Setting up thresholds in LHC Beam Loss Monitors

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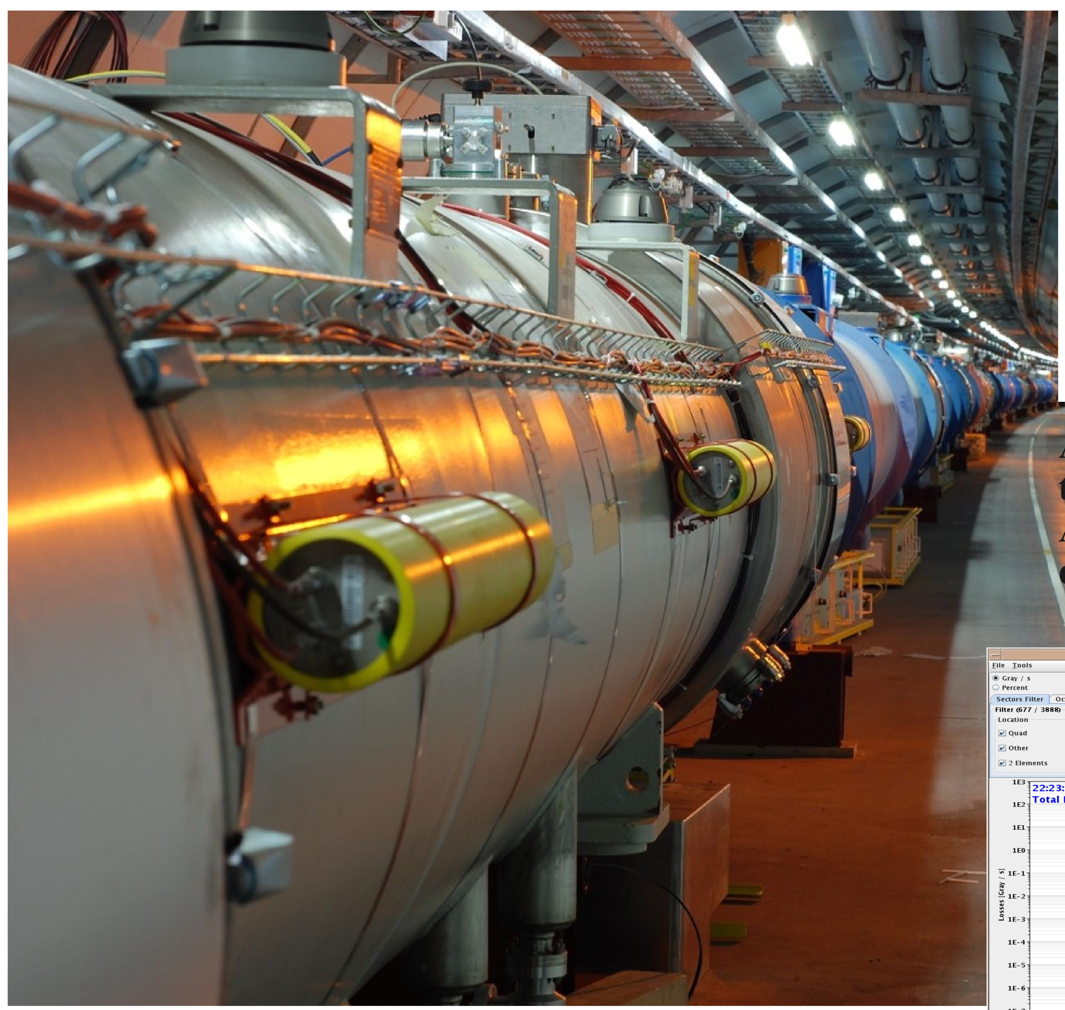
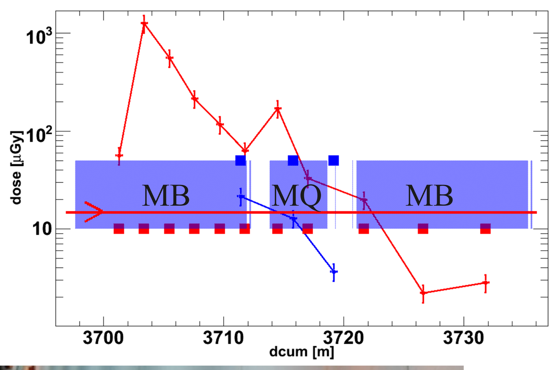
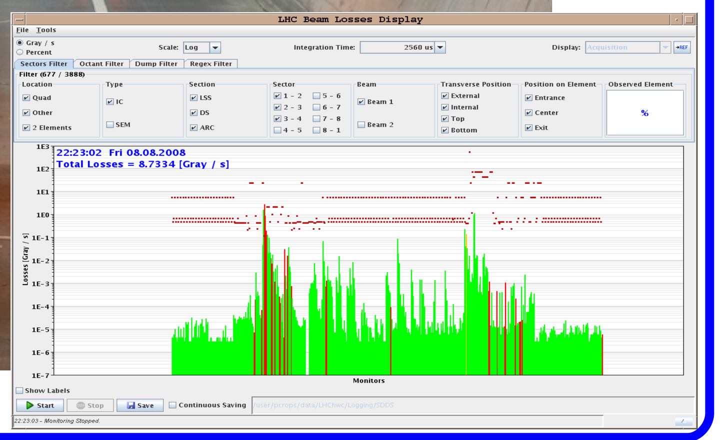
Abstract: *LHC Beam Loss Monitoring system contains almost 4000 sensors protecting various elements of the machine against damage due to the beam losses. The procedures to obtain the beam-abort threshold settings are presented. Specific cases are discused: cold magnets, Inner Triplet case where BLM protection is limited and Collimators. The object-oriented software library to perform the threshold table unfolding is presented together with user interface to the threshold database.*

The system





Almost 4000 monitors connected to beam dump system
Almost every monitor can send dump signal



Thresholds

Threshold: **D [Gy] = Q$_{BLM}$ [C] H$_{cable}$[mJ/cm^3]/E$_D$[mJ/cm^3]**

typically the thresholds are expressed in dose [Gy] for various integration times

• H_{cable} is superconducting cable enthalpy in case of short transient losses
but it can be instead:
• Maximum power which can be evacuated from a coil to the cryogenic system in case of steady-state beam losses
Collimator/warm magnet damage threshold,.... etc...

Every threshold is a TABLE of numbers: 12(integration times) x 32(beam energy levels)
= 384 numbers/ monitor
signal is integrated for 40 µs ... 84 s.

Total number of thresholds for the whole system: **1495296** (now, can increase up to 2457600)

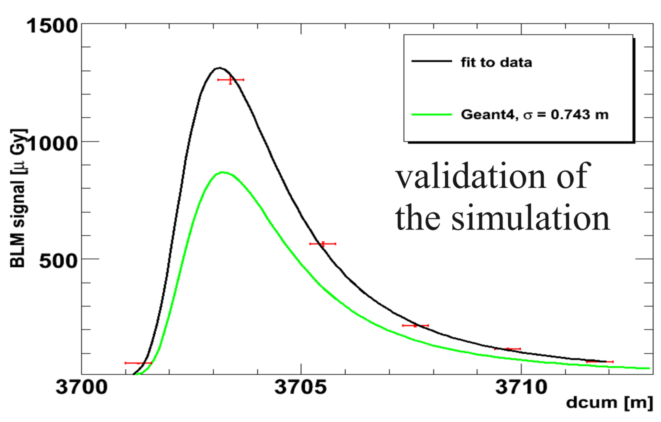
Prescription is complex:
• Loss pattern simulations – from Collimation WG or deduced from beam optics,
• Extensive Geant4/FLUKA simulations of radiation levels in coils and outside,
• Interpolating thresholds values between fast and steady-state loss durations,
• Grouping monitors in FAMILIES with the same thresholds,
• Storing as much as possible of the threshold informations in structured database (part of LSA – LHC Software Architecture),
• Learning from experience with beam – proved in 2008.

for example: Cold Magnets

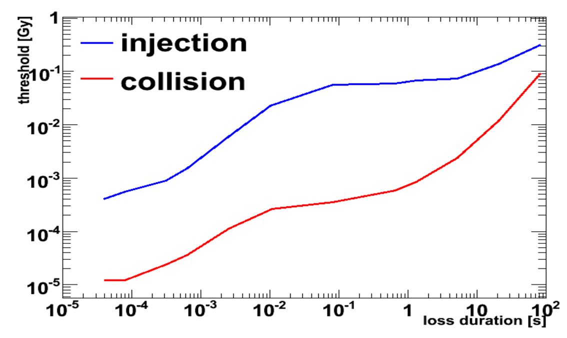
(with A. Priebe, Ch. Kurfuerst)

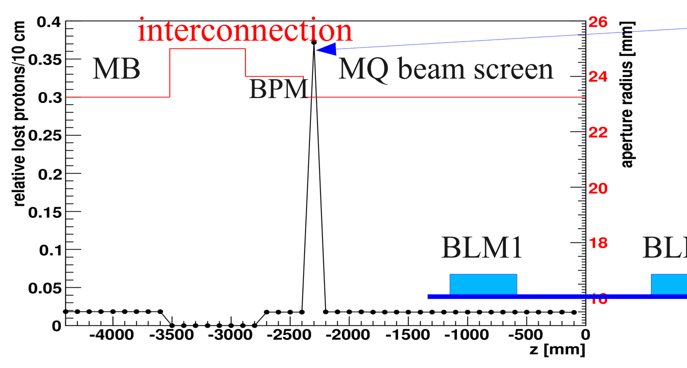
Main cases, precisely simulated:
• MB – loss inside magnet long cold mass (not likely to happen in reality) LHC-Project-Note-422
• MQ – loss on the interconnection

•MB case: thresholds for distributed losses are about 4-5 times higher then for point losses – because the signal outside cryostat is 4-5 times more spread then the deposited energy distribution in the coil
•The threshold value changes by factor 50 between injection and collision energy
•Time-behavior of the thresholds is a complex issue, treated for instance in LHC Note 44 (J.B. Jeanneret et al)



validation of the simulation





Max loss appears at the front of MQ beam screen

loss pattern	beam energy [TeV]	threshold [μGy] BLM 1	BLM 2	BLM 3
	0.45	5340	340	72

radius=500 mm

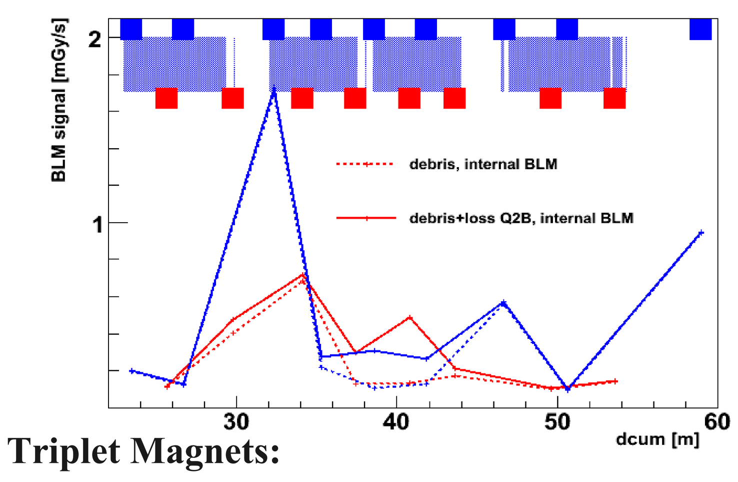
for example: Triplet magnets

(with Ch. Hoa, A. Mereghetti, F. Cerutti)

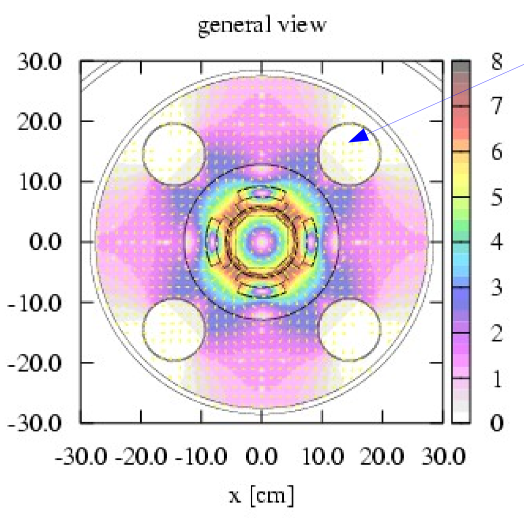
In BLMs installed on Inner Triplet Magnets there is a constant signal from interaction debris in IP.

For steady-state losses this signal masks the signal from loss causing quench!

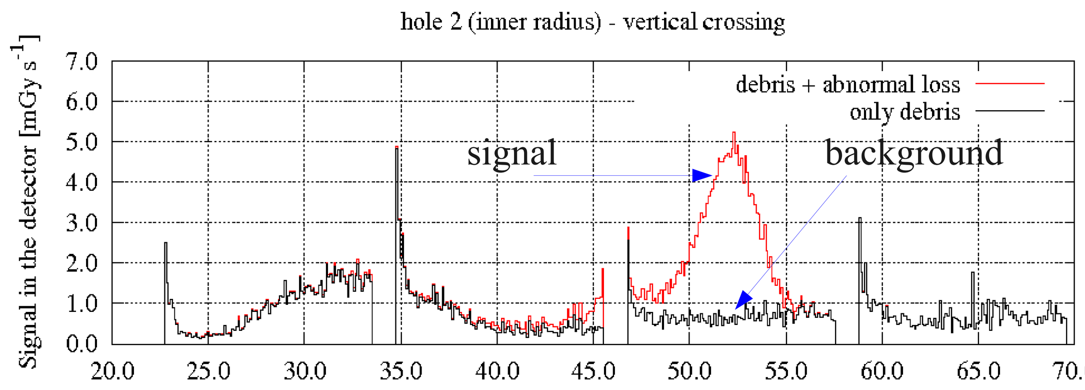
Current system
cannot protect Triplets for steady-state losses.



Something has to be changed for next-generation Triplet Magnets:



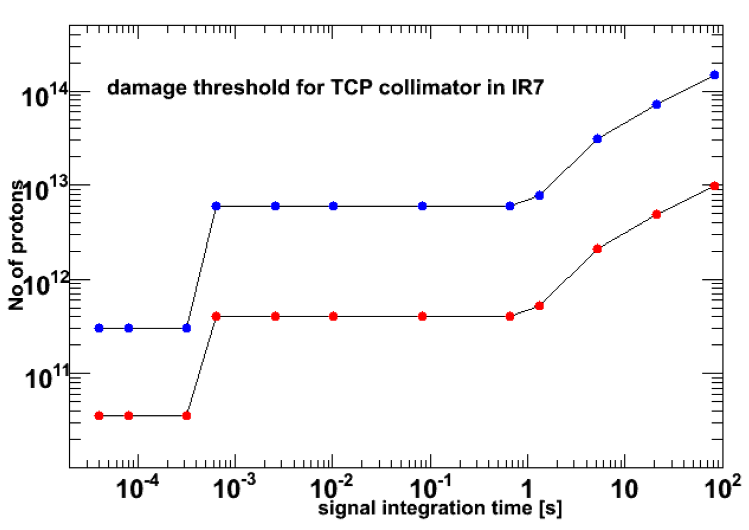
New detector placed inside magnet yoke technology: He^3 chamber, silicon, diamond, LHe, SPND...?



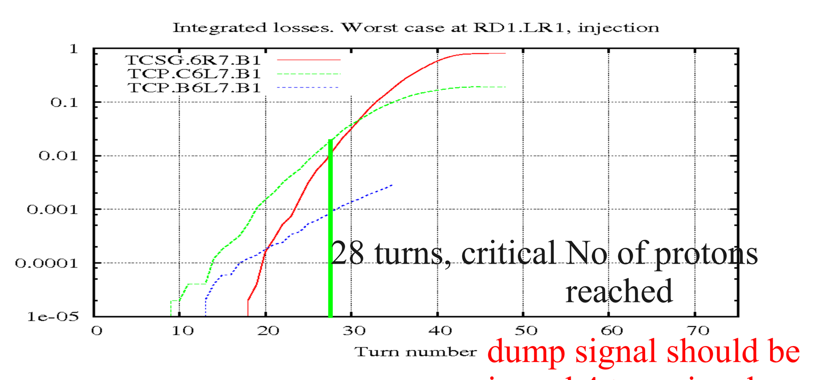
for example: Collimators

(with A. Gomes, T. Boehlen)

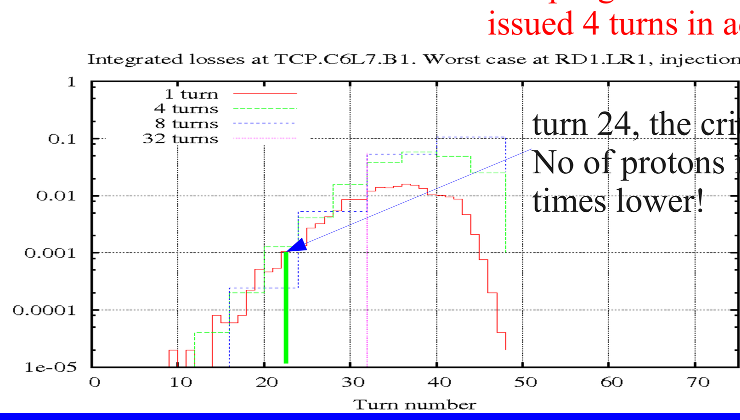
Device	Location	Beam Energy	t > 10s	1s < t < 10s	t < 1s
			dN$_{>10}$/dt [p/s]	dN$_{1-10}$/dt [p/s]	N$_{<1}$ [p]
TCP	IR3	450 GeV	1.20E+12	6.00E+12	6.00E+12
TCP	IR3	7 TeV	8.00E+10	4.00E+11	4.00E+11
TCP	IR7	450 GeV	1.20E+12	6.00E+12	6.00E+12
TCP	IR7	7 TeV	8.00E+10	4.00E+11	4.00E+11
TCSG	IR3	450 GeV	1.20E+11	6.00E+11	6.00E+11
TCSG	IR3	7 TeV	8.00E+09	4.00E+10	4.00E+10
TCSG	IR7	450 GeV	1.20E+11	6.00E+11	6.00E+11
TCSG	IR7	7 TeV	8.00E+09	4.00E+10	4.00E+10
TCLA	IR3	450 GeV	6.00E+08	3.00E+09	3.00E+09
TCLA	IR3, IR7	7 TeV	4.00E+07	2.00E+08	2.00E+08
TCLA	IR7	450 GeV	6.00E+08	3.00E+09	3.00E+09
TCLA	IR3, IR7	7 TeV	4.00E+07	2.00E+08	2.00E+08
TCTH, TCTVA, TCTVB	IR1, IR2, IR5, IR8	450 GeV	6.00E+08	3.00E+09	3.00E+09



• Input from Collimation WG – maximum allowed lost protons on various collimators – determined by beam lifetime or collimators' damage threshold
• Correction for very fast magnet failures (wrong powering of separation dipoles)



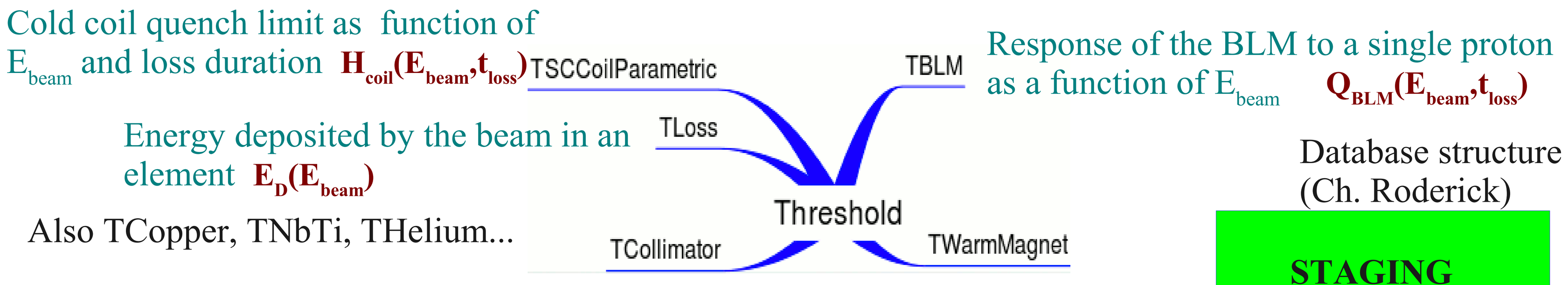
28 turns, critical No of protons reached
dump signal should be issued 4 turns in advance.



turn 24, the critical No of protons is 20 times lower!

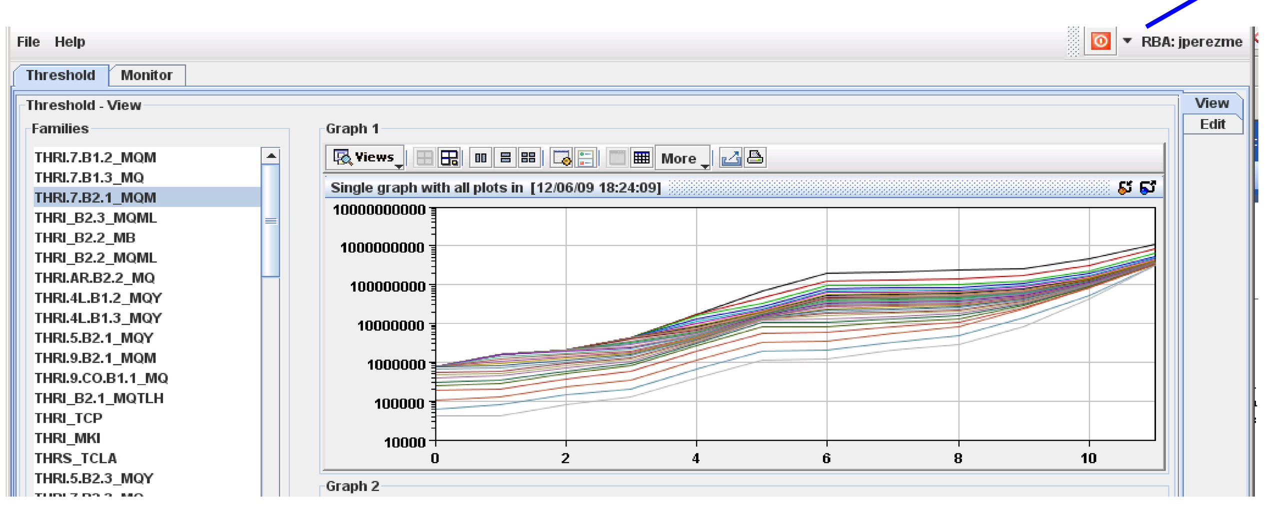
Software

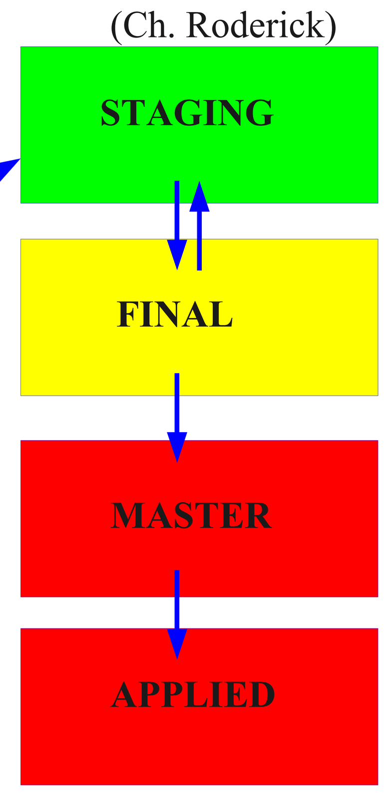
(with Annika Nordt) thrc++: object oriented program using root objects (TF1, TEnv, etc)



Database structure (Ch. Roderick)

(with J. Perez and S. Jackson) BLM Expert Threshold Application





Conclusions and Acknowledgments

The initial settings of quench-preventing thresholds for the LHC elements has been done, based on work of many people:
• Simulation of the BLM response function (Ionisation Chamber and Secondary Emission Monitor)
• Simulations, calculations and measurements of the Quench Margin of the magnet coils,
• Simulations of proton interactions and shower development inside the magnet (Geant4, FLUKA)
• Database and software development... not even speaking about complex electronics!
The first beam-induced quenches of MB magnet (2008) provided interesting data, which validate the simulations and could help to determine the systematic difference between simulations and reality.

Credits:
The Geant4 geometry of the magnet has been programmed mainly by Agnieszka Priebe.
The work is at the end of a long chain of thresholds simulations, among many references see:
• Jeanneret J.B. et al. LHC Project Note 44 (1996)
• A. Arauzo LHC Project Note 238 (dispersion supressor)
• E. Gschwendtner, L. Ponce, R. Bruce (thesis) and others
The key people, authors of the concepts: Bernd Dehning, Christos Zamntzas, Barbara Holzer and other colleagues from BE-BI-BL

Many thanks to: David Schiebol and Nikolai Schwerg (ROXIE), Elena Benedetto, Chiara Bracco, Thomas Weiler, Mike Lamont, Markus Stockner, Daniel Kramer, Chris Roderick, Ralph Assman, Simone Gilardoni, Markus Brugger, Elias Lebbos and Geant4 team especially Alexander Howard and Gunter Folger and others.