS05	RS06	RS07	RS08	RS09	RS10	RS11	RS12
1	256000	512000	2048000	4096000	16384000	65536000	524288000	2619024365	5238048697	20952194742	83808778820	134094119887
2	256000	512000	2048000	4096000	16384000	65536000	524288000	2619024365	5238048697	20952194742	83808778820	134094119887
3	256000	512000	2048000	4096000	16384000	65536000	524288000	2619024365	5238048697	20952194742	83808778820	134094119887

Family: THRI.DS.B1_MQM
Monitor Factor: 0.6
Monitor_1
Monitor_2

Beam_POS	RS01	RS02	RS03	RS04	RS05	RS06	RS07	RS08	RS09	RS10	RS11	RS12
1	256000	512000	2048000	4096000	16384000	65536000	524288000	2619024365	5238048697	20952194742	83808778820	134094119887
2	256000	512000	2048000	4096000	16384000	65536000	524288000	2619024365	5238048697	20952194742	83808778820	134094119887
3	256000	512000	2048000	4096000	16384000	65536000	524288000	2619024365	5238048697	20952194742	83808778820	134094119887

Difference:

Beam_POS	RS01	RS02	RS03	RS04	RS05	RS06	RS07	RS08	RS09	RS10	RS11	RS12
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0

Ratio:

Beam_POS	RS01	RS02	RS03	RS04	RS05	RS06	RS07	RS08	RS09	RS10	RS11	RS12
1	1	1	1	1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	1	1	1	1	1
3	1	1	1	1	1	1	1	1	1	1	1	1

BASIC FLOW:

1. User selects a family and adds it to the list for comparison.
 2. User repeats first step. Then selects a date of view for each family
 3. User selects view; Master Thresholds or Applied Threshold and clicks Compare.
 4. System displays Stage and Final threshold tables and their differences and ratio.
- Also System displays monitor factors and monitors that belongs to the each family.
 - User has ability to change the view by choosing different monitor factor

History: Summary View

BASIC FLOW:

1. User types a date of changes.
2. System displays all changed families and their number of changes until the typed day.

User ability:

- View number of changes in each family

Parameterization	Testing	History	Committing and Reports
		Summary	Parametrization

Type a date of changes FROM:

Family Name	Number of Changes
THRI.AR.B1.1_MQ	2
THRI.AR.B2.1_MQ	6
THRI.DS.B1.1_MQ	1
THRI.DS.B1.1_MQM	1
THRI.DS.B1.1_MQM_RC	8
THRI.DS.B2.1_MQ	7
THRI.DS.B2.1_MQM	1
THRI.SS.B1.1_MQ	1
THRI.SS.B1.1_MQM	1
THRI.SS.B1.1_MQM_RC	2
THRI.SS.B1.1_MQY	1

History: Parametrisation View

Parameterization
Testing
History
Committing and Reports

Summary
Parameterization

Select date: 18/07/2012 ▼
Roll-back

Family Category: Cold Magnets 1

mgEniSlope: 2.327 mgEniOffSet: -0.982	mgHeFrac: 0.09 lossEdepThermalSlope - 2.786275e-6 lossEdepThermalOffSet: 5.312762e-04
mgQuilSlope: 12.409 mgQuilOffSet: -1.237	lossEdepMaxSlope:- 2.056726e-02 lossEdepMaxOffSet: 5.710620e-04
mgTauMeSlope: 4.1052e-8 mgTauMeOffSet: - 0.246e-2	mgTauHeSlope: 12.81e-4 mgTauHeOffSet: - 2.262e-7

Corrections

all corrections with parameters for selected family displayed

Family Category: Cold Magnets 1 Current mgHeFrac: 0.05

mgEniSlope: 3.642 mgEniOffSet: -0.512	lossEdepThermalSlope - 6.923077e-10 lossEdepThermalOffSet: 3.153846e-08
mgQuilSlope: 25.305 mgQuilOffSet: -2.901	lossEdepMaxSlope:- 6.021978e-09 lossEdepMaxOffSet: 9.560440e-08
mgTauMeSlope: 6.2061e-3 mgTauMeOffSet: - 0.458e-3	mgTauHeSlope: 46.47e-3 mgTauHeOffSet: - 5.496e-3

Corrections

all corrections with parameters for selected family displayed

BASIC FLOW:

1. User selects a family and date of changes.
 2. System displays current and historical parametrisation of selected family.
- System also highlights all differences in colours

User ability:

- Display current and old thresholds for selected family

Generate reports and Commit to final

BASIC FLOW - Reports:

1. User clicks Generate button.
2. System generates report of all changed families

Report includes:


- all changed families
- new and old thresholds (master and applied) with their differences and ratio for 3 beam energy levels

BASIC FLOW – Commit:

1. User clicks commit button
2. System pushes all thresholds from stage to final.

User ability:

- Generate reports
- Commit changes from Stage to Final



The screenshot shows a web interface with a navigation bar at the top containing four tabs: 'Parameterization', 'Testing', 'History', and 'Committing and Reports'. The 'Committing and Reports' tab is selected and highlighted in blue. Below the navigation bar, the page is divided into two main sections by a horizontal line. The upper section is titled 'Reports' and contains the text 'Generate report:' followed by a 'Generate' button. The lower section is titled 'Commit' and contains the text 'Commit to Final:' followed by a 'Commit' button.

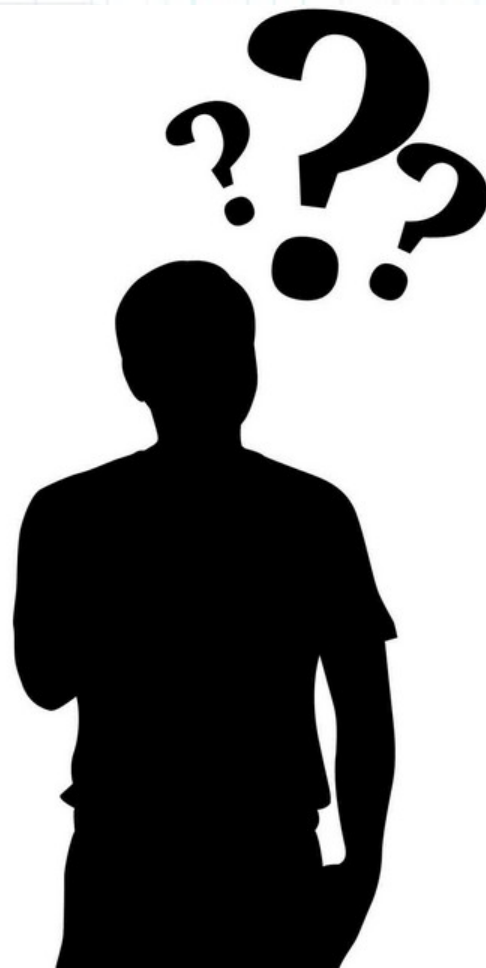
Conclusion

- **Benefits of new approach**
 - Maintainability: - administrator's responsibility, not user's
 - Security: - data security and consistency, system security; RBAC
 - Change management: - ability to track changes in thresholds
 - Graphical User Interface for calculation thresholds
 - Ability to view history of threshold changes
- **Limitations of new approach**
 - Flexibility: User is limited in actions that can perform
 - Delete/edit algorithm parameters → **only** database administrator

Summary

- **Main Points:**
 - Overview of BLM abort threshold Algorithm and algorithm corrections
 - Life-cycle and problems of current calculation approach
 - Introduced a new threshold calculation approach and its features
 - Introduced RBAC security
 - Introduced proposed Graphical User Interface for calculation, testing, generating reports and committing abort thresholds
 - Conclude benefits and limitations of new calculation approach

Questions?



Backup Slides

Thresholds Testing

- Thresholds are stored in LSA Database
- LSA security levels:
 - **Stage** – temporarily storage to add and test thresholds
 - **Final** – tested thresholds from stage are pushed to the final
 - **Master** – thresholds from final are pushed to the master
- Master thresholds are produced by combining the data from different final tables