Building a hadron calorimeter prototype with SCG1-C glasses

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University and INFN of Udine

12th Aug 2011, Fermilab

SCG1-C glass

- By Ohara Optical Glass, Inc. [(1)]
- Density is 3.36 g/cm^3 [(3)]
- Radiation length is 4.26 cm [(3)]
- Interaction length is 44.5 cm (for pions with 30-200 GeV energy) [(3)]
- Reminder for the simulation: for protons λ is shorter than for pions
- Refraction index: n=1.61 [(4)]
- Cherenkov emission angle θ_c=51.6°
- Scintillation decay time: 70 ns [(2)]
- Cherenkov to scintillation signal: *C/S*=40/60 [(2)]

salt	Percent (by weight) [(1)]
BaO	43.4%
SiO_2 (α-quartz)	42.5%
Li_2O	4.0%
MgO	3.3%
K_2O	3.3%
Al_2O_3	2.0%
Ce_2O_3	1.5%

(1) B. Cox, et al., IEEE Transactions on Nuclear Science, Vol. NS-30, No 1, 1983
(2) G.E. Theodosiou, et al., IEEE Transactions on Nuclear Science, Vol. NS-31, No 1, 1984
(3) L. Antoniazzi, et al., The Experiment 705 Electromagnetic Shower Calorimeter, FERMILAB-Pub-93/001 E705, 1993
(4) Estimated from Y. Yoshimura, et al., Nucl. Instr. and Meth. 137 (1976), 57

Glass inventory

- I found 74 ‘big’ but only 161 out of 212 ‘small’ glasses in the store place

type	Dimensions (cm^3)	#	# found
Main array big	**15 x 15 x 89**	**74**	**74**
Main array small	7.5 x 7.5 x 89	92	
Active converter	7.5 x 7.5 x 97.5	120	
total		**74** + 212	**74** + 161

- We are short of glass for full containment
- We have to content ourselves of partial containment and then correct for leakage

95% lateral containment

- Lateral containment of the shower at the 95% level, is given by a formula taken from (*)

$$R_{95\%} = \lambda(0.29 + 0.30u) = 13.22 + 0.30x$$

$$(E = 10GeV)$$

where the value of the *slope parameter* has been *linearly extrapolated* from the data at 50 and 140 GeV (see next slide) and the intercept parameter has been considered to be *independent* of energy

- x is the longitudinal coordinate and $u = x/\lambda$
- In 3-D this formula represents a truncated cone

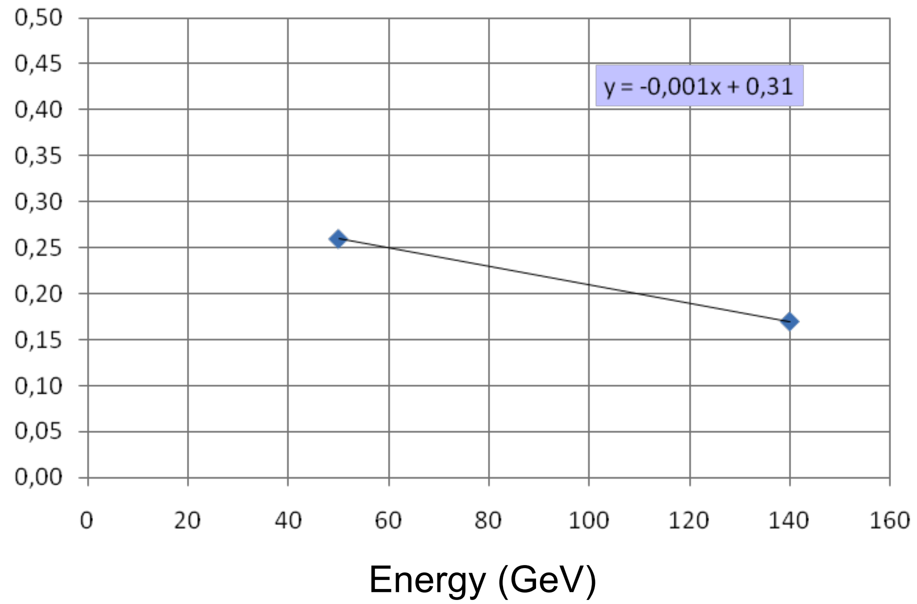
(*) R. Frühwirth et al., Data Analysis Techniques for High-Energy Physics, Cambridge Monographs, edition 2000, pag. 199.

Slope parameter

$$R_{95\%} = \lambda(0.29 + 0.30u) = 13.22 + 0.30x$$

$$(E = 10GeV)$$

energy (GeV)	cntnmnt slope (%/cm)
50	0,26
140	0,17
	extrapolation
10	0,30
20	0,29
30	0,28
40	0,27
50	0,26



Longitudinal containment (Fabjan)

- Longitudinal containment of the shower at the 95% level, is given by a formula taken from (*)

$$x_{95\%} = x_{\max} + 2.5 x_{att}$$

- where $x_{\max} = \lambda\left(0.7 + 0.2 \log E\right)$ $x_{att} = \lambda E^{0.13}$
- $x_{95\%}$ fits the available data to within 10% for E in the range few GeV - few 100 GeV
- x_{max} describes the position of the shower maximun
- x_{att} describes the exponential decay of the shower beyond x_{max}

(*) C.W. Fabjan, Calorimetry in High-Energy Physics, in *Techniques and Concepts of High-Energy Physics III*, editor T. Ferbel, Plenum Press, 1985, pag. 297.

Longitudinal containment (Fabjan)

- We can go as high as 10 GeV and attain 95% containment

Lengths in cm

E(GeV)	x_max	x_att	x_95%	miss.glass.lngth
10	52	60	202	1.2
20	58	66	222	21.5
30	61	69	235	34.0
40	64	72	244	43.2
50	66	74	251	50.5

Length of missing glass to attain 95% longitudinal containment

Longitudinal containment (Wigmans)

- But according to Wigmans we can even attain something like 98% containment at 10 GeV with the glass we have

Longitudinal containment (Wigmans)

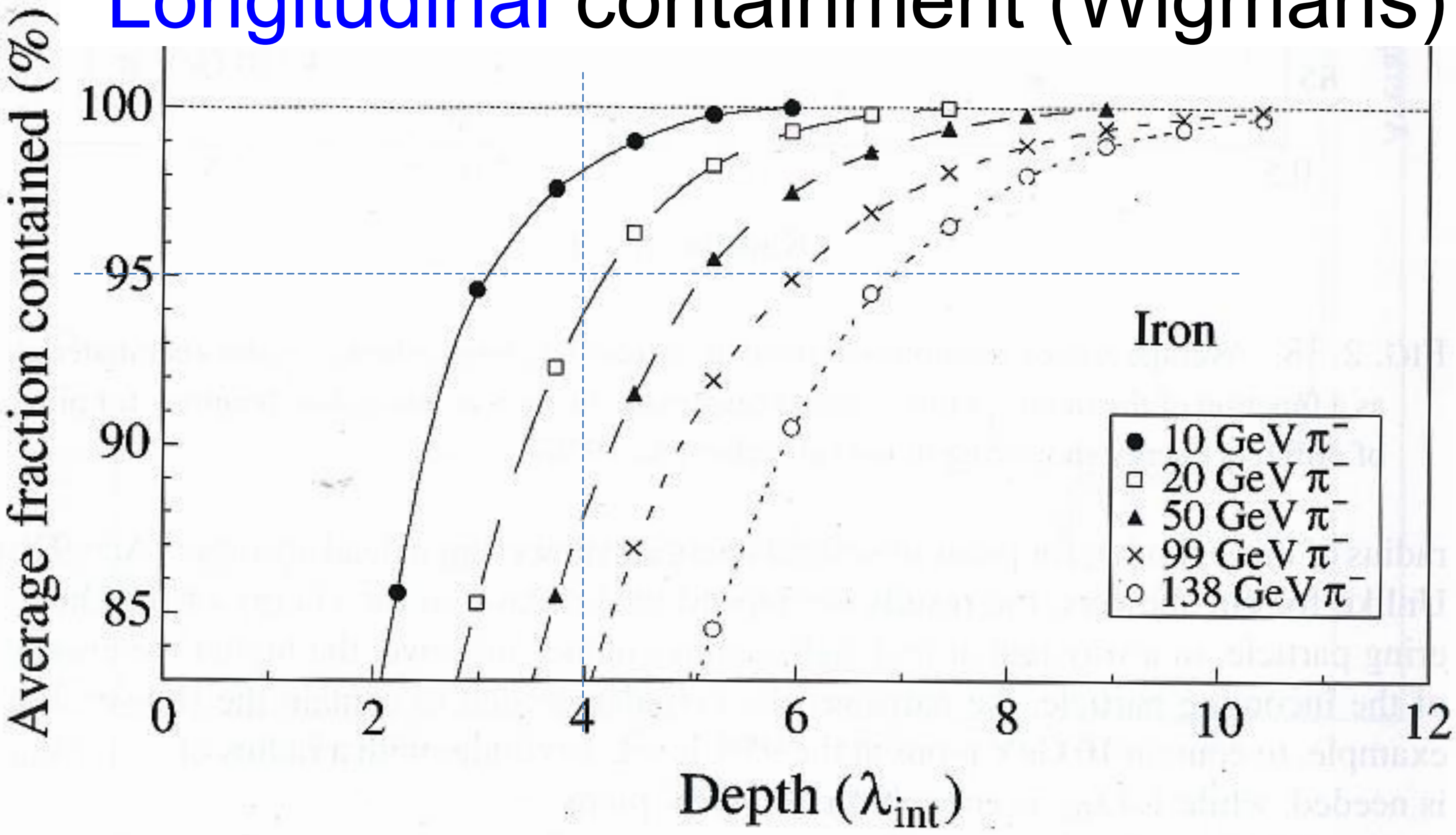


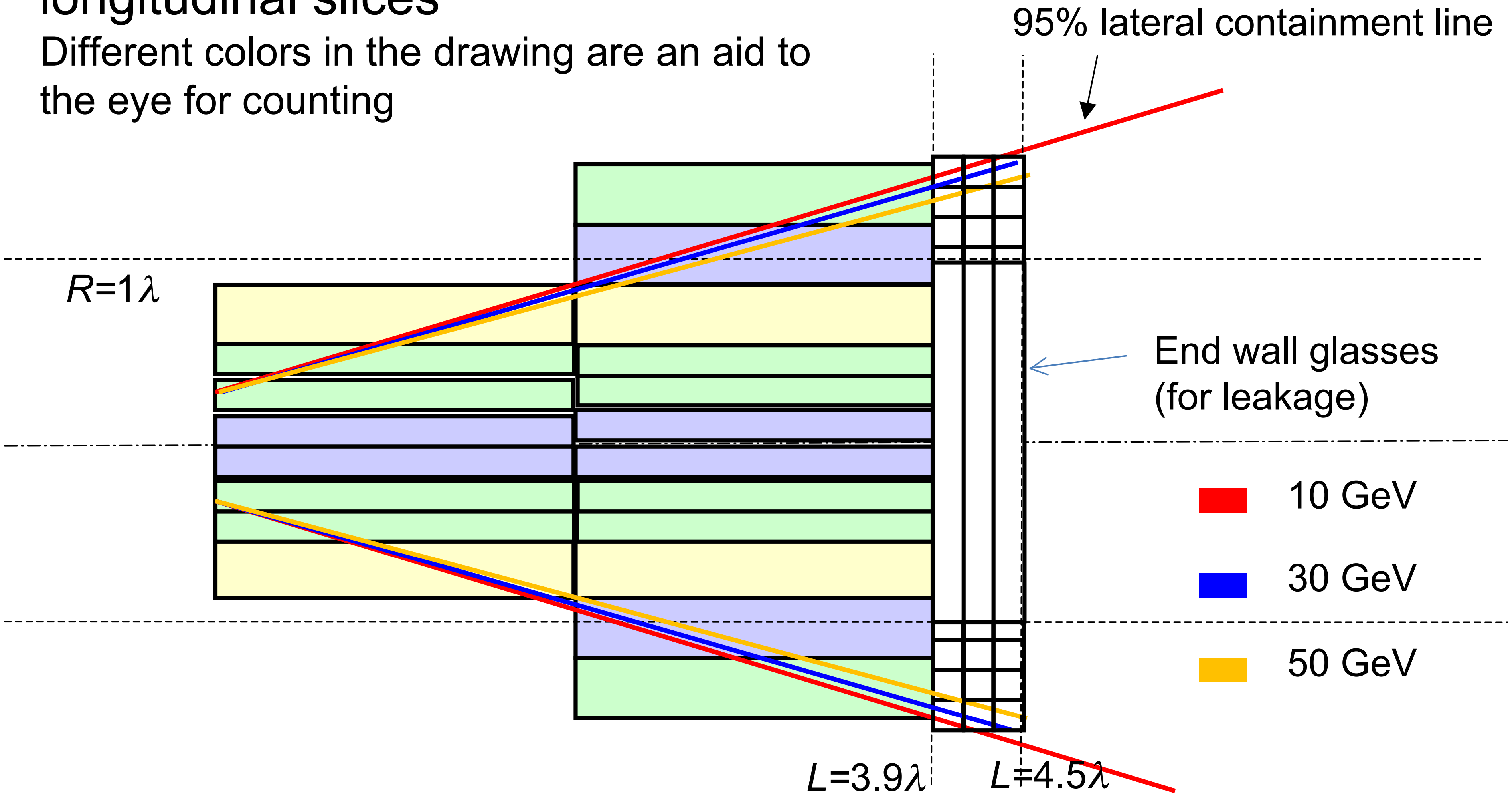
FIG. 2.37. Average energy fraction contained in a block of matter with infinite transverse dimensions, as a function of the thickness of this absorber, expressed in nuclear interaction lengths. Shown are results for showers induced by pions of various energies in iron absorber [Abr 81].

Figure taken from R. Wigmans, Calorimetry, Oxford Science Publications. See bibliography wherein.

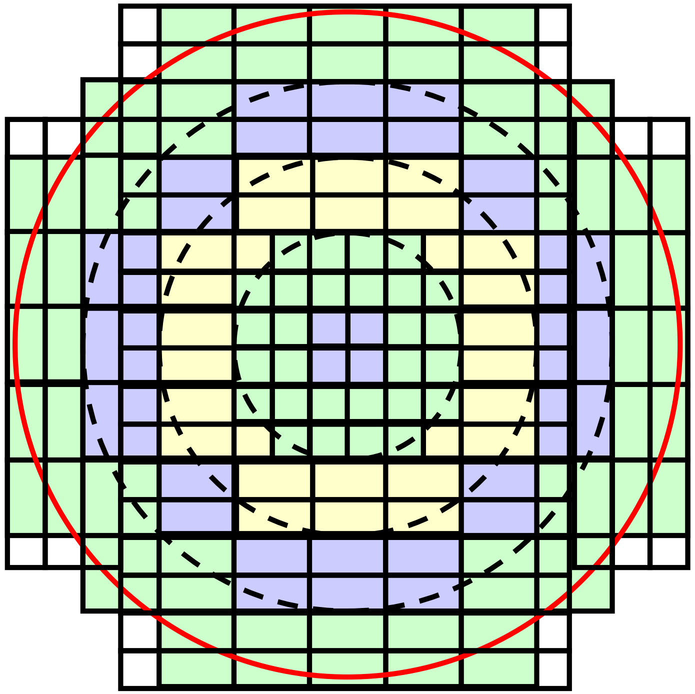
Putting glasses together, longitudinally

Example of glass arrangement in longitudinal slices

Different colors in the drawing are an aid to the eye for counting



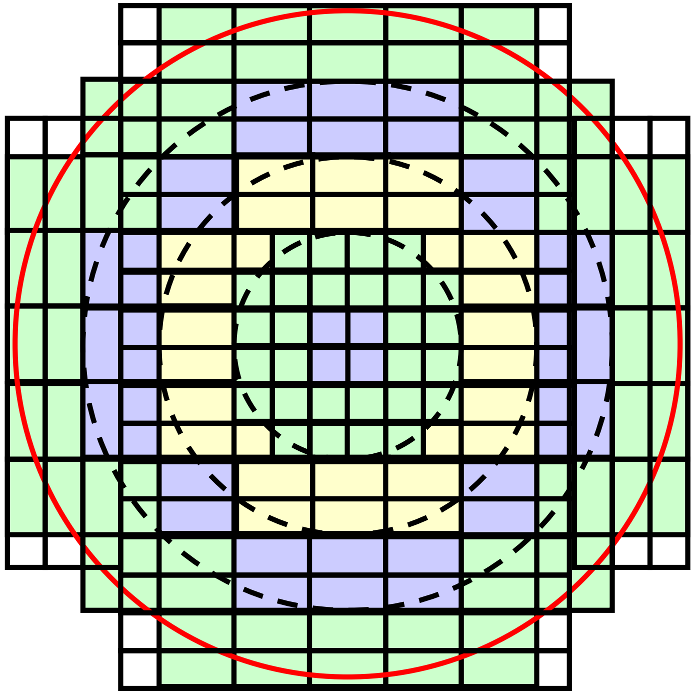
Putting glasses together, radially



Example of glass arrangement in 'concentric' radial sheaths

Different colors in the drawing are an aid to the eye for counting

sheath (radial)	# sm gl./sheath	# big gl./sheath	# slices (long.)	total # sm gl.	total # big gl.
1	4	**0**	2	8	0
2	28	**0**	2	56	0
3	4	**12**	2	8	24
4	0	**16**	1	0	16
5	0	**32**	1	0	32
total	end-wall	excepted		72	72



Different colors in the drawing and table are an aid to the eye for counting

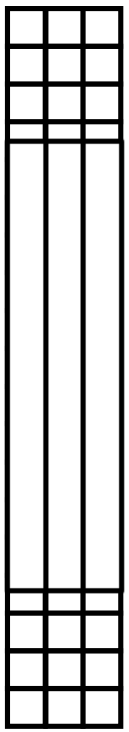
GLASS BUDGET

212 (161) + **74**

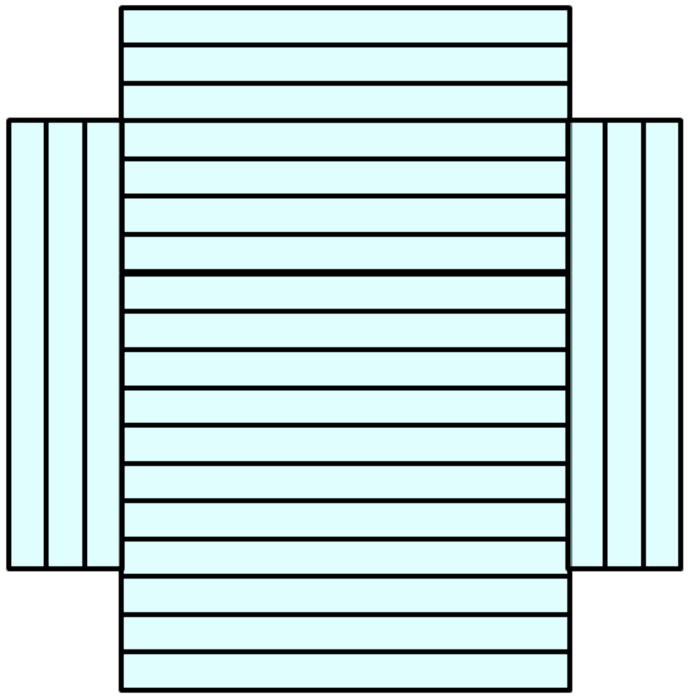
Longitudinal leakage: end-wall glasses

- Three longitudinal layers of 24 glasses each for a total of 72 glasses (it amounts to 22.5 cm only, in depth)

Longitudinal view



Transverse view



Lateral leakage

- To study the lateral leakage, we will use the outermost glasses of the stack in the radial direction

Conclusions

- A Geant-based simulation is underway (see Anna's talk)
- It can helps us to choose the best shape and radial, longitudinal dimensions