CLIC-ILC Cost & Schedule Working Group Meeting

TILC09 – Sunday, April 19, 2009

reported by Peter H. Garbincius

CLIC_ILC_phg_21april09.ppt

Program

* Philippe Lebrun: CLIC Cost & Schedule W.G. mandate, organization, & activities 2009
* Philippe Lebrun: Probabilistic Cost Analysis
* Katy Foraz: LHC Scheduling Applied to CLIC & LHC
* Brian Foster: Issues Relating to ILC Governance

Peter Garbincius: Demonstration & Status of Triad's ICET

All: Work toward common CLIC-ILC document on Cost Risk

Also participating: Germana Riddone, Tetsuo Shidara, Jean-Pierre Delahaye, John Carwardine, Emmanuel Tsesmelis, Claude Hauvillier, Louis Rinolfi, Vic Kuchler, Chris Adolphsen

* denotes presentations posted on TILC09 INDICO website

CLIC Cost &Schedule Mandate

- Establish and optimize the **cost** of the CLIC complex at the nominal colliding beam energy of **3 TeV**, as well as that of an optional first phase with a colliding beam energy of **500 GeV**
- Define and optimize the general **schedule** for the 3 TeV and 500 GeV projects defined above
- Estimate the **electrical power consumption** of the 3 TeV and 500 GeV projects defined above
- Identify possible modifications of parameters and/or equipment leading to substantial capital and/or operational cost savings, in order to define **best compromise between performance and cost**
- Develop **collaboration with ILC** project on cost estimate methodology and cost of common or comparable systems, aiming at mutual transparency
- Document the process and conclusions in the **CDR in 2010**

(see posting for Methodology & Activities)

Analytical basis is PBS

level 1		level 2	level 3	level 4	level 5
Beam and Services	Domain	Technical responsible	Sub-domain	System	Component
Main Beam Production					
	1.1 Injectors	L. Rinolfi			
			1.1.1. Thermoionic gun unpolarized e-		
			1.1.2. Primary e- beam linac for e+		
			1.1.3. e-/e+ Target		
			1.1.4. Pre-injector Linac for e+		
			1.1.5. DC gun Polarised e-		
			1.1.6. Pre-injector Linac for e-		
			1.1.7. Injector Linac		
	1.2 Damping Rings	Y. Papaphilippou			
			1.2.1. Pre-damping Ring e+		
			1.2.2. Pre-damping Ring e-		
			1.2.3. Damping Ring e+		
			1.2.4. Damping Ring e-		
	1.3. Beam transport	L. Rinolfi			
			1.3.1. Bunch Compressor #1 e+		
			1.3.2. Bunch Compressor #1 e-		
			1.3.3. Booster Linac		
			1.3.4. Transfer to Tunnel e+		
			1.3.5. Transfer to Tunnel e-		
			1.3.6. Long Transfer Line e+		
			1.3.7. Long Transfer Line e-		
			1.3.8. Turnaround e+		
			1.3.9. Turnaround e-		
			1.3.10. Bunch compressor #2 e+		
			1.3.11. Bunch compressor #2 e-		
Drive Beam Production					
	2.1. Injectors	tbc			
			2.1.1. Linac e+		
			2.1.2. Linac e-		
	2.2. Frequency Multiplication	B. Jeanneret			
			2.2.1. Delay Loop e+		
			2.2.2. Delay Loop e-		
			2.2.3. Combiner Ring #1 e+		
			2.2.4. Combiner Ring #1 e-		
			2.2.5. Combiner Ring #2 e+		
			2.2.6. Combiner Ring #2 e-		
	2.3. Beam transport	B. Jeanneret			
			2.3.1. Transfer to Tunnel e+		
			2.3.2. Transfer to Tunnel e-		
			2.3.3. Long Transfer Line e+		
			2.3.4. Long Transfer Line e-		
			2.3.5. Turnaround and Bunch Compressor e+		
			2.3.6. Turnaround and Bunch Compressor e-		
Two-beam accelerator					
	3.1. Two-beam modules	G. Riddone			
			3.1.1. Two-Beam Modules Type 0 e+		

Coordinators per domain/subdomain

Identified for analytical costing based on level 5 description

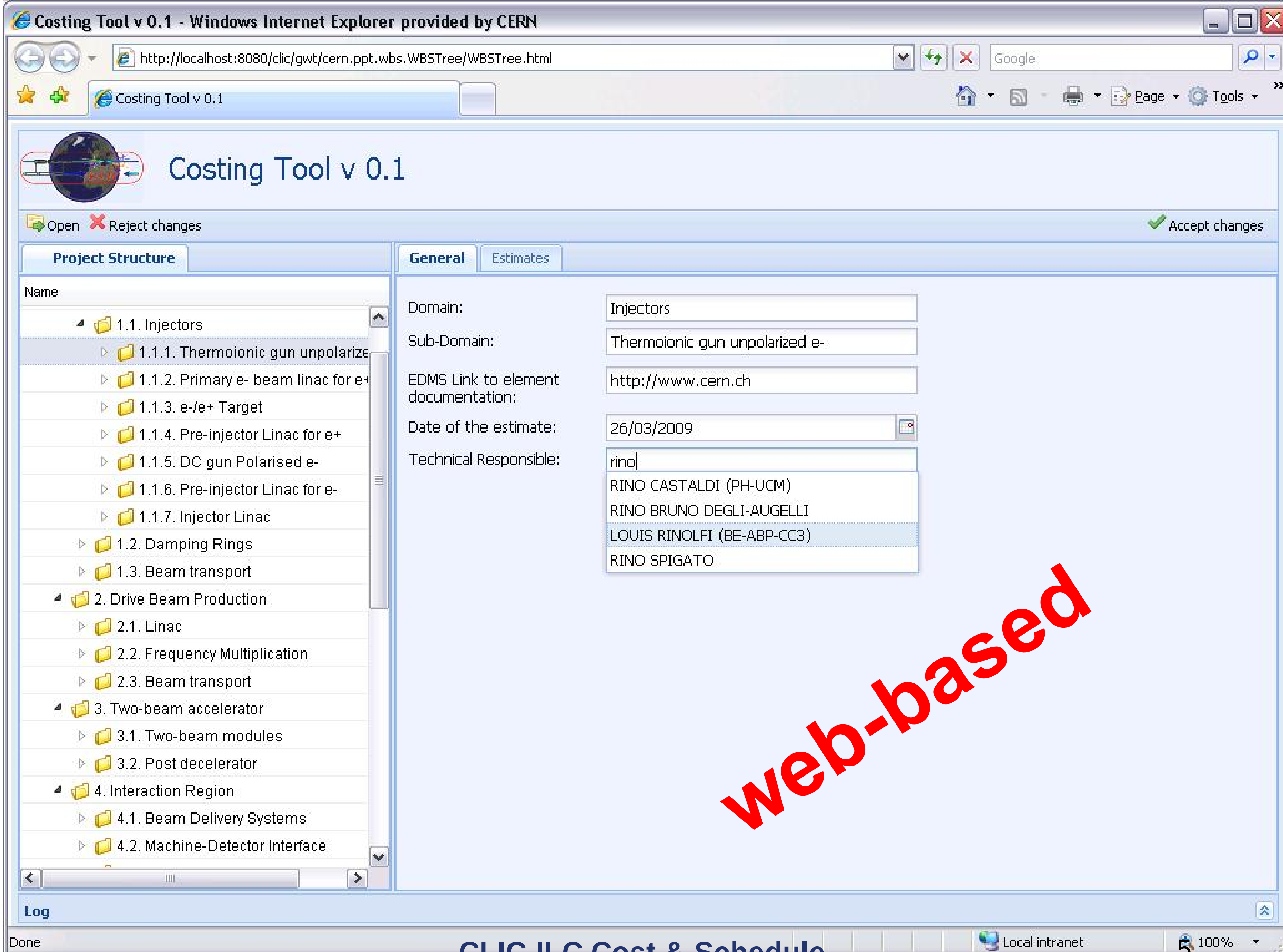
Component level not yet defined

Level 4 system

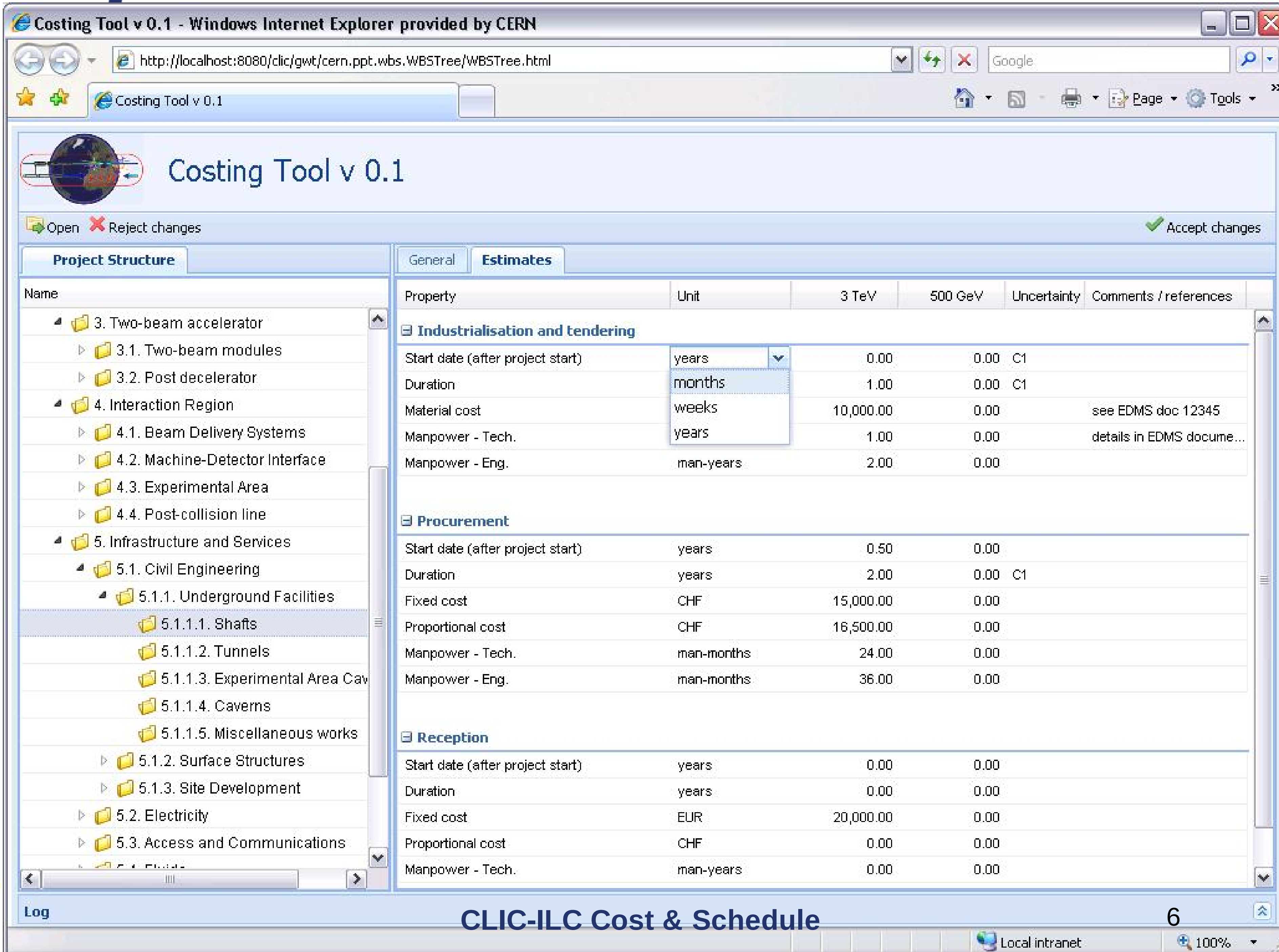
1 RF System
2 RF Powering System
3 Vacuum System
4 Magnet Powering System
5 Magnet System
6 Cooling System
7 Beam Instrumentation System
8 Supporting System
9 Alignment system
10 Kicker system
11 Cryogenic system
12 Laser system
13 Collimation system
14 Stabilisation System
15 Absorbers
16 Damping system
17 Electron Gun
18 RF deflectors
19 Installation
20 Commissioning

List of systems standardized

Contact experts per system


Costing Tool v 0.1 - Windows Internet Explorer provided by CERN
http://localhost:8080/clic/gwt/cern.ppt.wbs.WBSTree/WBSTree.html
Costing Tool v 0.1
Open
Reject changes
Accept changes
Project Structure
Name
1.1. Injectors
1.1.1. Thermoionic gun unpolarize
1.1.2. Primary e- beam linac for e+
1.1.3. e-/e+ Target
1.1.4. Pre-injector Linac for e+
1.1.5. DC gun Polarised e-
1.1.6. Pre-injector Linac for e-
1.1.7. Injector Linac
1.2. Damping Rings
1.3. Beam transport
2. Drive Beam Production
2.1. Linac
2.2. Frequency Multiplication
2.3. Beam transport
3. Two-beam accelerator
3.1. Two-beam modules
3.2. Post decelerator
4. Interaction Region
4.1. Beam Delivery Systems
4.2. Machine-Detector Interface
General
Estimates
Domain: Injectors
Sub-Domain: Thermoionic gun unpolarized e-
EDMS Link to element documentation: http://www.cern.ch
Date of the estimate: 26/03/2009
Technical Responsible: rino
RINO CASTALDI (PH-UCM)
RINO BRUNO DEGLI-AUGELLI
LOUIS RINOLFI (BE-ABP-CC3)
RINO SPIGATO
Log
Done
Local intranet
100%

web-based


Costing Tool v 0.1 - Windows Internet Explorer provided by CERN
http://localhost:8080/clic/gwt/cern.ppt.wbs.WBSTree/WBSTree.html
Costing Tool v 0.1
Open
Reject changes
Accept changes
Project Structure
General
Estimates
Name
3. Two-beam accelerator
3.1. Two-beam modules
3.2. Post decelerator
4. Interaction Region
4.1. Beam Delivery Systems
4.2. Machine-Detector Interface
4.3. Experimental Area
4.4. Post-collision line
5. Infrastructure and Services
5.1. Civil Engineering
5.1.1. Underground Facilities
5.1.1.1. Shafts
5.1.1.2. Tunnels
5.1.1.3. Experimental Area Cav
5.1.1.4. Caverns
5.1.1.5. Miscellaneous works
5.1.2. Surface Structures
5.1.3. Site Development
5.2. Electricity
5.3. Access and Communications
Property
Unit
3 TeV
500 GeV
Uncertainty
Comments / references
Industrialisation and tendering
Start date (after project start) years 0.00 0.00 C1
months
weeks
years
Duration 1.00 0.00 C1
Material cost 10,000.00 0.00 see EDMS doc 12345
Manpower - Tech. 1.00 0.00 details in EDMS docume...
Manpower - Eng. man-years 2.00 0.00
Procurement
Start date (after project start) years 0.50 0.00
Duration years 2.00 0.00 C1
Fixed cost CHF 15,000.00 0.00
Proportional cost CHF 16,500.00 0.00
Manpower - Tech. man-months 24.00 0.00
Manpower - Eng. man-months 36.00 0.00
Reception
Start date (after project start) years 0.00 0.00
Duration years 0.00 0.00
Fixed cost EUR 20,000.00 0.00
Proportional cost CHF 0.00 0.00
Manpower - Tech. man-years 0.00 0.00
Log
Local intranet
100%

Cost variance analysis => Probabilistic approach depends on ***correlations*** between estimated items

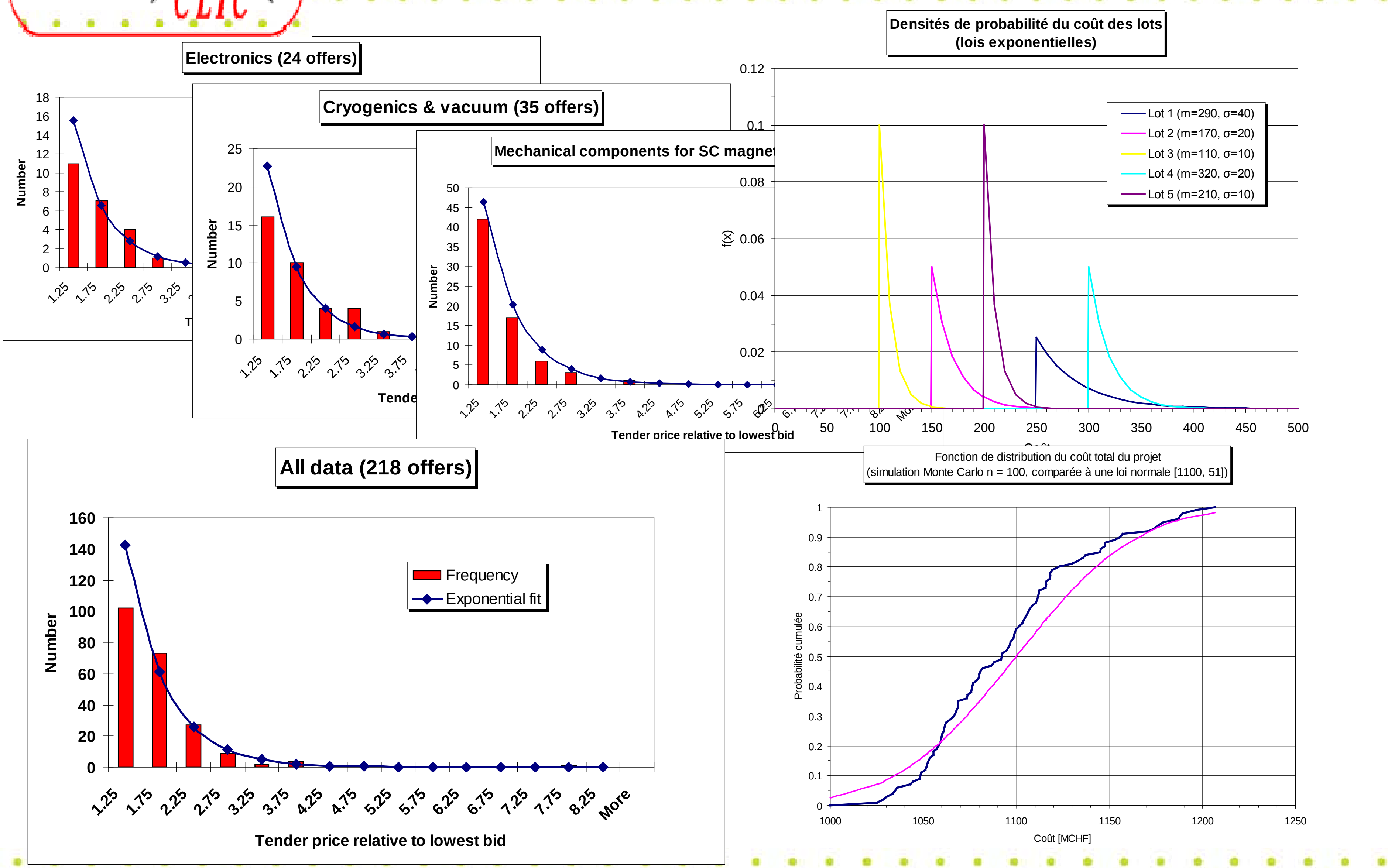
Cost variance factor	Evolution of configuration	Technical risk in execution	Evolution of market	Commercial strategy of vendor	Industrial price index	Exchange rates, taxes, custom duties
Lot 1						
Lot 2						
Lot 3						
...						
Lot N						
Total						

Not addressed here (Evolution of configuration)

Coped for in tender price variance (Technical risk in execution; Evolution of market; Commercial strategy of vendor)

Deterministic & compensated, not addressed here (Industrial price index; Exchange rates, taxes, custom duties)

LHC experience on tenders

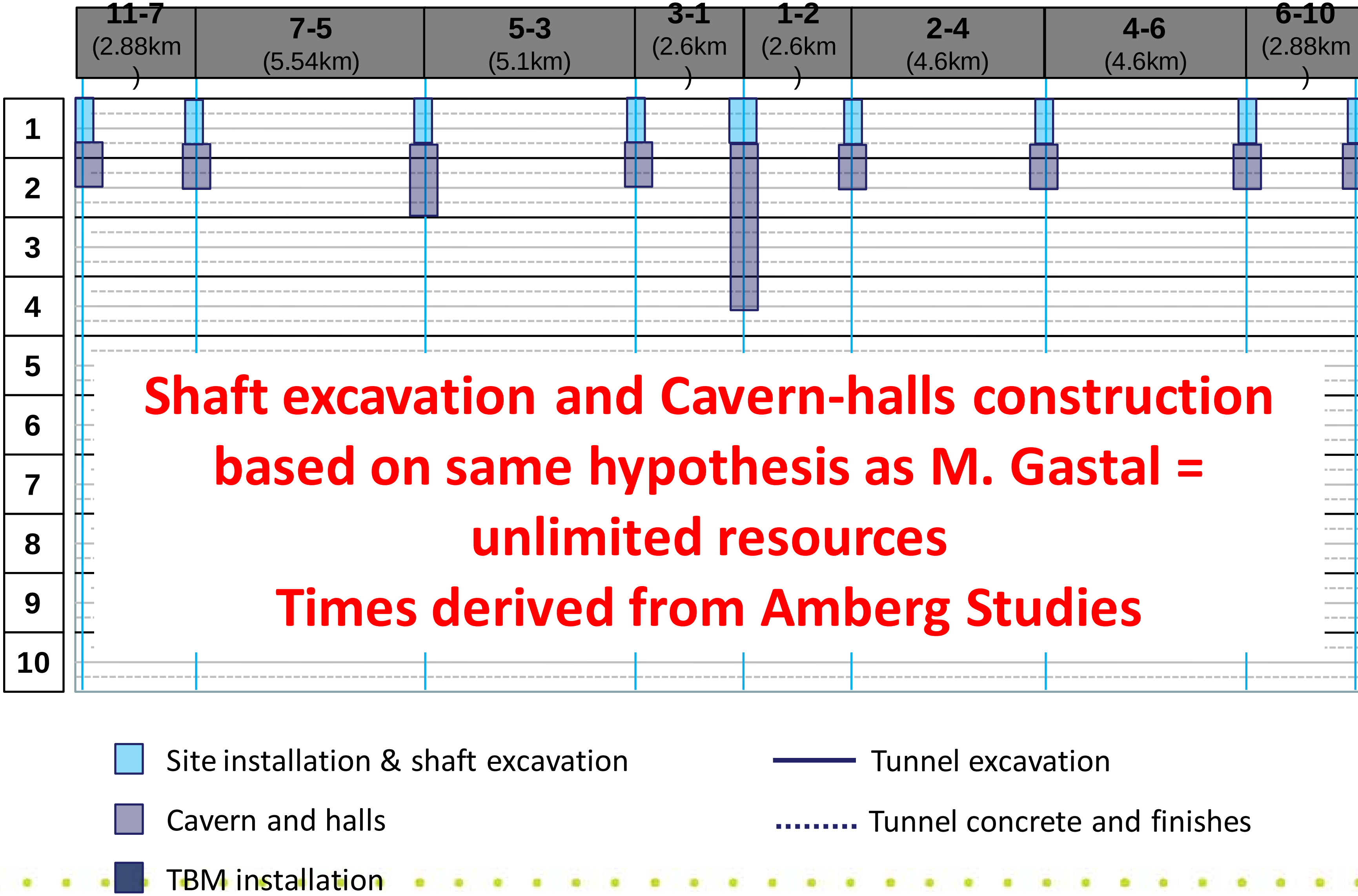


Conclusion: proposed procedure for probabilistic cost analysis

- Identify sources of cost variance and separate deterministic effects
- Identify correlated random effects and estimate their standard deviations (not to be added quadratically!)
- Estimate mean value and standard deviation of independant elementary costs and modelize by simple skew law, e.g. exponential
- Apply central-limit theorem and/or Monte-Carlo on sum of independant elementary costs
- Apply uncertainty due to correlated random effects on previous result
- Apply compensation of deterministic effects by established factors (e.g. currency exchange rates & industrial price indices)

vital question: what items are or what fraction is correlated?

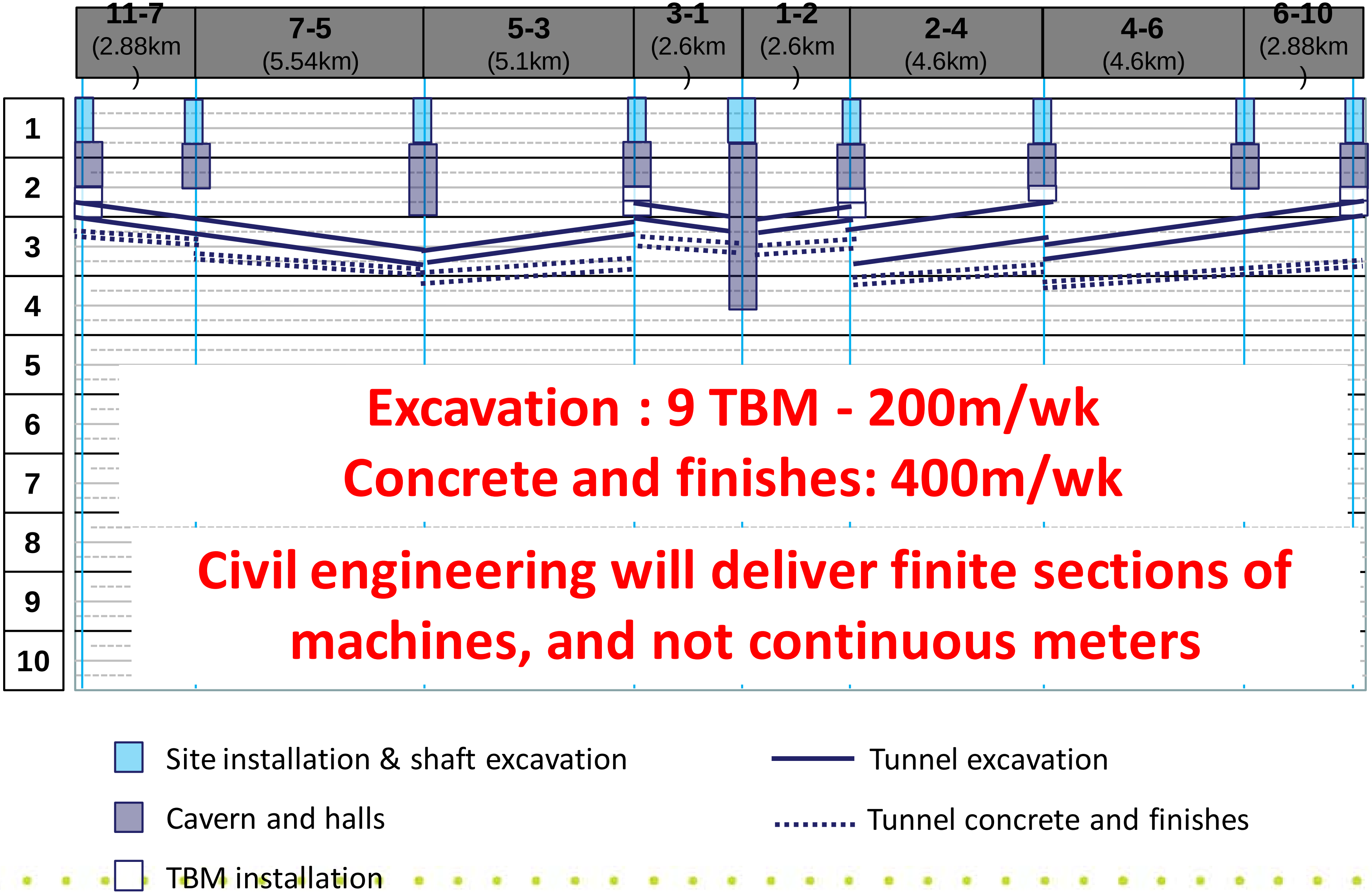
ILC - Civil engineering works



Shaft excavation and Cavern-halls construction based on same hypothesis as M. Gastal = unlimited resources

Times derived from Amberg Studies

ILC - Civil engineering works

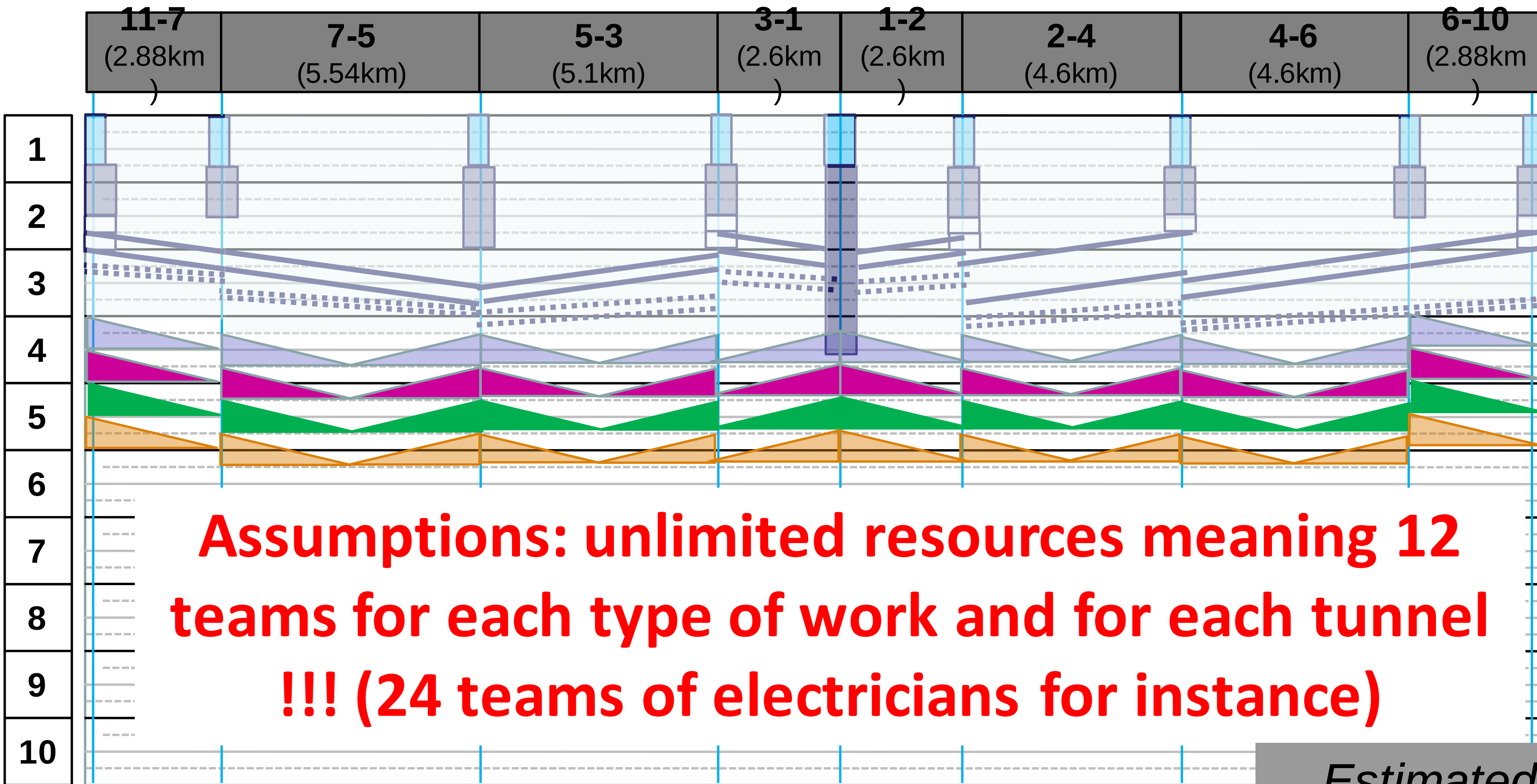


Excavation : 9 TBM - 200m/wk

Concrete and finishes: 400m/wk

Civil engineering will deliver finite sections of machines, and not continuous meters

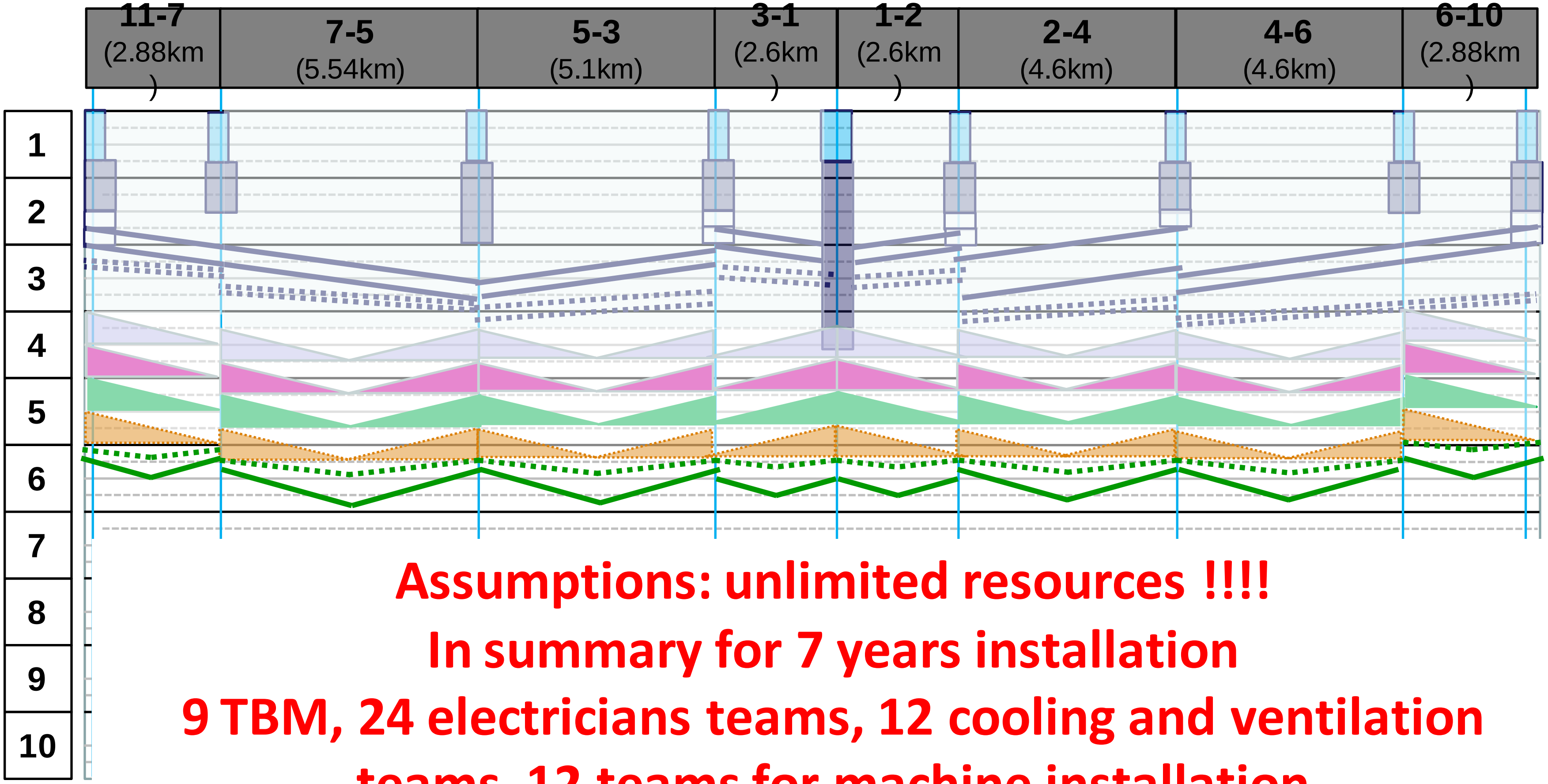
ILC - General Services



- Survey : geodesics & marking positions
- Electrical general services
- Piping & ventilation
- Cabling

Estimated progress rate per team: around 120m/wks

ILC - Machine installation



Assumptions: unlimited resources !!!!

In summary for 7 years installation

9 TBM, 24 electricians teams, 12 cooling and ventilation teams, 12 teams for machine installation

Support installation and alignment (250m/wk)

Machine inst.: transport and interconnections (progress rate to be confirmed 100m/wk)

maybe more realistic: 4 TBM, 8 elec, 4 hvac, 2 mach inst => 8.5 yrs

Questions of Order of Construction Relation to Commissioning Plan

- How to optimize commissioning – earliest dates?

  Electron source, Auxiliary positron source, DRs
- Need entire Main Linac tunnel completed and people excluded to bring beam to far end to study RTML transport, turn-around, bunch compressors and to start beam @ low energy end of Main Linac
- Do you concentrate on 1 ML early or both later?
- Personnel exclusion during RF (cryo?) testing
- Need ILC plan - learn from LHC experience!

ICET – WBS Configuration File.xls

sets links

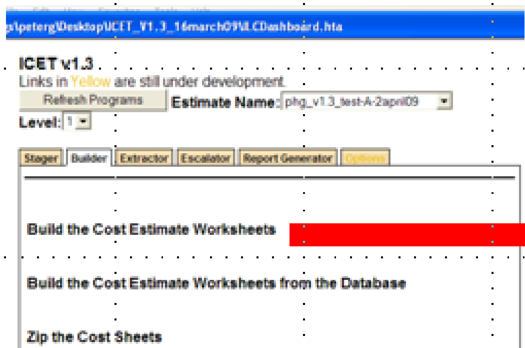
“atomic” parts

Part	WBS	Description	Workbook	Worksheet	Quantity
	1	TEC - test Construction format	TopLevel.xls	Level_1	1
	1.1	Construction - Americas Region	TopLevel.xls	Construction	1
	1.1.1	Civil Construction	Construction.xls	Civil	1
	1.1.1.1	Engineering, study work, documenation	Civil.xls	Civil_Eng	1
	1.1.1.1.1	In-house Engineering	Civil_Eng.xls	In-house	1
p	1.1.1.1.1.1	Electron Source	in-house.xls	Electron_Source	1
p	1.1.1.1.1.2	Positron Source	in-house.xls	Positron_Source	1
p	1.1.1.1.1.3	Damping Rings	in-house.xls	Damping_Rings	1
p	1.1.1.1.1.4	RTML	in-house.xls	RTML	1
p	1.1.1.1.1.5	Main Linac	in-house.xls	Main_Linac	1
p	1.1.1.1.1.6	BDS	in-house.xls	BDS	1
p	1.1.1.1.1.7	Experimental Area	in-house.xls	Exp_Area	1
p	1.1.1.1.1.8	Common	in-house.xls	Common	1
	1.1.1.1.2	Outsourced Consultancy	Civil_Eng.xls	Consultancy	1
p	1.1.1.1.2.1	Electron Source	consultancy.xls	Electron_Source	2
p	1.1.1.1.2.2	Positron Source	consultancy.xls	Positron_Source	2
p	1.1.1.1.2.3	Damping Rings	consultancy.xls	Damping_Rings	2
p	1.1.1.1.2.4	RTML	consultancy.xls	RTML	2
p	1.1.1.1.2.5	Main Linac	consultancy.xls	Main_Linac	2
p	1.1.1.1.2.6	BDS	consultancy.xls	BDS	2
p	1.1.1.1.2.7	Experimental Area	consultancy.xls	Exp_Area	2
p	1.1.1.1.2.8	Common	consultancy.xls	Common	2
	1.1.1.2	Underground Facilities	Civil.xls	Underground	1
	1.1.1.2.1	Shafts	Underground.xls	Shafts	1
	1.1.1.2.1.1	Electron_Source	Shafts.xls	Electron_Source	1
p	1.1.1.2.1.1.1	electron shaft part			1
	1.1.1.2.1.2	Positron_Source	Shafts.xls	Positron_Source	1
p	1.1.1.2.1.2.1	positron shaft part			1
	1.1.1.2.1.3	Damping_Rings	Shafts.xls	Damping_Rings	1
p	1.1.1.2.1.3.1	dr shaft part			1
	1.1.1.2.1.4	RTML	Shafts.xls	RTML	1
p	1.1.1.2.1.4.1	rtml shaft part			1
	1.1.1.2.1.5	Main_Linac	Shafts.xls	Main_Linac	1
p	1.1.1.2.1.5.1	ml shaft part			1
	1.1.1.2.1.6	BDS	Shafts.xls	BDS	1
p	1.1.1.2.1.6.1	bds shaft part			1
	1.1.1.2.1.7	Exp_Facilities	Shafts.xls	Exp_Facilities	1
p	1.1.1.2.1.7.1	exp shaft part			1

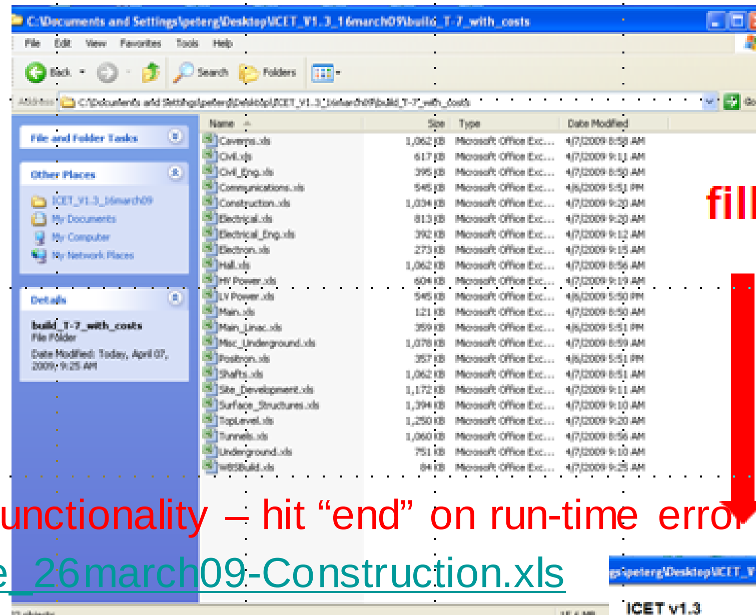
under test…
dummy data

WBS Configuration File: **ILC WBS v3.3 truncated.xls**

BUILD



(blank) Estimating_Module.xls workbooks

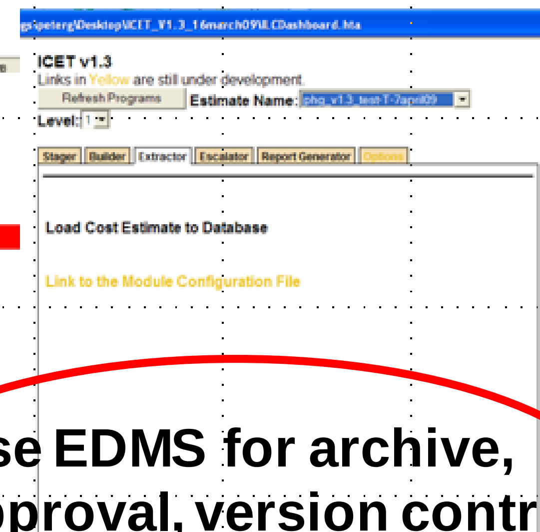


fill by hand

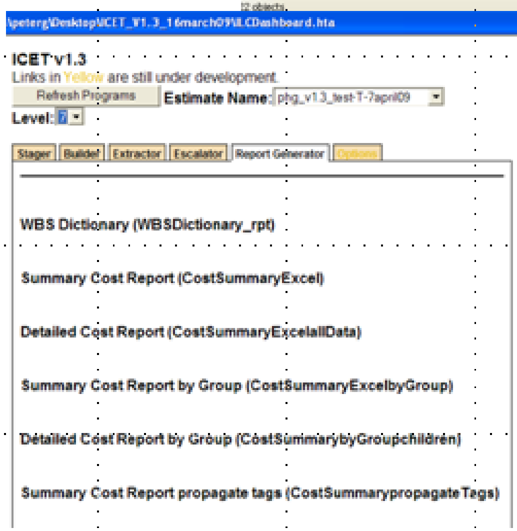
Try the below link to a filled-in Cost Estimating Module Excel file

Be sure to enable macros for full functionality – hit “end” on run-time error

http://www-ilcdcb.fnal.gov/example_26march09-Construction.xls



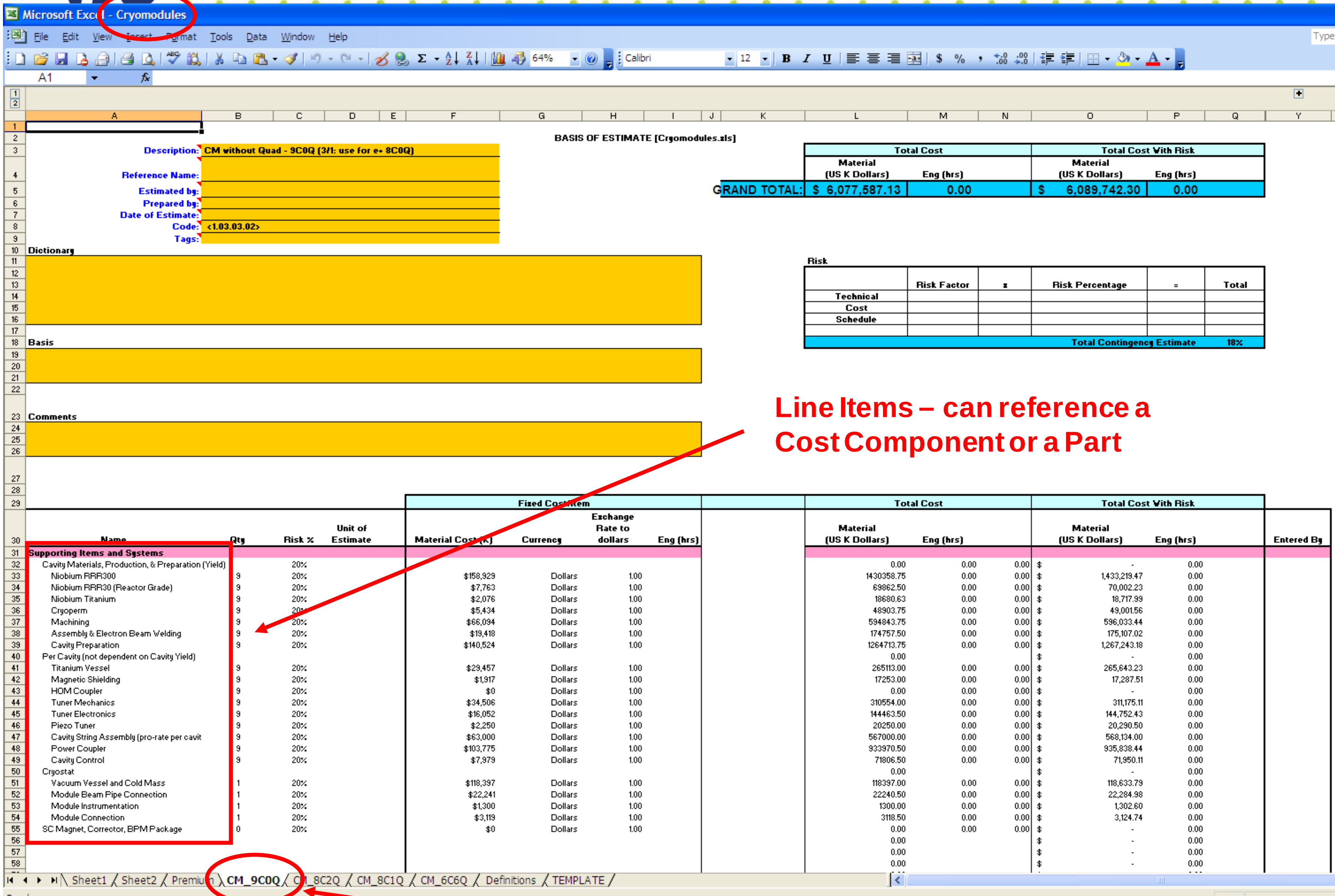
EXTRACT to DB



Generate EXCEL Reports

Use EDMS for archive, approval, version control
current Triad emphasis

Cost Estimate Module example



Microsoft Excel - Cryomodules

BASIS OF ESTIMATE [Cryomodules.xls]

Description:	CM without Quad - 9C0Q (3/1: use for e+ 8C0Q)
Reference Name:	
Estimated by:	
Prepared by:	
Date of Estimate:	
Code:	<1.03.03.02>
Tags:	

Dictionary

Basis

Comments

	Total Cost		Total Cost With Risk	
	Material (US K Dollars)	Eng (hrs)	Material (US K Dollars)	Eng (hrs)
GRAND TOTAL:	$ 6,077,587.13	0.00	$ 6,089,742.30	0.00

Risk

	Risk Factor	x	Risk Percentage	=	Total
Technical					
Cost					
Schedule					
			Total Contingency Estimate		18%

Name	Qty	Risk %	Unit of Estimate	Fixed Cost Item: Material Cost (K)	Currency	Exchange Rate to dollars	Eng (hrs)	Total Cost: Material (US K Dollars)	Total Cost: Eng (hrs)		Total Cost With Risk: Material (US K Dollars)	Total Cost With Risk: Eng (hrs)	Entered By
Supporting Items and Systems													
Cavity Materials, Production, & Preparation (Yield)		20%						0.00	0.00	0.00	$ -	0.00	
Niobium RRR300	9	20%		$158,929	Dollars	1.00		1430358.75	0.00	0.00	$ 1,433,219.47	0.00	
Niobium RRR30 (Reactor Grade)	9	20%		$7,763	Dollars	1.00		69862.50	0.00	0.00	$ 70,002.23	0.00	
Niobium Titanium	9	20%		$2,076	Dollars	1.00		18680.63	0.00	0.00	$ 18,717.99	0.00	
Cryoperm	9	20%		$5,434	Dollars	1.00		48903.75	0.00	0.00	$ 49,001.56	0.00	
Machining	9	20%		$66,094	Dollars	1.00		594843.75	0.00	0.00	$ 596,033.44	0.00	
Assembly & Electron Beam Welding	9	20%		$19,418	Dollars	1.00		174757.50	0.00	0.00	$ 175,107.02	0.00	
Cavity Preparation	9	20%		$140,524	Dollars	1.00		1264713.75	0.00	0.00	$ 1,267,243.18	0.00	
Per Cavity (not dependent on Cavity Yield)								0.00			$ -	0.00	
Titanium Vessel	9	20%		$29,457	Dollars	1.00		265113.00	0.00	0.00	$ 265,643.23	0.00	
Magnetic Shielding	9	20%		$1,917	Dollars	1.00		17253.00	0.00	0.00	$ 17,287.51	0.00	
HOM Coupler	9	20%		$0	Dollars	1.00		0.00	0.00	0.00	$ -	0.00	
Tuner Mechanics	9	20%		$34,506	Dollars	1.00		310554.00	0.00	0.00	$ 311,175.11	0.00	
Tuner Electronics	9	20%		$16,052	Dollars	1.00		144463.50	0.00	0.00	$ 144,752.43	0.00	
Piezo Tuner	9	20%		$2,250	Dollars	1.00		20250.00	0.00	0.00	$ 20,290.50	0.00	
Cavity String Assembly (pro-rate per cavit	9	20%		$63,000	Dollars	1.00		567000.00	0.00	0.00	$ 568,134.00	0.00	
Power Coupler	9	20%		$103,775	Dollars	1.00		933970.50	0.00	0.00	$ 935,838.44	0.00	
Cavity Control	9	20%		$7,979	Dollars	1.00		71806.50	0.00	0.00	$ 71,950.11	0.00	
Cryostat								0.00			$ -	0.00	
Vacuum Vessel and Cold Mass	1	20%		$118,397	Dollars	1.00		118397.00	0.00	0.00	$ 118,633.79	0.00	
Module Beam Pipe Connection	1	20%		$22,241	Dollars	1.00		22240.50	0.00	0.00	$ 22,284.98	0.00	
Module Instrumentation	1	20%		$1,300	Dollars	1.00		1300.00	0.00	0.00	$ 1,302.60	0.00	
Module Connection	1	20%		$3,119	Dollars	1.00		3118.50	0.00	0.00	$ 3,124.74	0.00	
SC Magnet, Corrector, BPM Package	0	20%		$0	Dollars	1.00		0.00	0.00	0.00	$ -	0.00	

Sheet1 / Sheet2 / Premium / CM_9C0Q / CM_8C2Q / CM_8C1Q / CM_6C6Q / Definitions / TEMPLATE

Ready

Line Items – can reference a Cost Component or a Part

Cost Component sheet for a specific cryomodule type

Example of Report – studying tags

atomic parts

Common parts from Cryomodules.xls

WBS	Description	Materials (U:	Qty	Region	Area	Tech & Global Sys
1.02	**Electron Source**	33,192	1	0	Electron Source	
1.02.01	electrons	33,192	1	0		
1.02.01.01	electron part 1	8,192	1	8192	Electron Source	Dumps & Collimators
1.02.01.02	electron part 2	0	1	0	Electron Source	Magnets & Power Supplie
1.02.01.03	8C1Q	5,000	5	0	Electron Source	Cryomodules
1.02.01.03.01	costs for 8C1Q	1,000	1	1000		Cryomodules
1.02.01.04	9C0Q	20,000	10	0	Electron Source	Cryomodules
1.02.01.04.01	costs for 9C0Q	2,000	1	2000		Cryomodules
1.03	**Positron Source**	50,000	1	0	Positron Source	
1.03.01	positrons	50,000	1	0		
1.03.01.01	a pot full of positron parts	0	1	0	Positron Source	Vacuum System
1.03.01.02	8C1Q	10,000	10	0	Positron Source	Cryomodules
1.03.01.02.01	costs for 8C1Q	1,000	1	1000		Cryomodules
1.03.01.03	9C0Q	40,000	20	0	Positron Source	Cryomodules
1.03.01.03.01	costs for 9C0Q	2,000	1	2000		Cryomodules
1.04	Damping Rings	0	1	0	Damping Rings	
1.04.01	rings	0	1	0	Damping Rings	
1.05	RTML	0	1	0	RTML	
1.05.01	turn-arounds	0	1	0	RTML	Construction (Conv. Facili
1.06	**Main Linac**	2,500,000	1	0	Main Linac	
1.06.01	Linacs	2,500,000	1	0		
1.06.01.01	linac item 1	0	1	0	Main Linac	Cryogenics
1.06.01.02	linac item 2	0	1	0	Main Linac	RF Power System
1.06.01.03	8C1Q	500,000	500	0	Main Linac	Cryomodules
1.06.01.03.01	costs for 8C1Q	1,000	1	1000		Cryomodules
1.06.01.04	9C0Q	2,000,000	1000	0	Main Linac	Cryomodules
1.06.01.04.01	costs for 9C0Q	2,000	1	2000		Cryomodules
1.07	Beam Delivery System	0	1	0	Beam Delivery System	
1.07.01	deliveries	0	1	0	Beam Delivery System	Cryogenics
1.08	Experimental Facilities	0	1	0	Experimental Facilities	
1.08.01	experiments	0	1	0	Experimental Facilities	Installation
1.09	Common	0	1	0	Common	
1.09.01	commonalities	0	1	0	Common	Phase & Timing (?)

under test … dummy data

our common plans - *11/08*:

- √ CLIC-ILC Cost & Schedule Working Group WEBEX Meetings
  1400 GMT - 2nd Thursday of each month
- √ Keep work towards cost estimate mutually transparent
- √ Profit by synergies
- √ Understand and communicate unavoidable differences in the methodologies used for the two projects
- √ Construction & installation schedules for CLIC & ILC w same methodology – 6/09
- Common ILC/CLIC notes (for mid '09)
  - Tunnel safety underground compliance
    defer to: Fabio Corsenego - ILC-CFS and CLIC-CES groups
  - Standardization methods to estimate cost of warm magnets including cabling and power supplies – Braun & Garbincius gathering materials, but international magnet fabrication experts ***– are just not available! - defer***
  - Description of cost risk assessment – Lebrun, Riddone, Lehner, Garbincius ***reviewed other applications, started outlining this mgt – outline soon!***

Backup slides

Methodology

- Establish rules & practices for cost estimation
  - **Analytical based on PBS at system/component level per subdomain**
  - **Synthetic estimators when detailed PBS not available**
  - **Key actors are PBS domain/subdomain coordinators**
  - **Address system experts through corresponding group leaders**
  - **Currency conversion & price escalation**
  - **Use of cost software tool**
- Identify major cost drivers & impact of alternative solutions and technological breakthroughs
- Whenever possible, define a parametric model for estimating variation of cost upon main technical parameters
- Identify sources of variance & conduct cost risk analyses
- Organize, maintain & update documentation with restricted access
- Report periodically to CLIC Steering Committee

Activities 2009

- Reception specified cost tool, including currency conversion & price escalation procedures, and start applying it
- Establish responsibilities, procedures & workpackages in cost assessment
- Identify domains of analytical costing and perform estimates
- Identify areas of potential cost reduction and perform studies
- Conduct proper technical/cost scaling of first phase at 500 GeV
- Refine general schedule and derive manufacturing/reception testing/installation constraints
- Update estimates of power & energy consumption, including part load operation
- Collaborate with ILC on previously defined cost topics
  - **Cost risk analysis**
  - **Cost of normal conducting magnets**
- …

e.g. PBS to level 4 & cost coordinators

		0.1	Cost coordinator
level 0	level 1	level 2	level 3
Project	**Beam and Services**	**Area**	**Sub-area**
CLIC			
	Main Beam		
		Injectors	H. Braun
			Thermoionic gun unpolarized e-
			Primary beam linac for e-
			e-/e+ target
			Pre-injector linac for e+
			DC gun Polarised e-
			Pre-injector linac for e-
			Injector linac
		Damping Rings	H. Braun
			Pre-damping Ring e+
			Pre-damping Ring e-
			Damping Ring e+
			Damping Ring e-
		Beam transport	B. Jeanneret
			Bunch compressor #1 e+

Level 4 systems	Experts
rf system	W. Wuensch
rf powering system	G. McMonagle
collimation system	R. Assmann
vacuum system	P. Strubin
magnet system	D. Tommasini, T. Zickler
powering system	TBD
cooling system	G. Riddone
beam instrumentation	T. Lefevre, H. Schmickler
supporting system	G. Riddone
stabilisation system	C. Hauviller
alignment system	H. Mainaud-Durand, JP. Quesnel
target system	K. Elsener

PBS comparison

level 0	level 1	level 2
Project	Beam and Services	Area
CLIC		
	Main Beam	
		Injectors
		Damping Rings
		Beam transport
		Linac Accelerators
		Beam Delivery Systems
		Post-collision line
	Drive Beam	
		Injectors
		Frequency multiplication
		Beam transport
		Linac Decelerator
		Dumps
	Interaction Region	
		Machine-Detector Interface
		Experimental Area
	CE and Services	
		Civil Engineering
		Electricity
		Access and Communications
		Fluids
		Transport / installation
		Safety
		Survey

1	TEC
1.01	Management
1.02	Conventional Construction
1.03	Electron Source
1.04	Positron Source
1.05	Damping Rings
1.06	Ring To Main Linac
1.07	Main Linac
1.08	Beam Delivery System
1.09	Experimental Systems
1.10	Global Systems
1.11	Common

Basis of probabilistic cost analysis

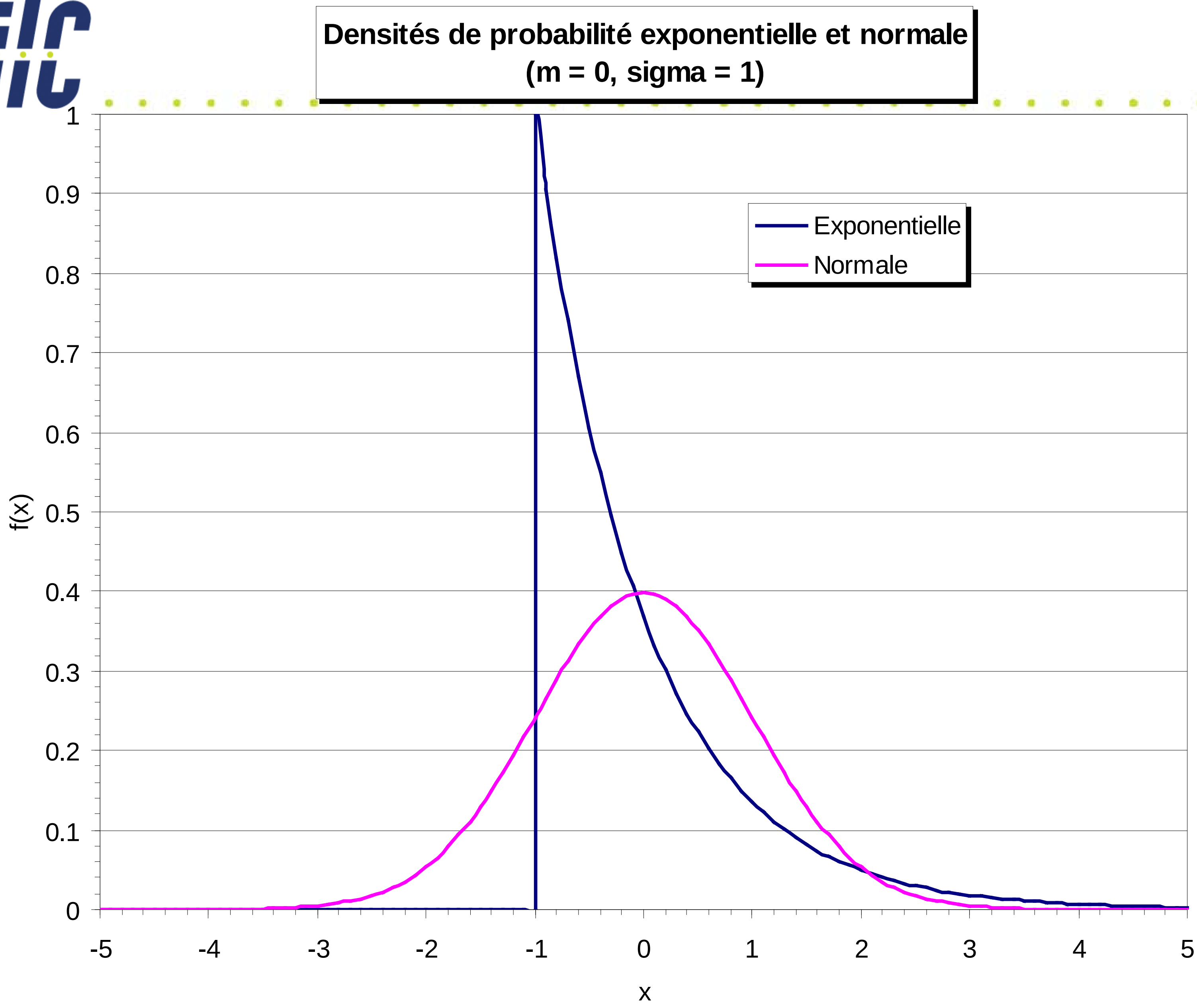
- Following the PBS, the project is split in i lots, the cost of which are random variables X_i with
  - **mean value m_i**
  - **standard deviation σ_i**
- The total cost of the project is a random variable $X = \Sigma X_i$
  - **with mean value $m = \Sigma m_i$**
- In the case when the X_i are statistically independant, $X = \Sigma X_i$ is characterized by
  - **standard deviation $\sigma = (\Sigma \sigma_i^2)^{1/2}$**
  - **probability density function (PDF) asymptotically tending to Gaussian (central-limit theorem)**
- Statistical independance or correlations between X_i is more important to probabilistic analysis of total cost, than detailed knowledge of the specific PDFs of X_i

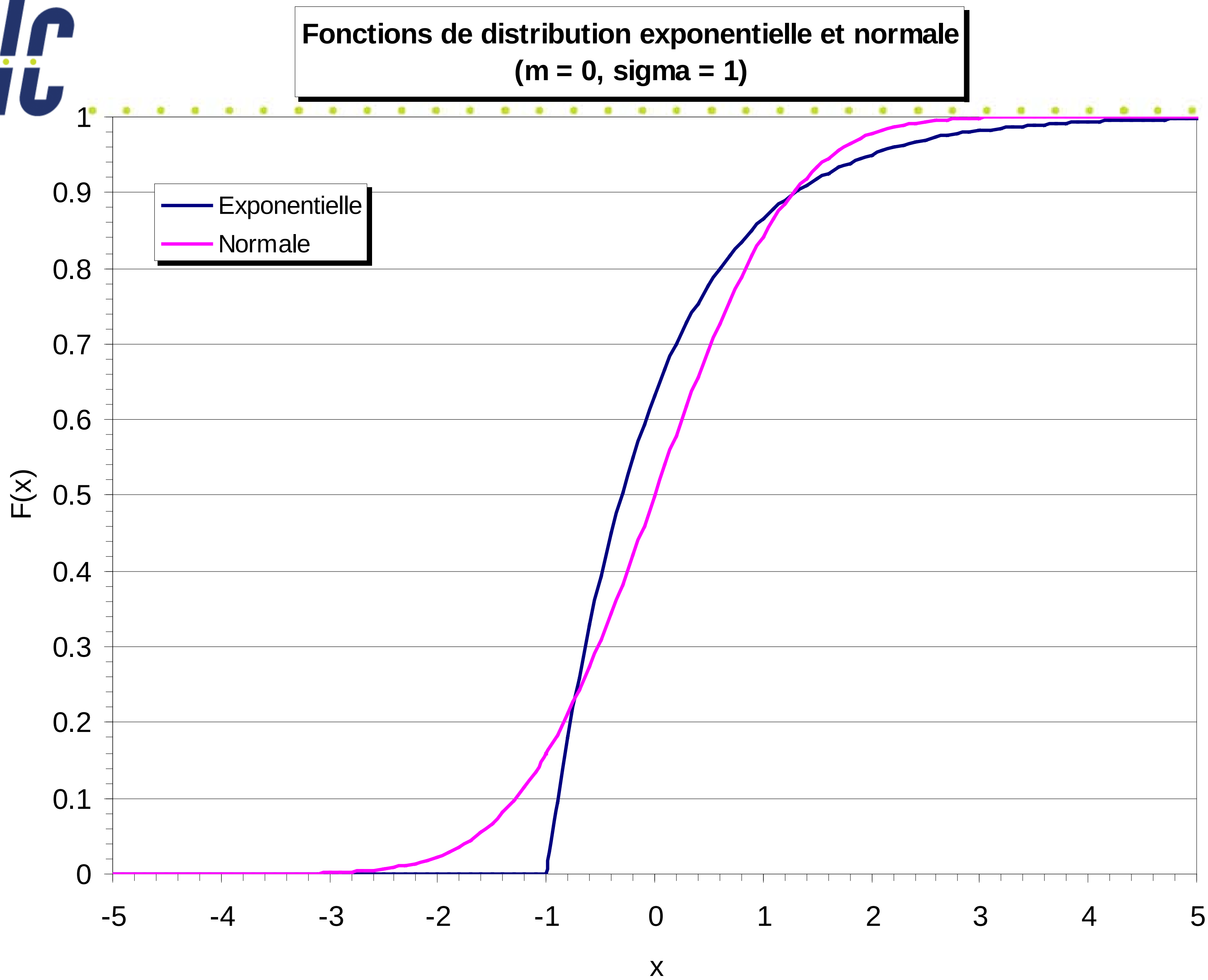
Statistical modeling of component costs

- Heuristic considerations
  - **things tend to cost more rather than less ⇒ statistical distributions of X_i are strongly skew**
  - **PDFs $f_i(x_i)$ are equal to zero for x_i below threshold values b_i equal to the lowest market prices available**
  - **commercial competition tends to crowd prices close to lowest ⇒ PDFs $f_i(x_i)$ are likely to be monotonously decreasing above threshold values b_i**
- The exponential PDF is a simple mathematical law satisfying these conditions

$$f(x) = 0 \qquad \text{for } x < b$$
$$f(x) = a \exp[-a(x-b)] \qquad \text{for } x \geq b$$

- Characteristics of the exponential law
  - **only two parameters a and b**
  - **threshold** — **b**
  - **mean value** — $m = 1/a + b$
  - **standard deviation** — $\sigma = 1/a = m - b$
  - **« mean value = threshold + one standard deviation »**

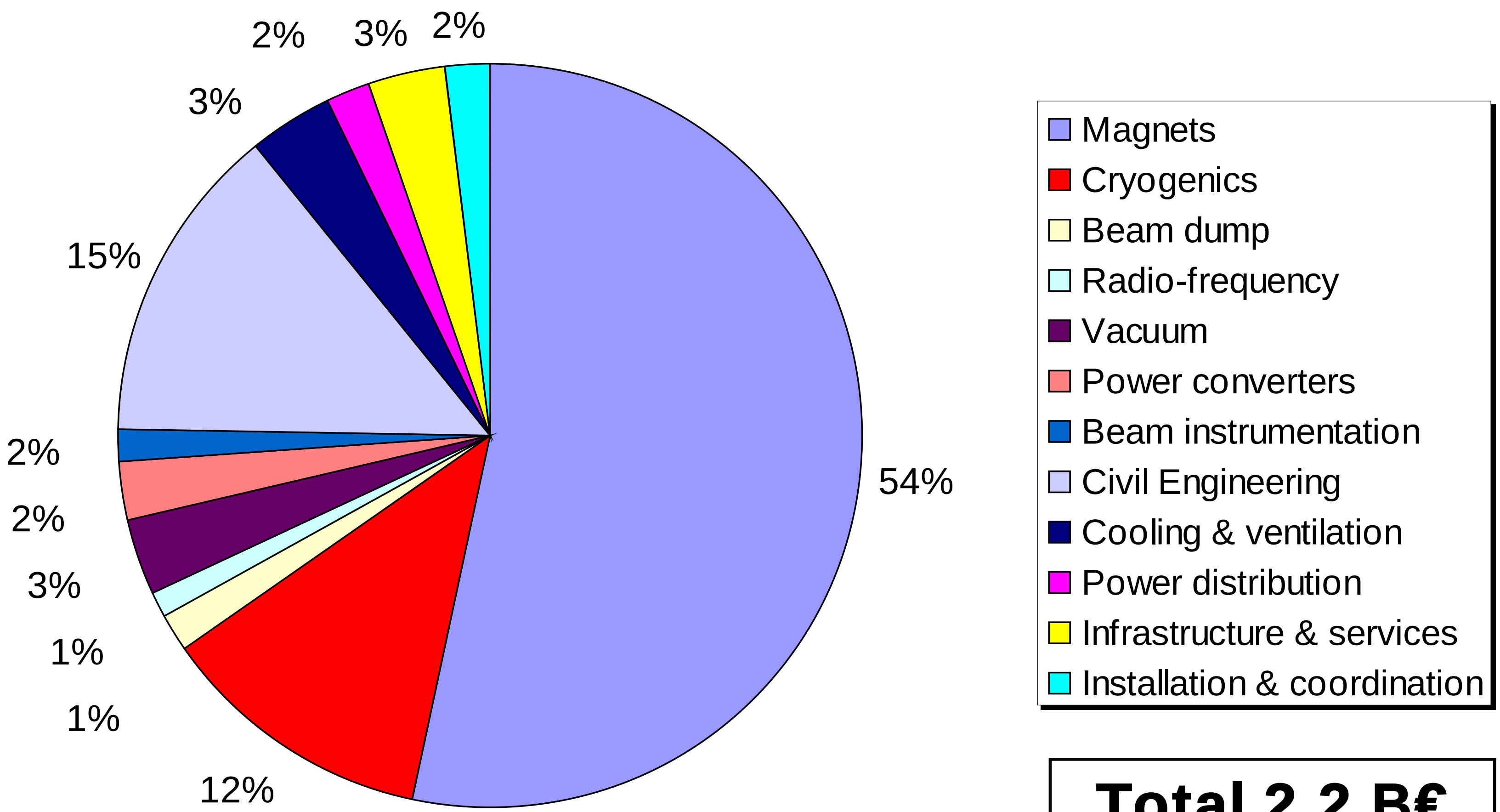

Densités de probabilité exponentielle et normale
(m = 0, sigma = 1)
Exponentielle
Normale
f(x)
x
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-5
-4
-3
-2
-1
0
1
2
3
4
5


Fonctions de distribution exponentielle et normale
(m = 0, sigma = 1)
Exponentielle
Normale
F(x)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
-5
-4
-3
-2
-1
0
1
2
3
4
5
x

Comparing Gaussian and exponential PDFs

- Gaussian
  - **$X \leq m - \sigma$ at confidence level 15,9%**
  - **$X \leq m$ at confidence level 50%**
  - **$X \leq m + 1{,}28\ \sigma$ at confidence level 90%**
  - **$X \leq m + 1{,}65\ \sigma$ at confidence level 95%**
  - **$X \leq m + 2{,}06\ \sigma$ at confidence level 98%**
- Exponential
  - **$X \leq m - \sigma$ at confidence level 0**
  - **$X \leq m$ at confidence level 63,2%**
  - **$X \leq m + 1{,}30\ \sigma$ at confidence level 90%**
  - **$X \leq m + 2{,}00\ \sigma$ at confidence level 95%**
  - **$X \leq m + 2{,}91\ \sigma$ at confidence level 98%**

LHC cost structure for contracts > 750 K€

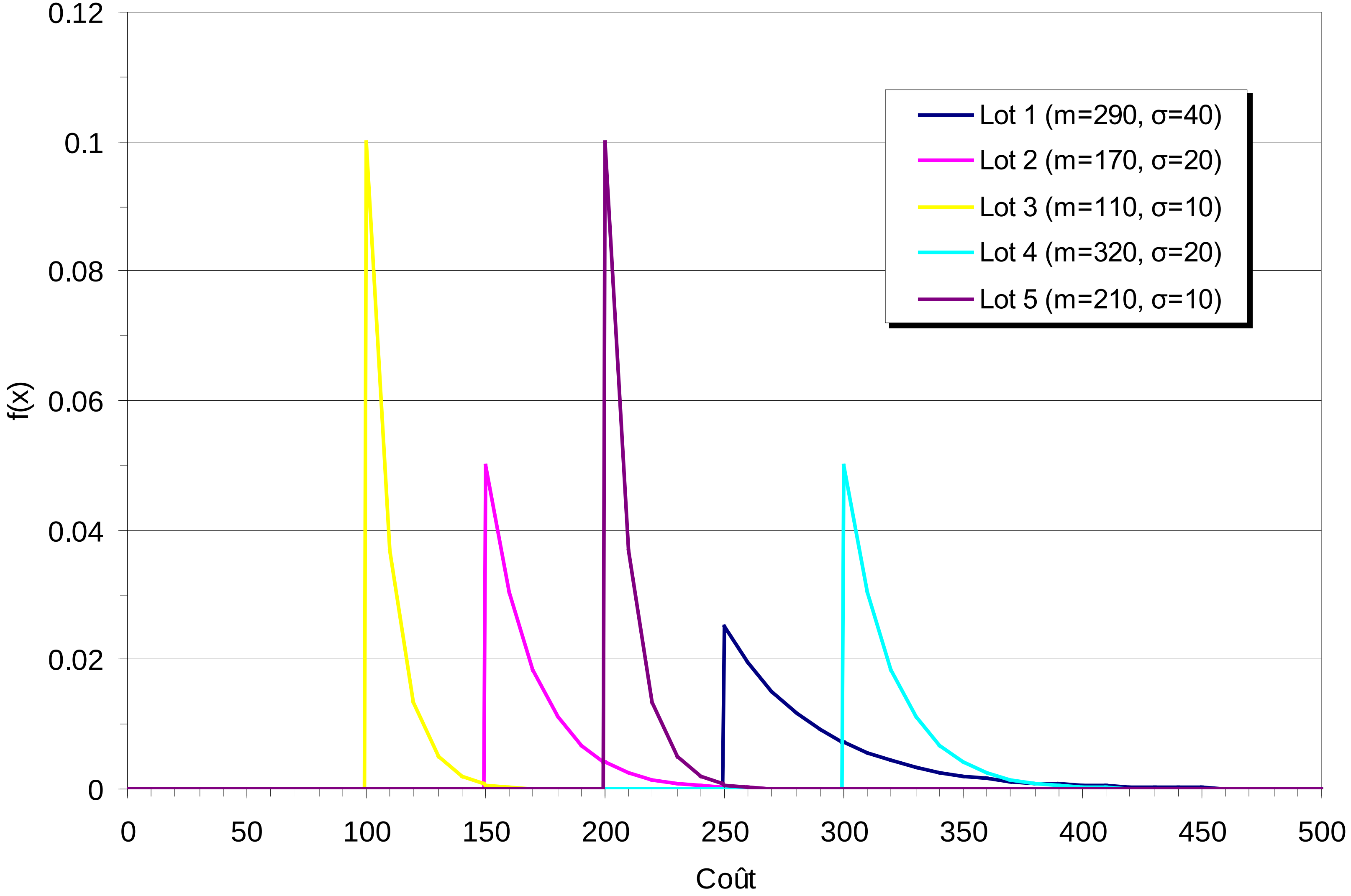


Total 2.2 B€

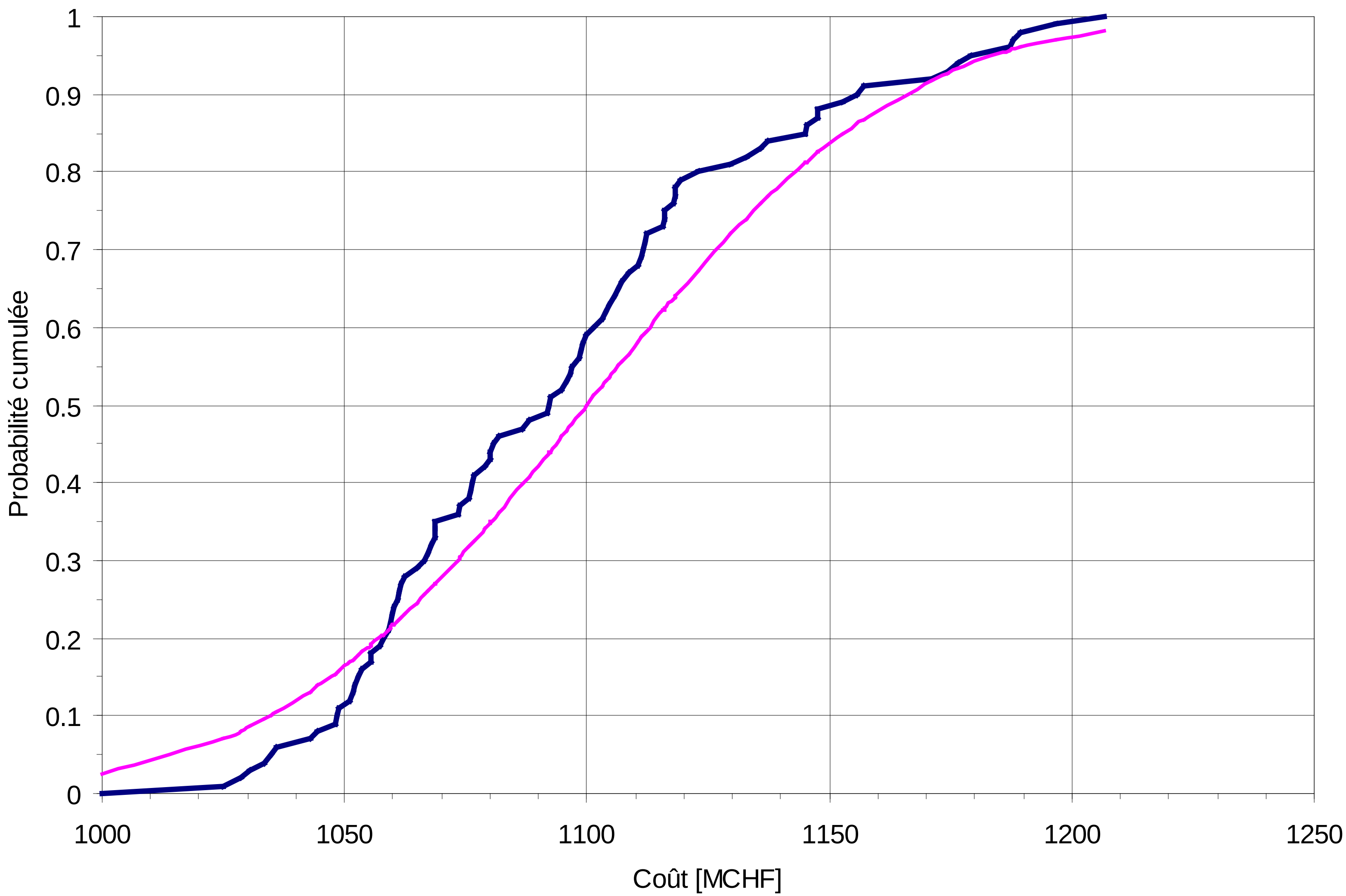
Scatter of LHC offers as a measure of cost variance

- Available data: CERN purchasing rules impose to procure on the basis of lowest valid offer ⇒ offers ranked by price with reference to lowest for adjudication by FC
- Postulate: scatter of (valid) offers received for procurement of LHC components is a measure of their cost variance due to technical, manufacturing and commercial aspects
- Survey of 218 offers for LHC machine components, grouped in classes of similar equipment
- Prices normalized to that of lowest valid offer, i.e. value of contract
- Exponential PDFs fitted to observed frequency distributions with same mean and standard deviation

Densités de probabilité du coût des lots (lois exponentielles)



Fonction de distribution du coût total du projet
(simulation Monte Carlo n = 100, comparée à une loi normale [1100, 51])



Remaining question for Philippe

- Distribution desired is not the distribution of all vendor quotes (which includes higher quotes which were not accepted), but given a model for how many vendors will quote under that distribution, what is the distribution of the ***lowest*** acceptable quotation.

A simple worked-out example

- Consider a project made of 5 lots according to the table below

Lot	Seuil	Ecart-type	Moyenne	Variance
1	250	40	290	1600
2	150	20	170	400
3	100	10	110	100
4	300	20	320	400
5	200	10	210	100
Somme	1000	100	1100	2600
Sigma				50.9901951

Application of central-limit theorem

- In case the elementary costs are statistically independent, the total cost is a random variable with
  - mean value $m = \Sigma\, m_i = 1100$
  - standard deviation $\sigma = (\Sigma\, \sigma_i^2)^{½} \approx 51$
- Its PDF tends towards a Gaussian law [1100, 51]
  - $X \leq 1165$ at confidence level 90%
  - $X \leq 1184$ at confidence level 95%
  - $X \leq 1205$ at confidence level 98%
- This law can be compared to the result of a Monte-carlo simulation based on exponential PDFs for elementary costs, treated as independent

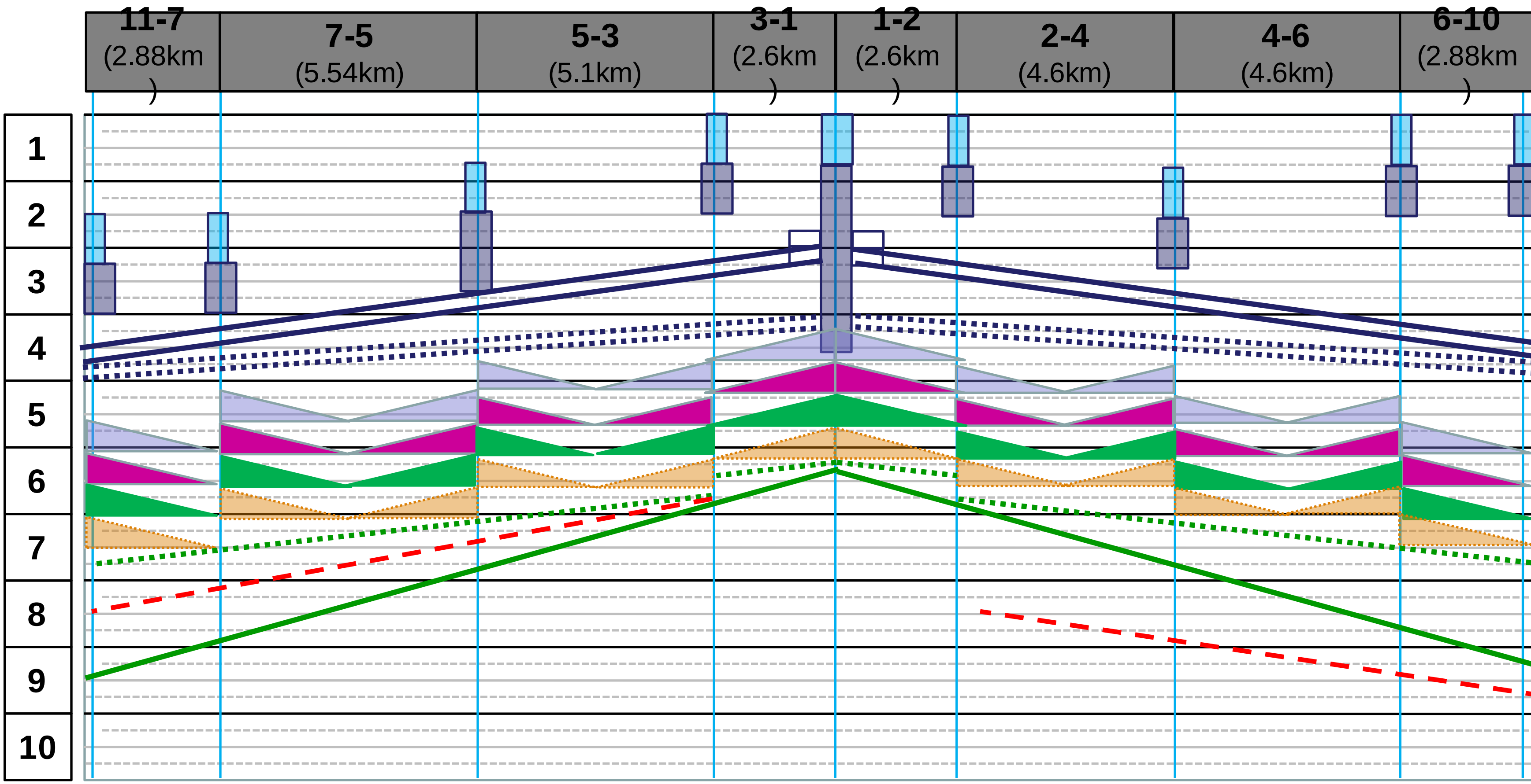
Resources comparison with CLIC

	CLIC (ϕ1)	CLIC (ϕ2)	ILC
Nb of TBM	2		9
Nb of teams for elec. general services	4		24
Nb of teams for cooling and ventilation	4		12
Nb of teams for cabling	4		24
Nb of teams for machine installation	2		12
	7.2y	**10.5y**	**6y**

What would be the ILC schedule if **machine installation is performed with 2 teams**,
& what shall be the other resources ?

7.2y	**10.5y**	**9.5y**

ILC Schedule smoothed



- - - Alternative deployment of machine installation crews (PHG)

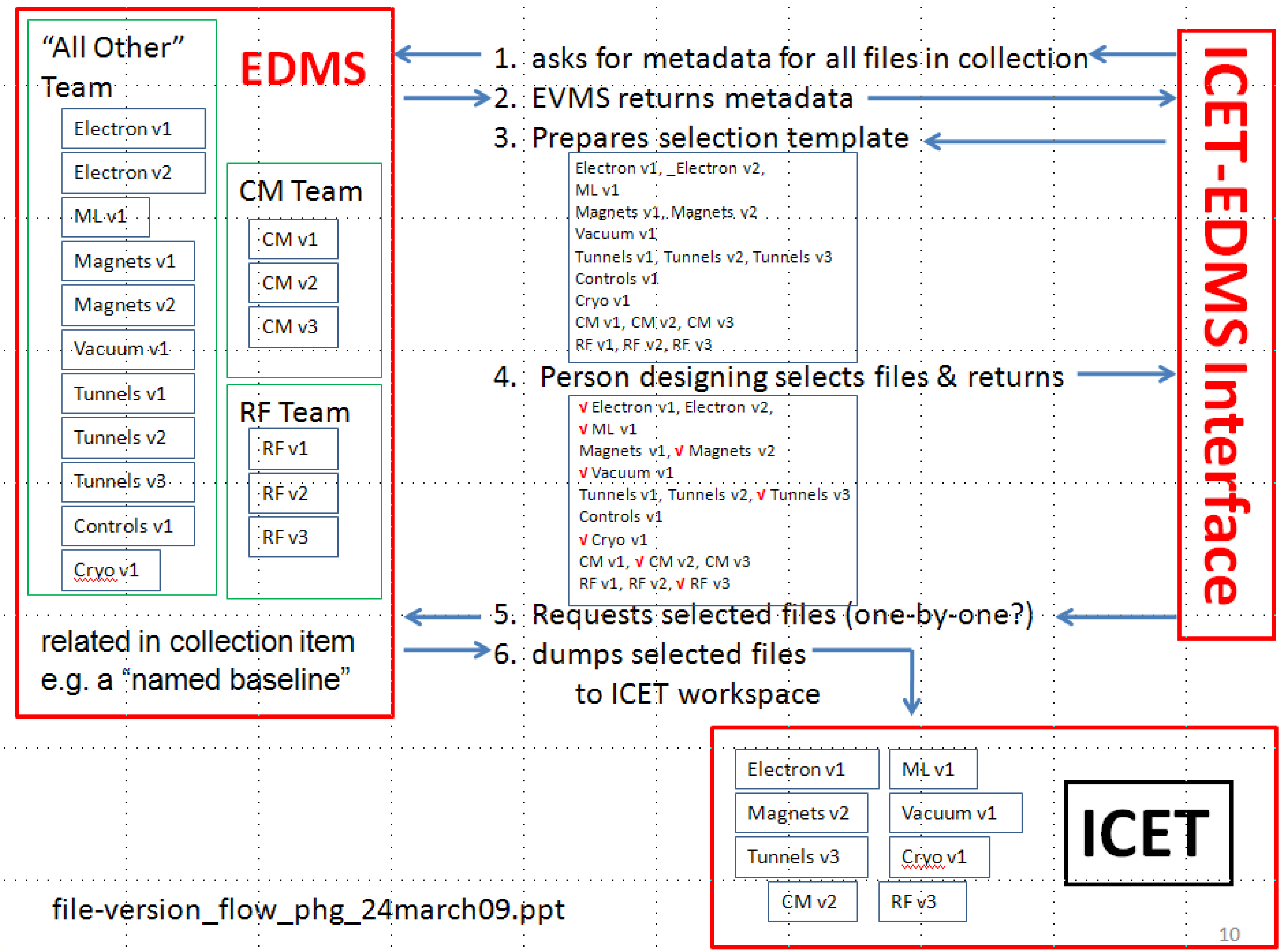
...... Support installation and alignment (250m/wk)

— Machine inst.: transport and interconnections (progress rate to be confirmed 100m/wk)

Resources comparison with CLIC

	CLIC (ϕ1)	CLIC (ϕ2)	ILC
Nb of TBM	2		4
Nb of teams for elec. general services	4		8
Nb of teams for cooling and ventilation	4		4
Nb of teams for cabling	4		8
Nb of teams for machine installation	2		2
	7.2y	10.5y	9.5y

Use EDMS for archive, approval, version control – *current emphasis*



Common Cost Risk Document

- Philippe and Peter: What do we need on Cost Risk Document? And who does what?
- Joined by Vic Kuchler and Chris Adolphsen
-
- This isn't including contingency.
-
- Assign and add a variance due to each of these.
- Should we provide the suggested variance due to each of the elements?
- Go to vendors (or Means), get their suggestions for uncertainties?
-
- Project uncertainty:
- Evolution of Configuration – is design mature? Are the specifications known? E.g. heat loads
    - But regulations could change.
    - E.g. didn't know actual number of circuits (unknown requirements or heat loads)
        - Had new problem => electron clouds
        - Breakthrough => HTSC leads reduced heat loads
- Vendor strategy – off-shelf, or custom –
    - Qualification and experience of vendor
- Technical difficulties in execution
    - Write specification too early, e.g. before having operational prototype
    - Rejection rate of industrial process – high rejection rate => higher costs
    - Qualification of vendor
- Evolution of Market
    - Raw material and Vendor is available, e.g. laminations by auto industry
        - Long term average – may tend to industrial price index
    - Monopoly or oligopoly (few companies) in the business
- Commercial Strategy of Vendor
    - Is vendor interested in entering new market.
-

- Not - Industrial Price Index – an add-on, not part of variance analysis
- Not - Exchange Rates – an add-on, not part of variance analysis
-
- Checklist for estimator, qualitative, how many of these factors are applicable
- What is important?
-
- These topics above seem to be trying to develop an uncertainty checklist/calculation similar to that used for a long time by DOE from Gary Sanders/Lockheed? Is there a reference?
- Such a general procedure is for early cost estimate studies, should use more detailed, particular information if available.
-
- Not necessarily to try to control
- Estimate of variance or variability
-
- Quantitative or semi-quantitative analysis of cost variance
- Important to understand approach before starting
- If you do it properly, you have problems with funding agency.
-
- What do we write?
- Principles
- Different implementations
-
- How do the uncertainties for the ILC and CLIC compare?
- Do we want to use DOE risk table? Or something else or similar?
- What is random and what is not? See Philippe's table?
-
- Treating uncorrelated is easy, fully correlated is easy, determining which is which is difficult
-