CLIC power consumption

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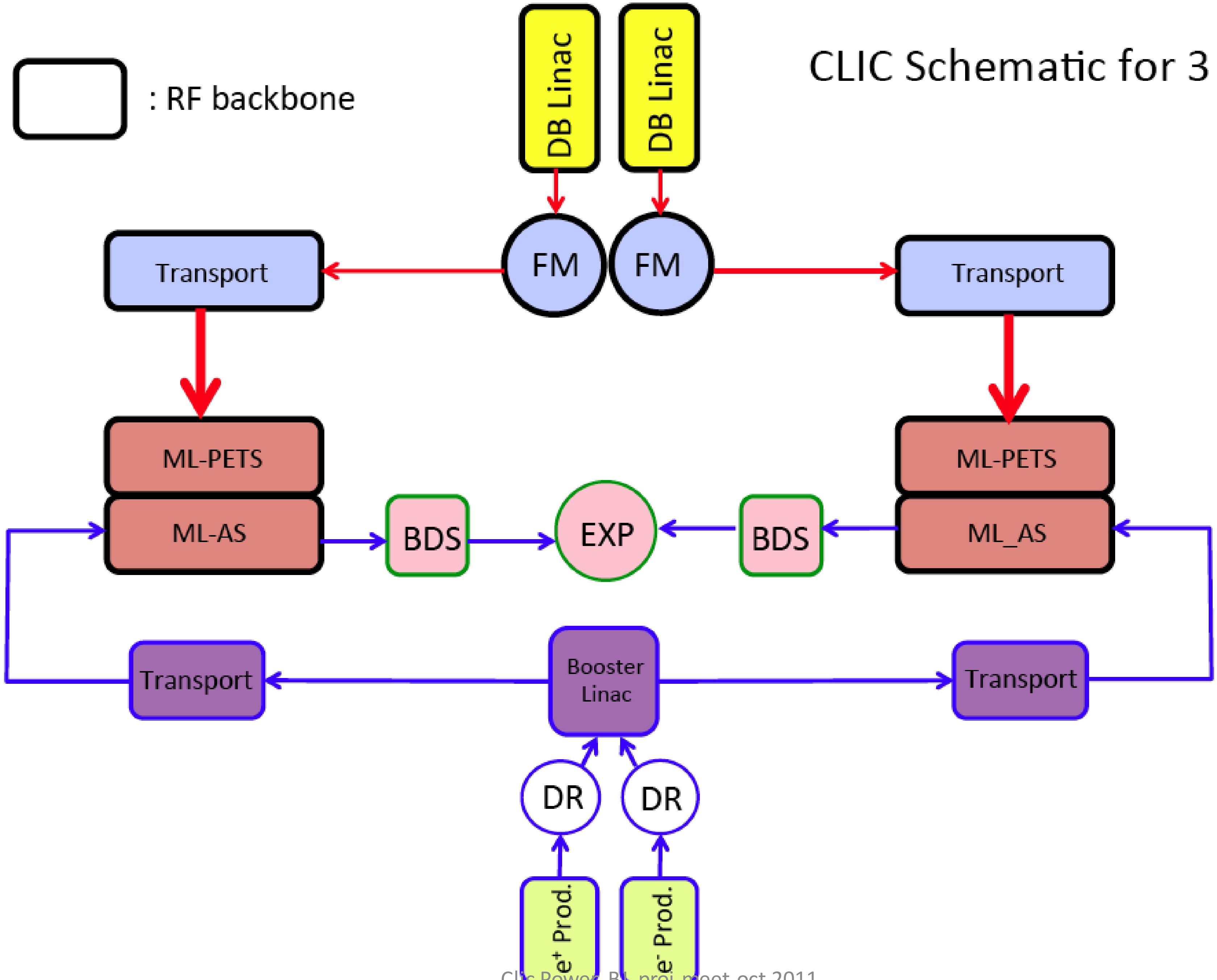
CLIC Project meeting, Oct 2011

CLIC Schematic for 3 TeV



Detailed power map nominal luminosity

all data in MW

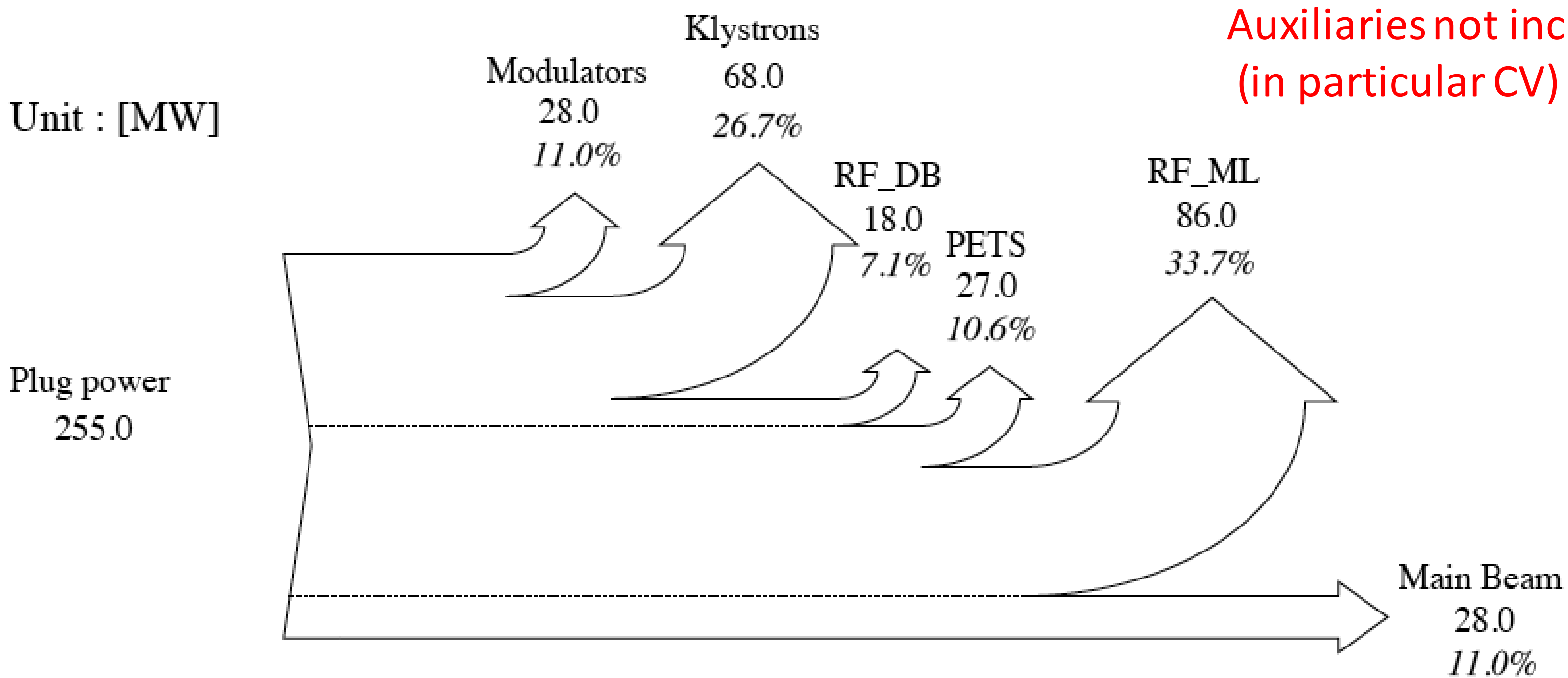
E_CM [TeV]	0.5	1.5	3
MB injectors magnets	1	1	1
MB injectors RF	24.3	16.5	16.5
MB PDR+DR magnets	5.1	5.1	5.1
MB PDR+DR RF	17.6	17.2	17.2
MB Transport	16.5	16.5	16.5
MB Long Transport Line	0.1	0.3	0.5
DB injectors Sol+Mag	3.4	3.4	6.8
DB injectors RF	66.8	127.6	255.2
DB FM	9.3	9.3	18.5
DB transport to tunnel	0.1	0.1	3.0
DB transport in tunnel	8.1	19.6	39.1
DB Long Delay Line	2.0	2.3	0.0
TBM MB	1.0	2.5	4.9
TBM DB	2.8	6.7	13.3
Post Decel	2.2	5.3	10.6
BDS	0.9	1.2	1.6
Interaction area	16.3	16.3	16.3
Dump Line	1.1	1.7	3.3
Experiment	15.0	15.0	15.0
Instrum. Main tunnel	2.1	5.0	10.0
Instrum. other	3.0	3.0	4.0
Control Main tunnel	0.4	1.0	2.0
Control other	0.8	0.8	1.0
Cooling & Ventilation	58.0	67.0	93.0
Network Losses	13.0	17.0	28.0
TOTAL	**271**	**361**	**582**

Detailed and precise evaluation made for most systems

- RF – DB Linac, E. Jensen, R. Wegner, G. McMonagle, D. Nisbet, S.Pittet
- RF – Main Linac, A. Grudiev, G. Riddone, I. Syratchev
- Magnet & rectifiers, M. Modena, A. Vorozhtsov, D. Siemaszko, S.Pittet
- Cooling and ventilation, M. Nonis
- Many others on less power-demanding systems

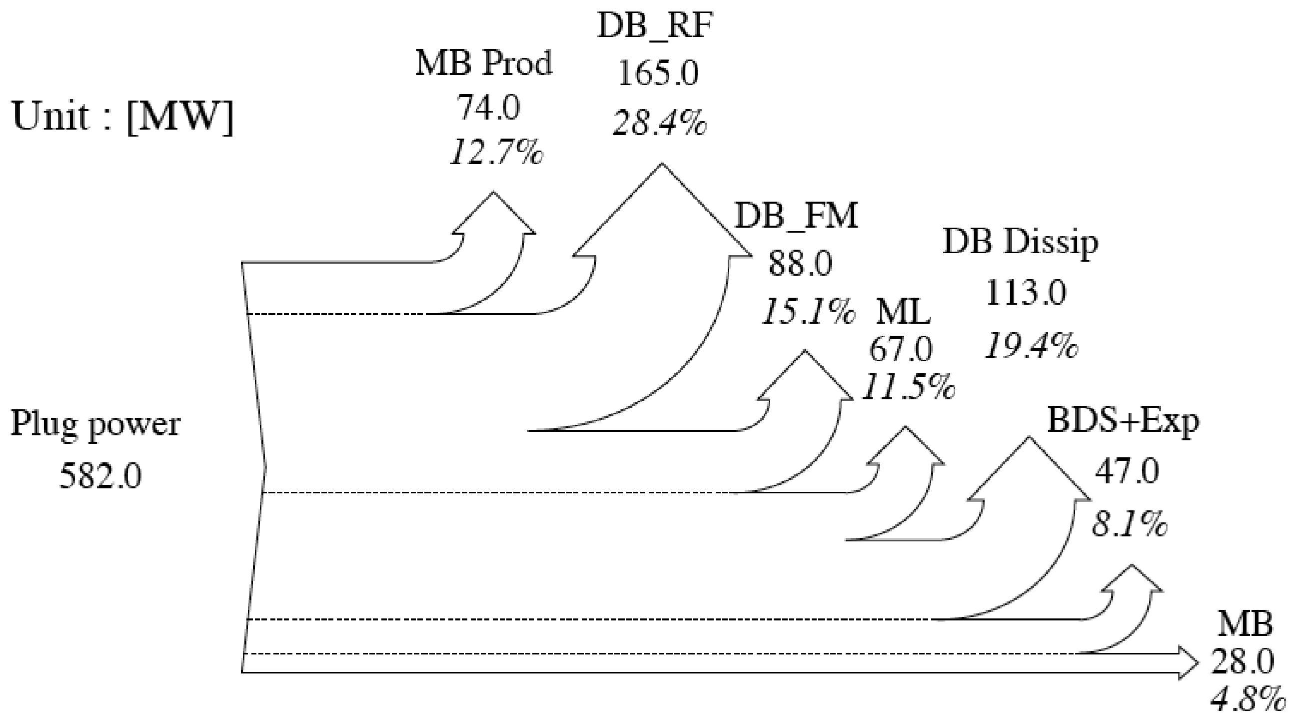
RF : from Drive Beam Linac to Main Beam - 3TeV

Auxiliaries not included here (in particular CV)



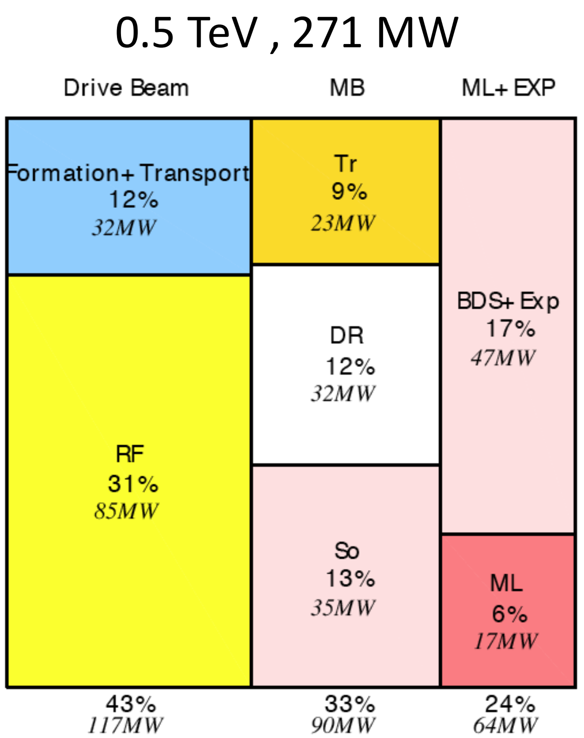
- Modulator yield : η = 0.89 : quite challenging (see talk S. Pittet)
- Klystron yield : η = 0.70 a bit beyond today's standards ← Keep with ?
- PETS : nearly perfect transformer (η = 0.98) , but 17% of drive beam power goes to dump
- Main Linac structure yield : compromize with total linac length and low-emittance preservation

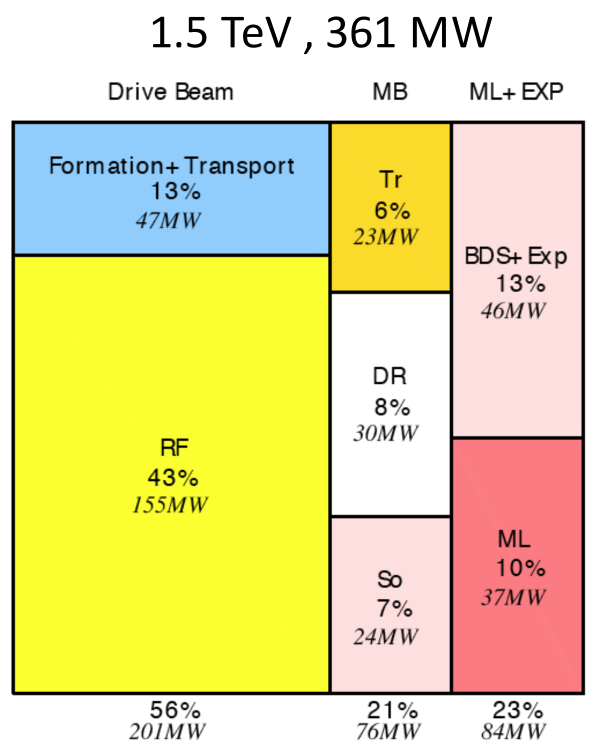
Overall power efficiency map - 3 TeV

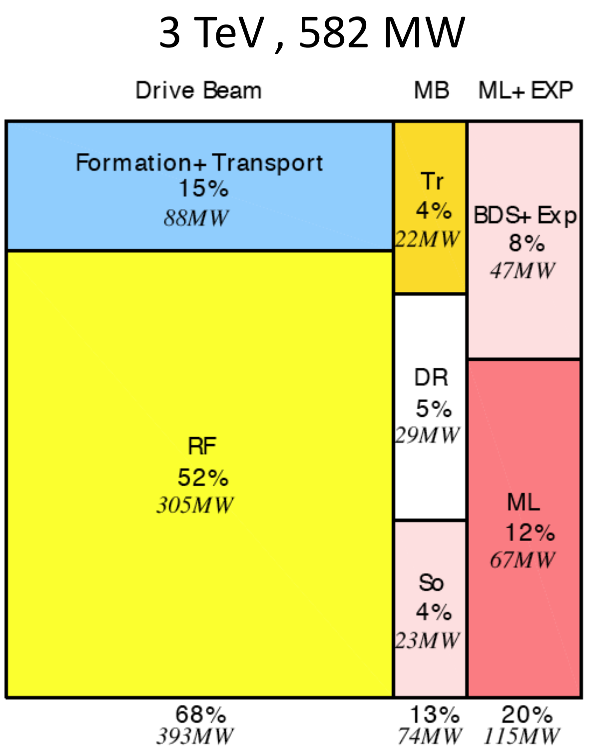


- RF alone will not produce luminosity. Need in addition
  - FM 1GHz→12 GHz + transport
  - MB production, BDS & Experiment
  - Auxiliaries are not marginal, see below
- Overall power efficiency is 5% ← indicator of relative value
- Luminosity/power is better estimator

Power by system at 3 CM-energies



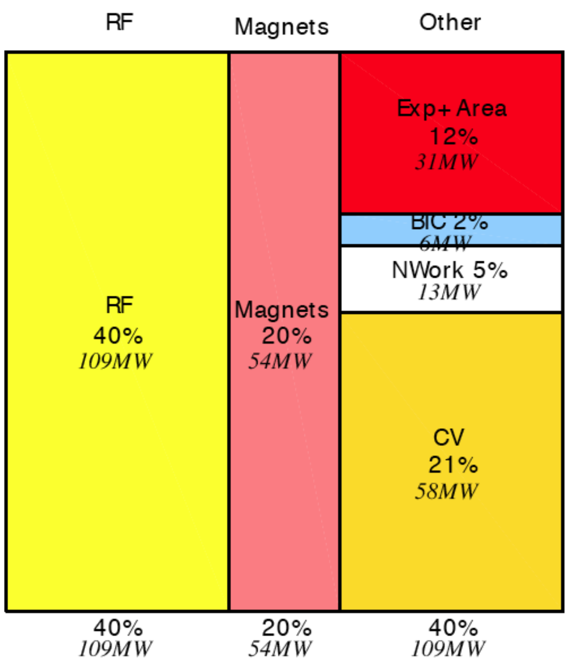




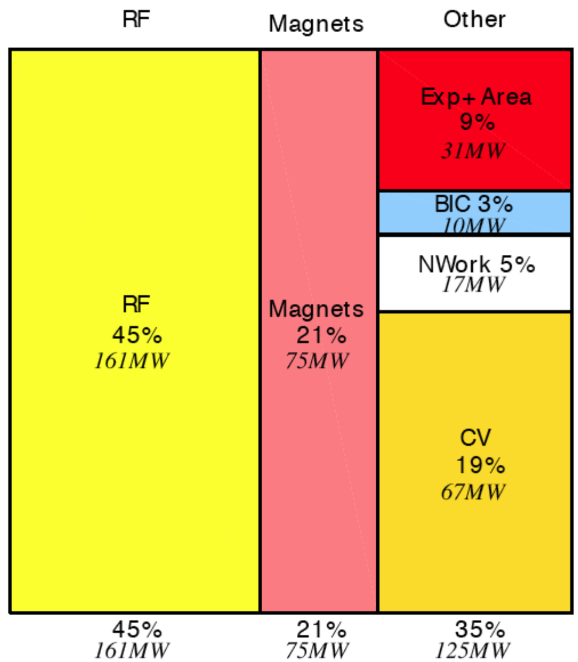
- CLIC is efficient at high CM energy (RF dominated : RF+ML 64% @ 3 TeV, 53% @ 1.5 TeV)
- Optimization effort was put on DB Linac up to now
- 500 GeV : requires further optimization on all other systems (mostly MB production and BDS+Exp)

Power by components

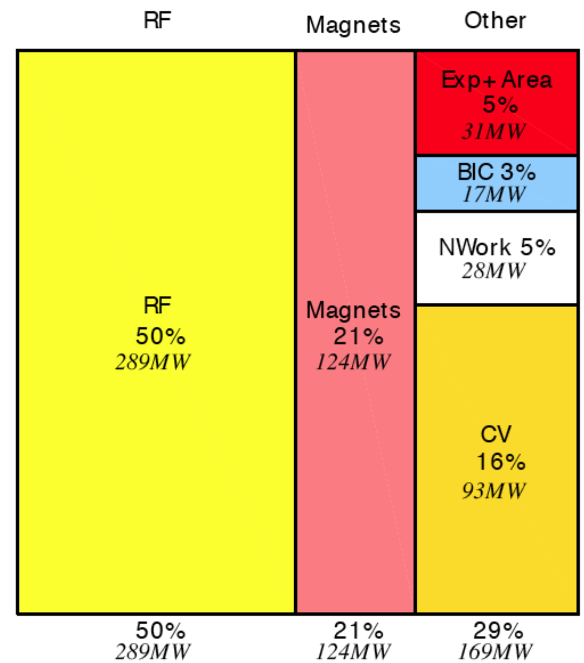
0.5 TeV , 271 MW



1.5 TeV , 361 MW

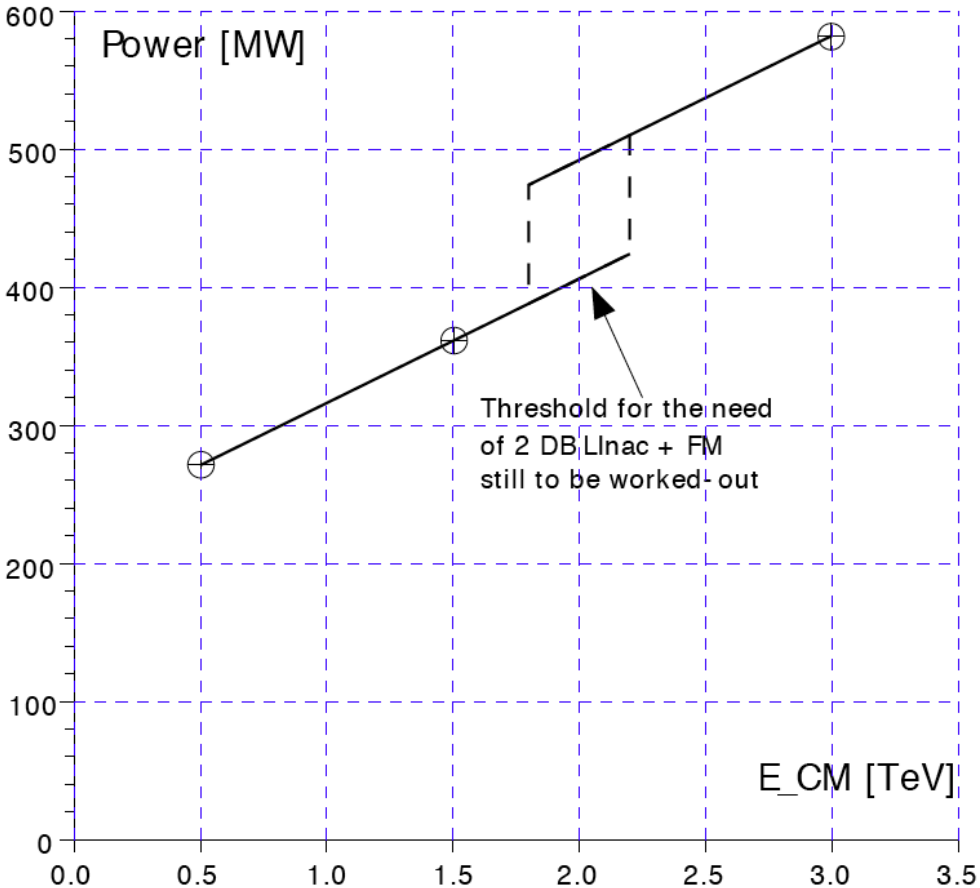


3 TeV , 582 MW



- Large contribution of cooling and ventilation at 500 GeV
  - Mostly related to the large size of the surface beam complex (20 km of beam line vs 10km for the 2 Main Linacs)

Total power consumption = f(E_{CM})



E_{CM} [TeV]	Luminosity 1% [$cm^{-2}s^{-1}$]	P_{MB}/P_{TOT}
0.5	1.40×10^{34}	3.6%
1.5	1.45×10^{34}	3.9%
3.0	2.0×10^{34}	4.8%

- If physics favours E_{CM}>1.5 TeV
  → need to determine the threshold 1→2 DB linac
- Maybe, rework a specific optimized case in the 1.5 TeV range

Mitigation of power budget - I

- RF already optimized/optimistic/challenging (DB modulators and klystrons, Main Linac)
- Magnets : may consider Permanent or Super-conducting/super-ferric
  - But not everywhere (SR issues, too large fields, reduced field quality/tunability)
  - Assume 50% power reduction
- Cooling & ventilation
  - Consider better buildings (air re-circulation, use heated cooling water for heating buildings, etc, …)
  - Expensive but may afford 30% reduction of ventilation power (60 MW at 3 TeV)
- Main beam production ? Detailed studies needed, keep as is.

	0.5 Tev	1.5 TeV	3 TeV
$0.5 \times P_{mag}$	27	37	62
$0.3 \times P_{CV\text{-}air}$	12	14	18
ΔP	39	51	80
$P - \Delta P$	232	310	502
P	271	361	582

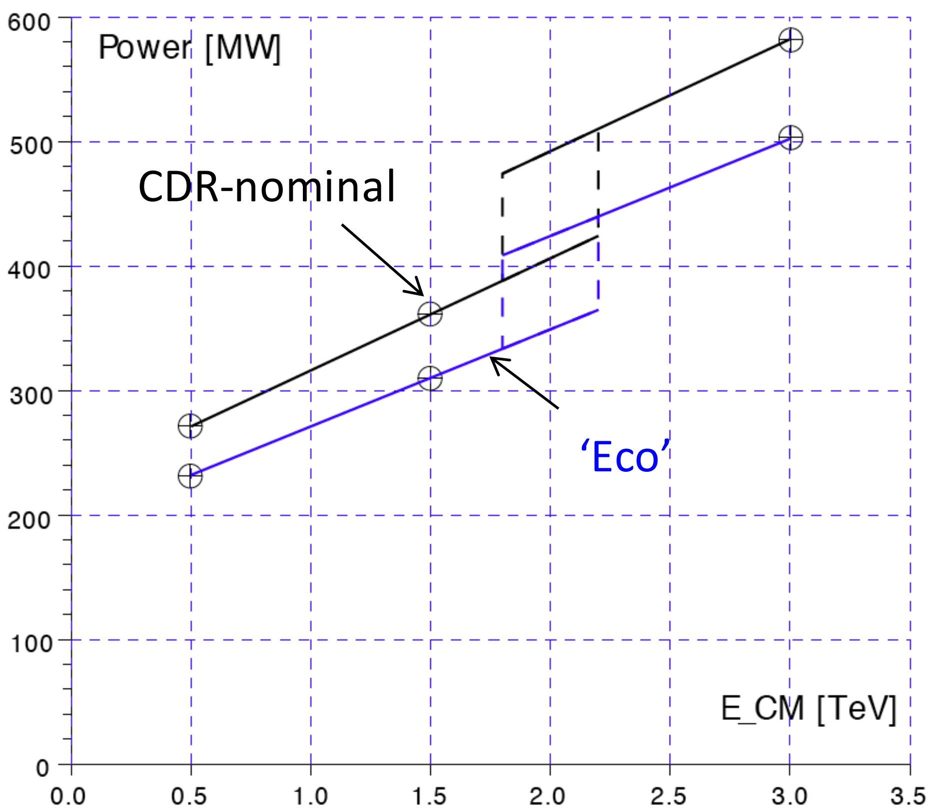
Cannot be 'sold' as is,
ΔP must be balanced with ΔCost
But incentive for further iterations

Energy consumption at 3 TeV

- Consider : programmed stops
  - 90 days of 'winter shut-down'
  - 2 days of short tech stop / 2 weeks + 7 days of tech stop / 2 months → 54 days
  - T = 365 – 90 – 54 = 221 days of operation
  - 20% of down-time because of faults (LHC 2010) : 44 days
  - Remains : beam days / full power : 177

	CDR			*ECONOMY*		
	Power [MW]	Days	Energy [TWh]	*Power [MW]*	*Days*	*Energy [TWh]*
Nominal peak power	582	177	2.47	*500*	*177*	*2.12*
Fault induced down-time	60	44	0.06	*40*	*44*	*0.04*
Programmed stops	60	144	0.21	*40*	*144*	*0.14*
Energy spent /year			2.74			*2.30*

Mitigation of power budget - II



- There is a potential of improvement with power
- But
  - Performance shall not be degraded (magnets)
  - Cost impact may be important
- Cannot be integrated to CDR without further detailed work

Producing part of our energy needs

Physicists encouraged to consider carbon footprint
By e-EPS. Published on 18 October 2011 in News, Physics World

… consider the impact of large scientific facilities – such as ground-based telescopes and particle accelerators, which can often have considerable energy demands – but also the effects on an individual scale. Marshall's research shows that – in the field of astrophysics alone – researchers themselves average 23,000 air miles each year to attend meetings and visit observatories, and use around 130 KWh of extra energy daily, compared to the average US citizen.

Marshall proposes … : future experiments are built to be carbon neutral; …physicists might opt to take part in overseas meetings through video conferencing, rather than flying there in person.

They gave an Exemple …

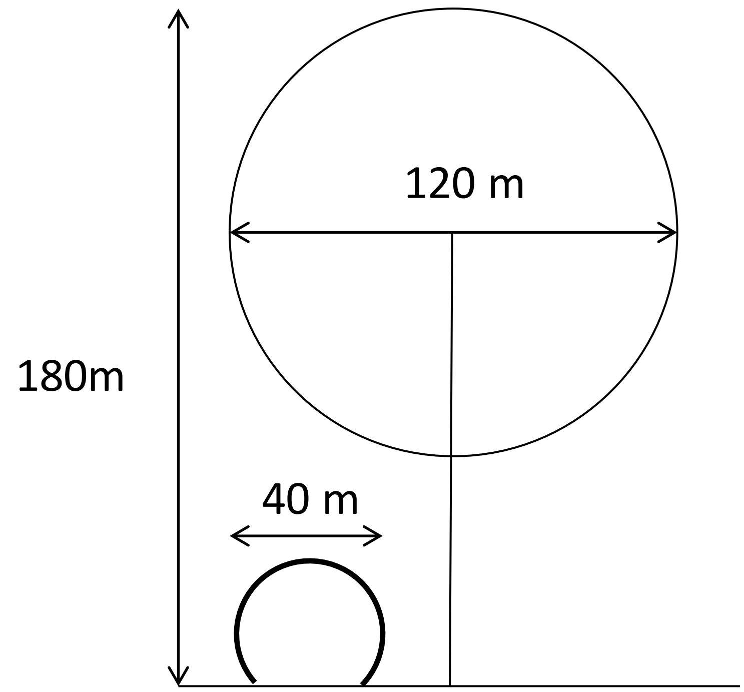
The article comes just before the First Joint Workshop on Energy Management for Large Scale Research Infrastructures, which is being at held in Lund, Sweden on 13-14 this month

CLIC will not escape agressive requests

Eolian energy

- CLIC 3 TeV , P_{nom}=500 MW, E_{year} = 2.3 TWh
- Consider p = 5 MW eolian unit
  - Average capacity factor c = 0.2
  - e_{year} = 8760pc = 0.86e-2 TWh
- N = E_{year}/e_{year} = 270 units

Around CERN ?



Solar energy

- Photovolatic cells on top of the DB Linac building :
  - Surface of the roof : $S = L \times W = 2500 \times 30 = 7.5$ e4 m2
  - $P_{solar,max} \approx 1KW/m^2$ at 12h00 in June
  - $S \times P_{solar,max} = 75$ MW
  - Averaged over year & wheater fluctuations:
    - $p \approx P_{solar,max}/12$
  - Optimistic electric yield : $\eta = 0.3$
- $\langle P_{electric,tot} \rangle = 0.3SP_{solar,max}/12 \approx 2$ MW

→ … Cosmetics …

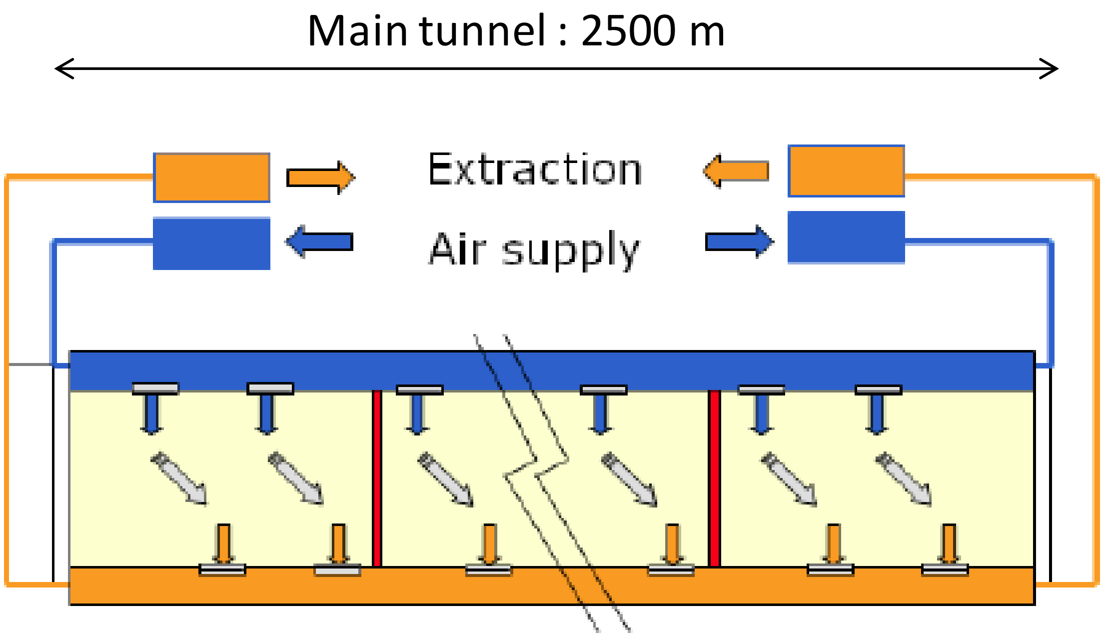
Going further

- RF power already optimized
- Magnets : going beyond 50% reduction ?
- Reduce the ventilation power to ≈ 0
- Reduce the water cooling
- Less magnets

Cool & Vent power, nominal	.5 TEV	1.5 TeV	3 TeV
Water	11	14	23
Chilled water	6	7	10
Air	41	46	60
TOTAL	58	67	93

Ventilation in tunnels

- Scheme imposed by safety issues (smoke extraction)
- Very poor conductance → high power
- Difficult to do better with the present constaints



CERN site : Few surface points allowed – busy area

Another location for CLIC

(CLIC is claimed to be a world-wide project)

- Flat, empty area
  - Allows for any density of surface points
  - May allow for natural ventilation
  - Improve water distribution
  - Rectifiers, electronics, etc : on surface (cooling much more easy)
- Windy and sunny
  - Own clean energy production
- Water nearby

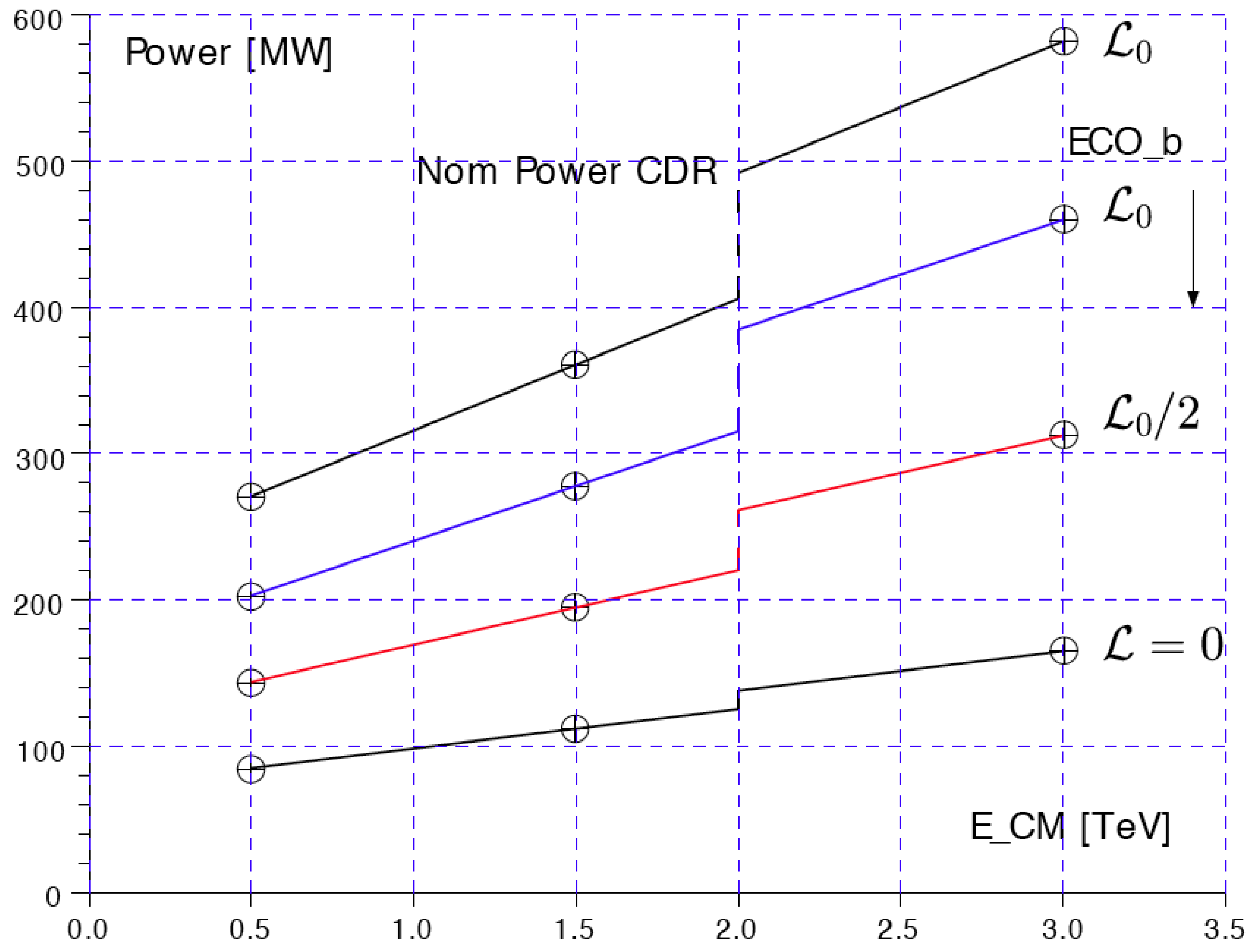
- Empty area - II
  - May reconsider the main beam production
  - One site at each main linac entry
    - No surface loop (1.5 km)
    - No turn-around (2 x 3 km of tunnels)
    - Booster Linac still needed (or combined with ML) ?
- Power economy : CV & beam lines
- As well : cost reduction (less deep, more on surface, optimization of surface complex

‘Eco’-b

- P_{magnet} ↘ 50% like above
- P_{air} = 0
- No change for water, no discount for MB loops

→ Still margin for improvement

A Starting point …



P/2 → L/4

Summary for power

Not 100% precise, a bit rounded

Power [MW]	.5 TeV	1.5 TeV	3 TeV
CDR nominal	270	360	580
Eco – a	230	310	500
Eco - b	200	280	460
Eco - c	180	250	410

Gain : 1/3

Better magnets, bld insulation

New, easier site :

$P_{air} = 0$, 50% P_{magnet}

$P_{air} = 0$, 50 % P_{water} , 70% P_{magnet}
Moving MB prod

- Power become a critical item, like nm, fs, RF modules, cost …
  - Requires more collaboration with Civil.Eng and CV
  - Freedom for the site allows for
    - Option Eco-c
    - Own clean energy production
    - Cost reductions