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

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Acknowledgements to project advisory group: *B. Dehning, E. B. Holzer, S. Jackson, C. Roderick, M. Sapinski, C. Zamantzas.*

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Introduction

- **Master Threshold** → T(Ebeam, t)
- **Applied Threshold** → t(Ebeam, t) = MF x T(Ebeam, 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.

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Abort Threshold Algorithm

BLM signal per lost proton.

Parameters used:
Min.: 4
Max: 16 or more

Main Formula:

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

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).

Quench level

Parameters used:
Min.: 9
Max: 384

Extended Formula (for particular families):

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

Parameters used:
Min.: 4
Max: 16 or more

Energy deposition in the coil

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Abort Threshold Algorithm Corrections

- Corrections are applied to the basic thresholds for several reasons:

  - *Electronic maximum, filters, injection loses...*

  - *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*

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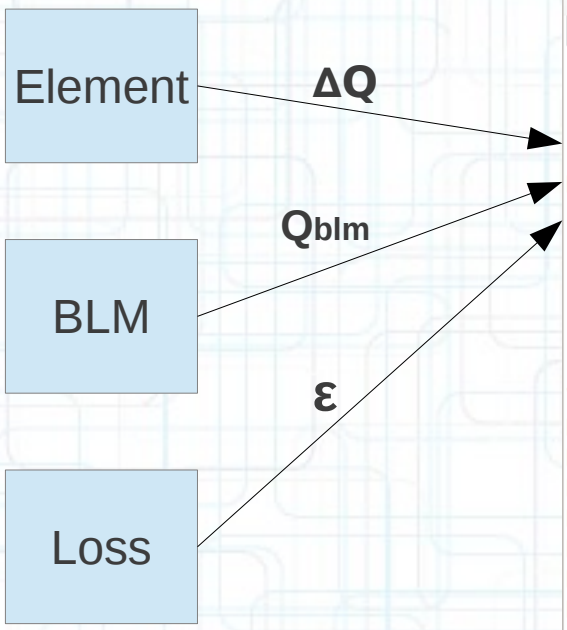
Current calculation approach

C++ and Root approach:

Configuration Files:



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 = 0.33333333333
RS08 = 0.33333333333
RS09 = 0.33333333333
RS10 = 0.33333333333
RS11 = 0.33333333333
RS12 = 0.33333333333

[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

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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

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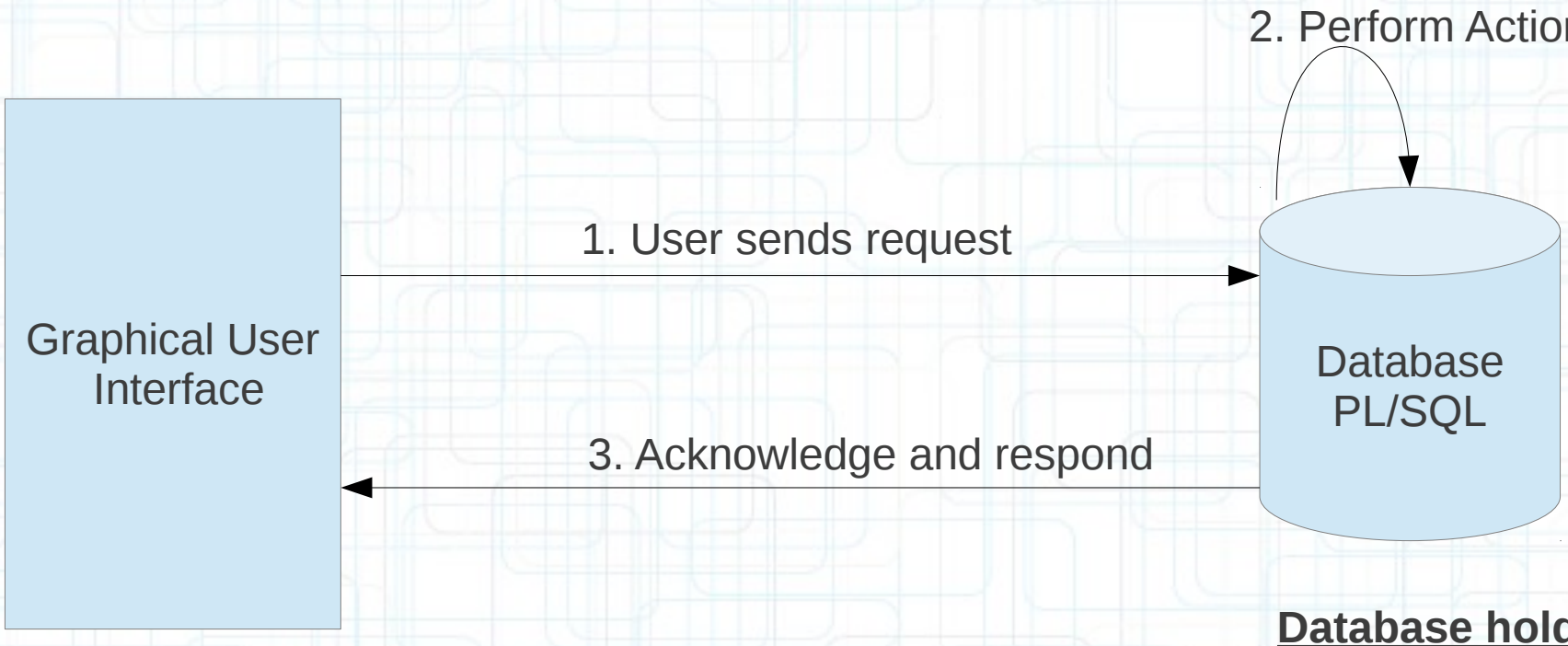
New automated database approach



Database holds:
- Thresholds
- Parametrisations
- List of all families
- Corrections

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

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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

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Parametrisation: View

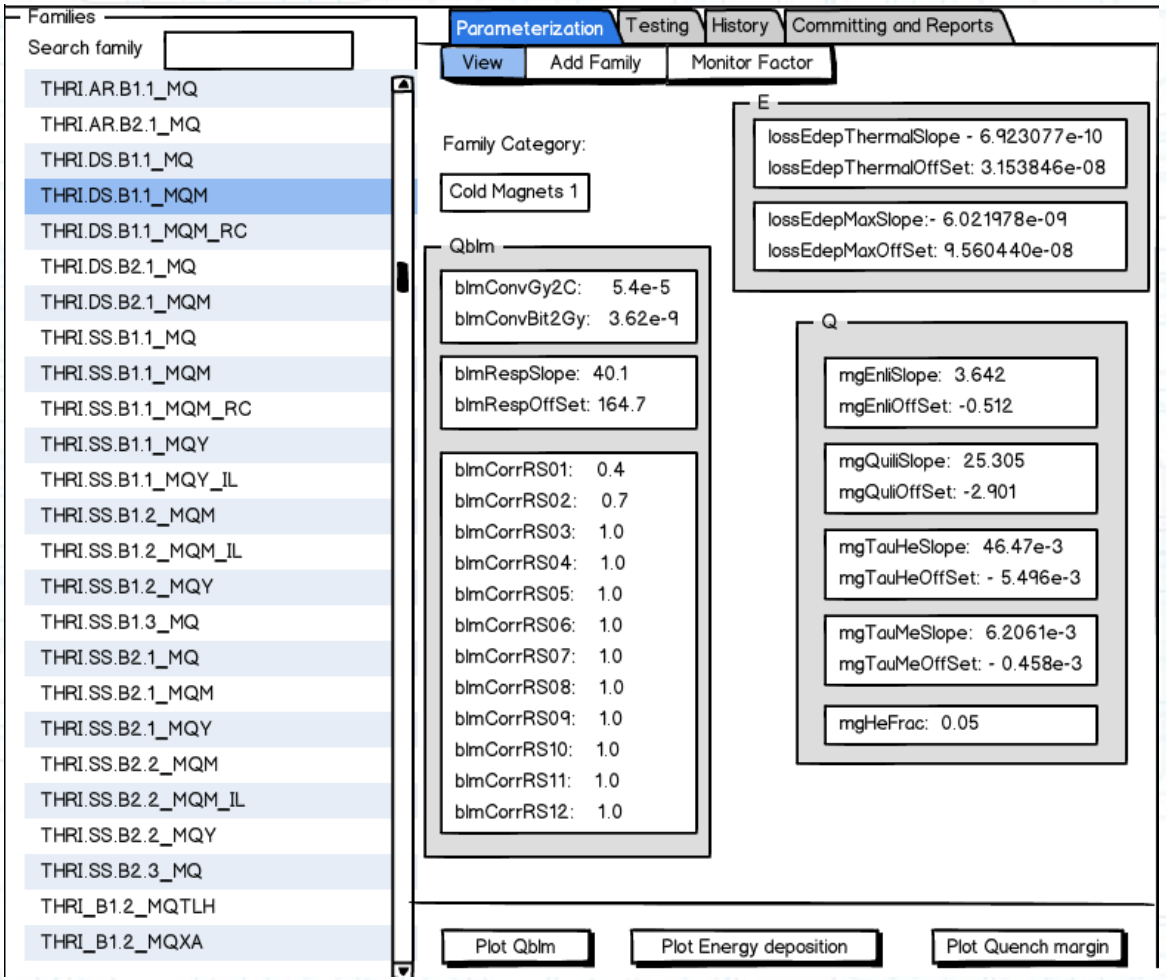
BASIC FLOW:

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



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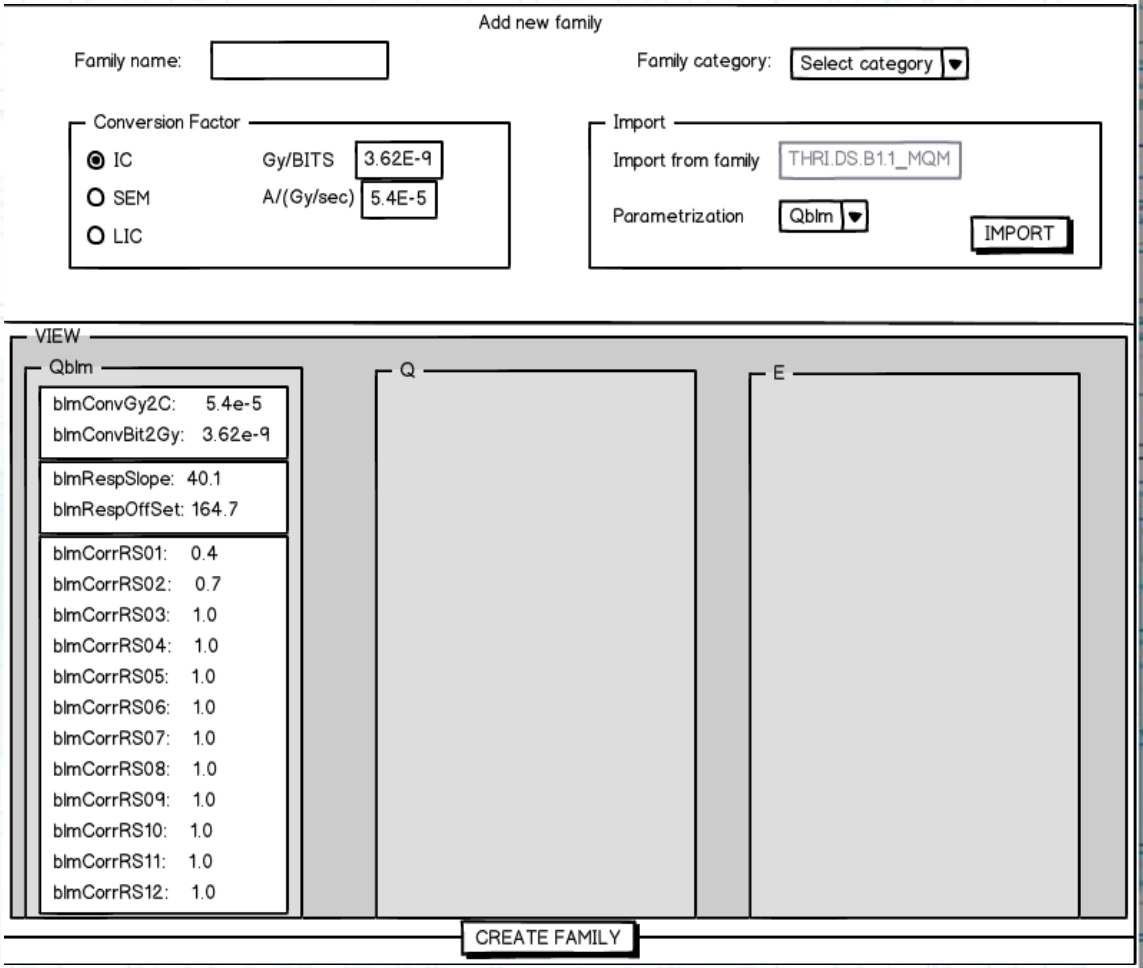
Parametrisation: Create new family

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.



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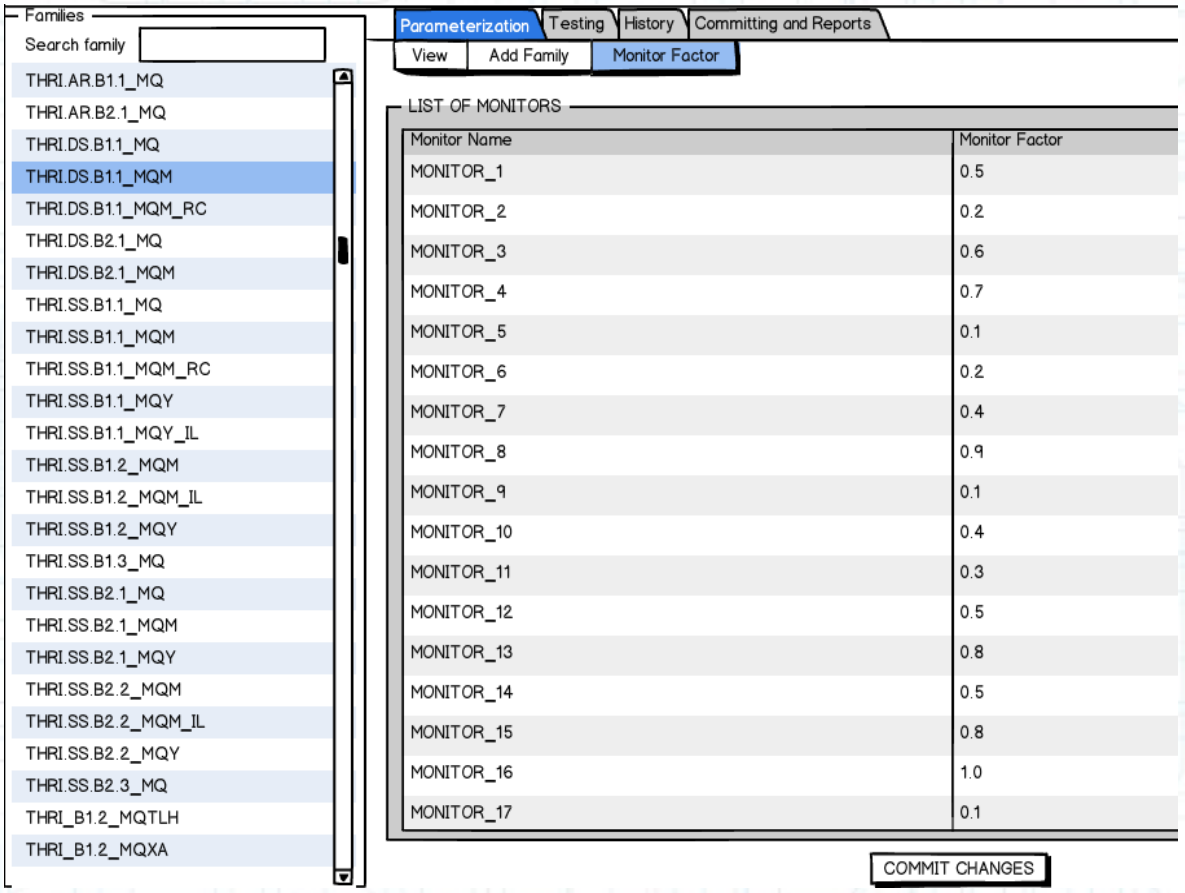
Parametrisation: Monitor Factor

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



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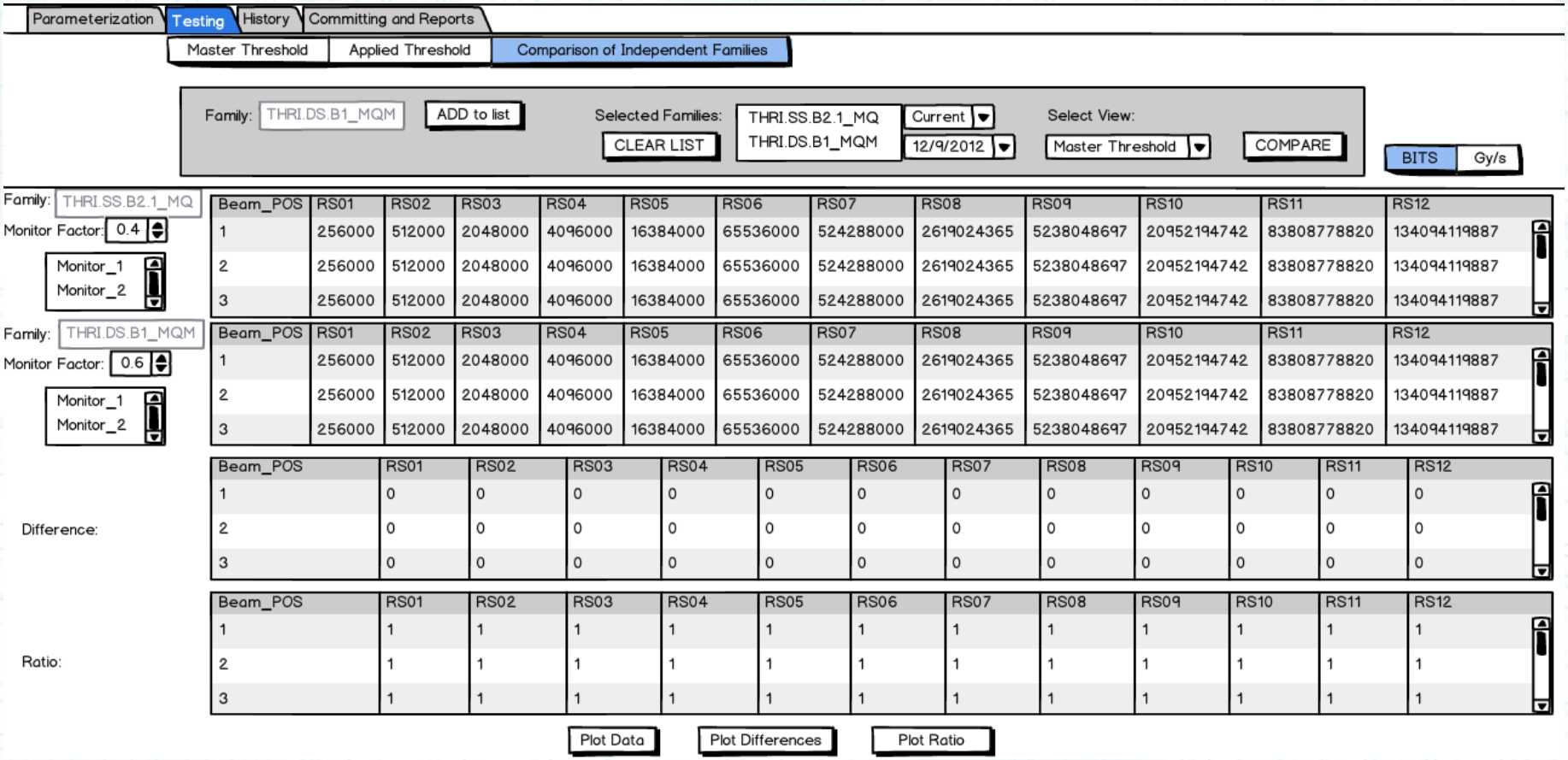
Testing: Comparison of Independent Families



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

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

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

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

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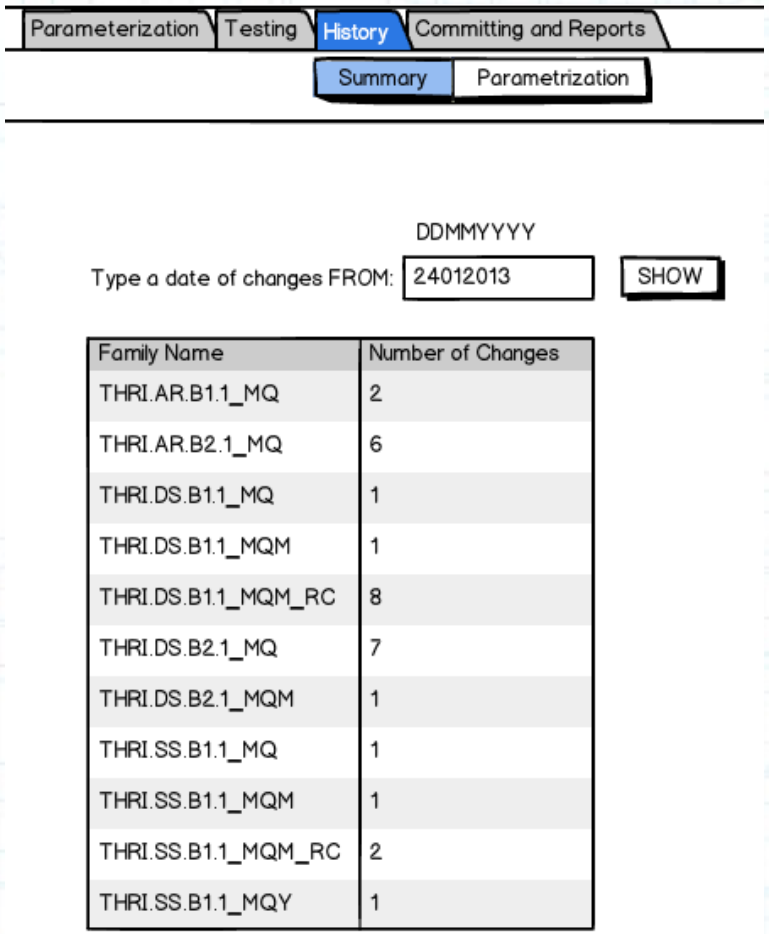
History: Summary View

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



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

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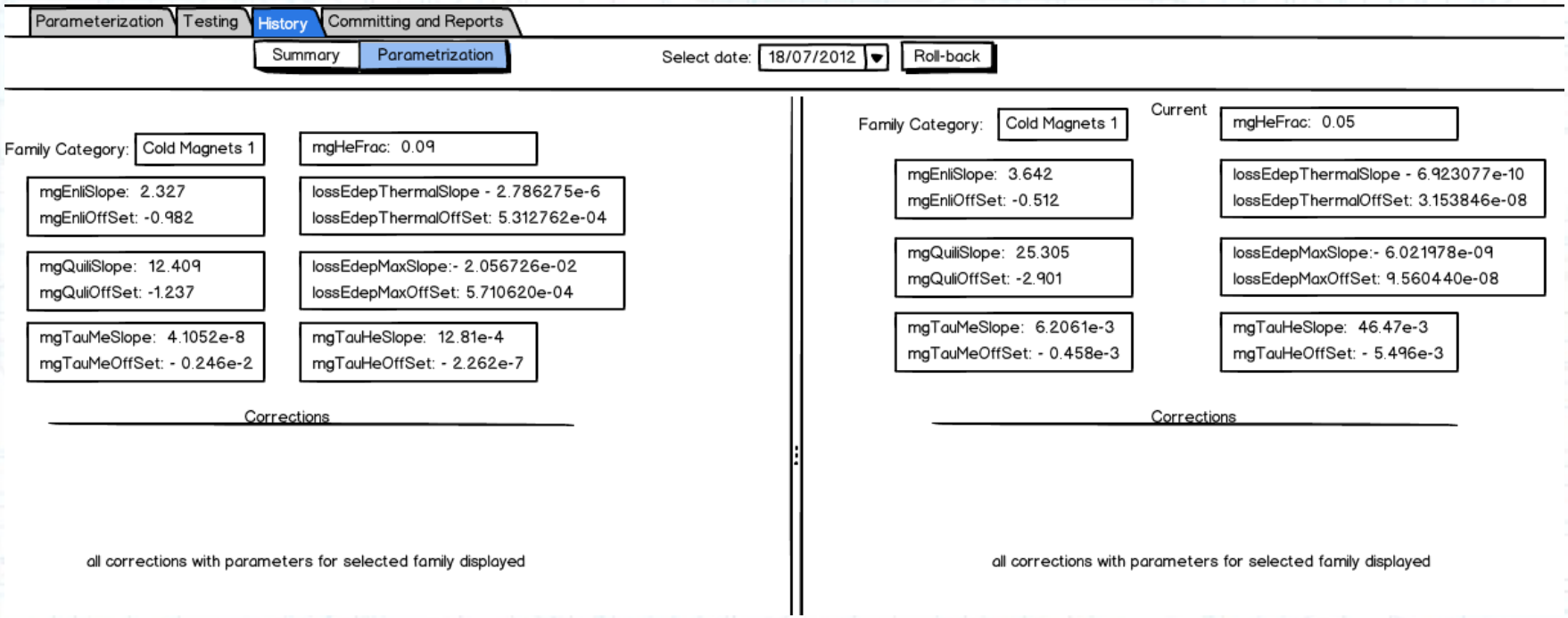
History: Parametrisation View



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

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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

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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

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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

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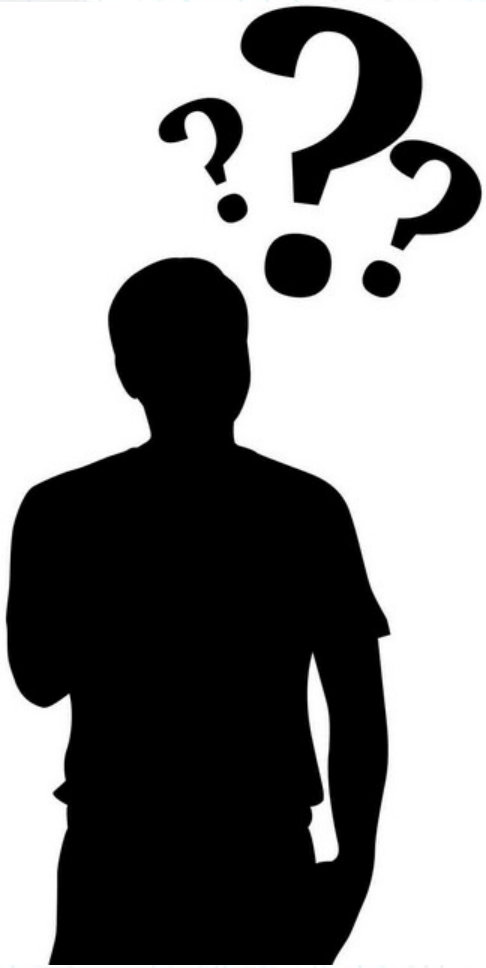
Questions?



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Backup Slides

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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

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