XFEL Cost and Uncertainties/risk Analysis

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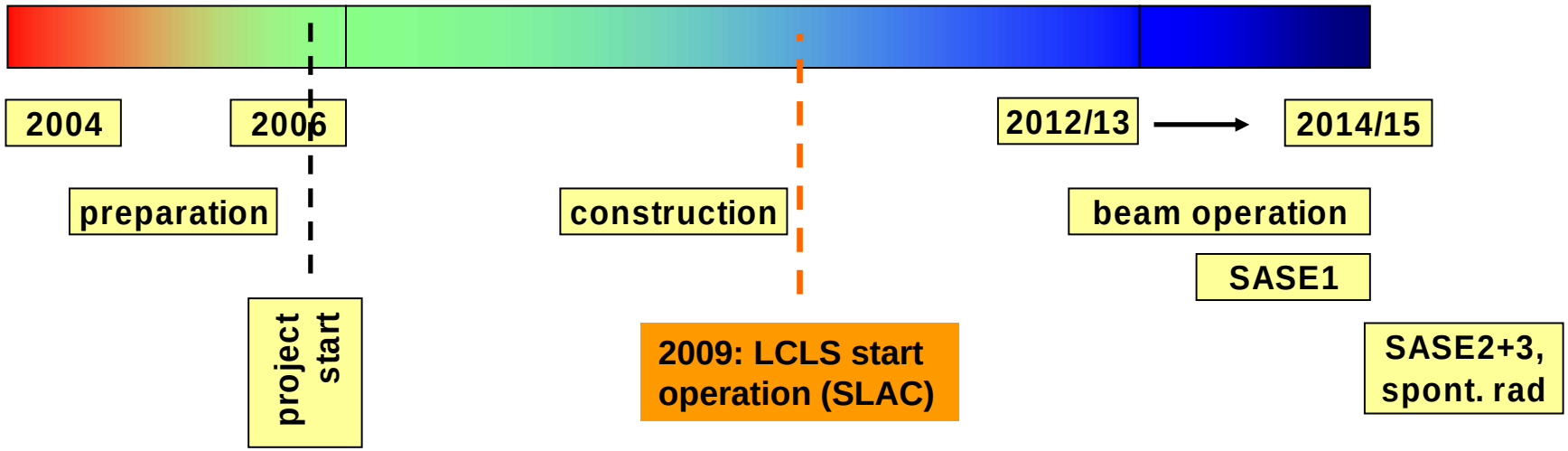
Introductory remarks

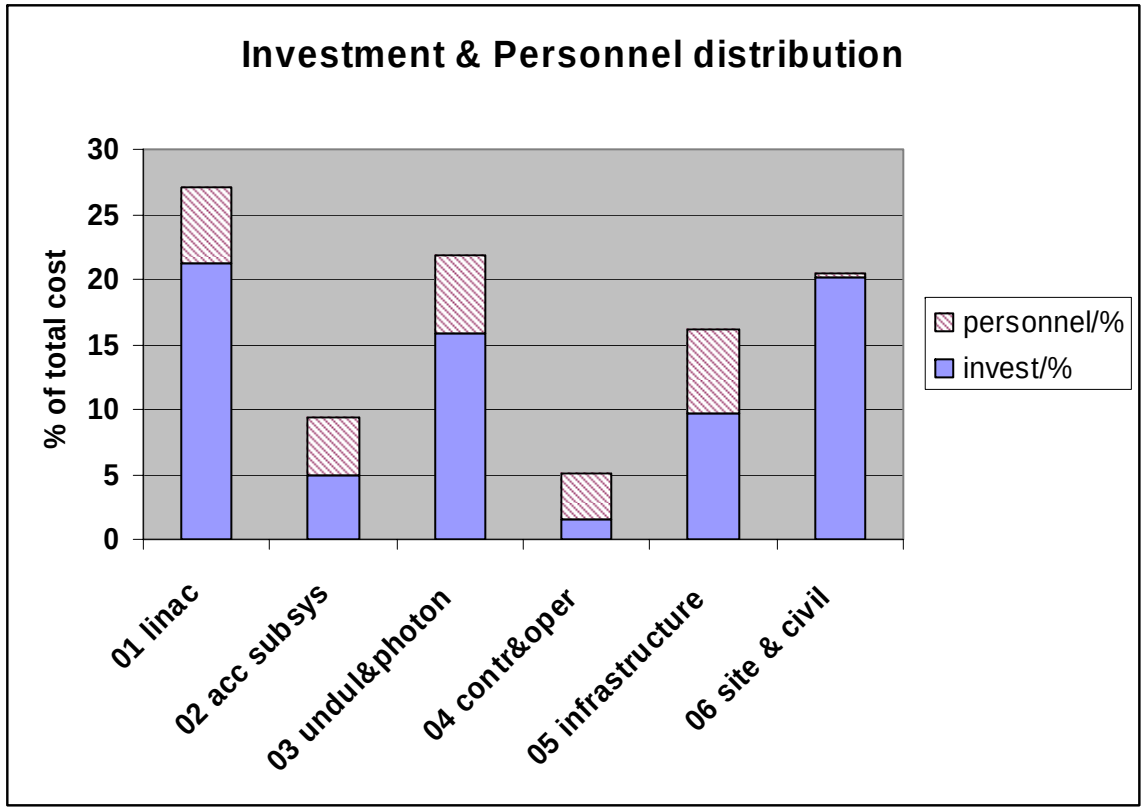
- Construction cost estimate is based on the XFEL design described in the Oct 2002 supplement to the TESLA TDR; prices have been adjusted to the **year 2005** (escalating with 1.5%/year from the original year 2000 basis)
- An update of the cost estimate is ongoing, will be completed by ~end 2005 as part of a new TDR (taking into account design changes, different site, more detailed analysis of some of the sub-systems, etc.)
- Personnel costs are estimated on the basis of salaries at DESY **(year 2005),** including an overhead to cover basic central services and administration *(different from 2002 TDR supplement)*

Project time schedule

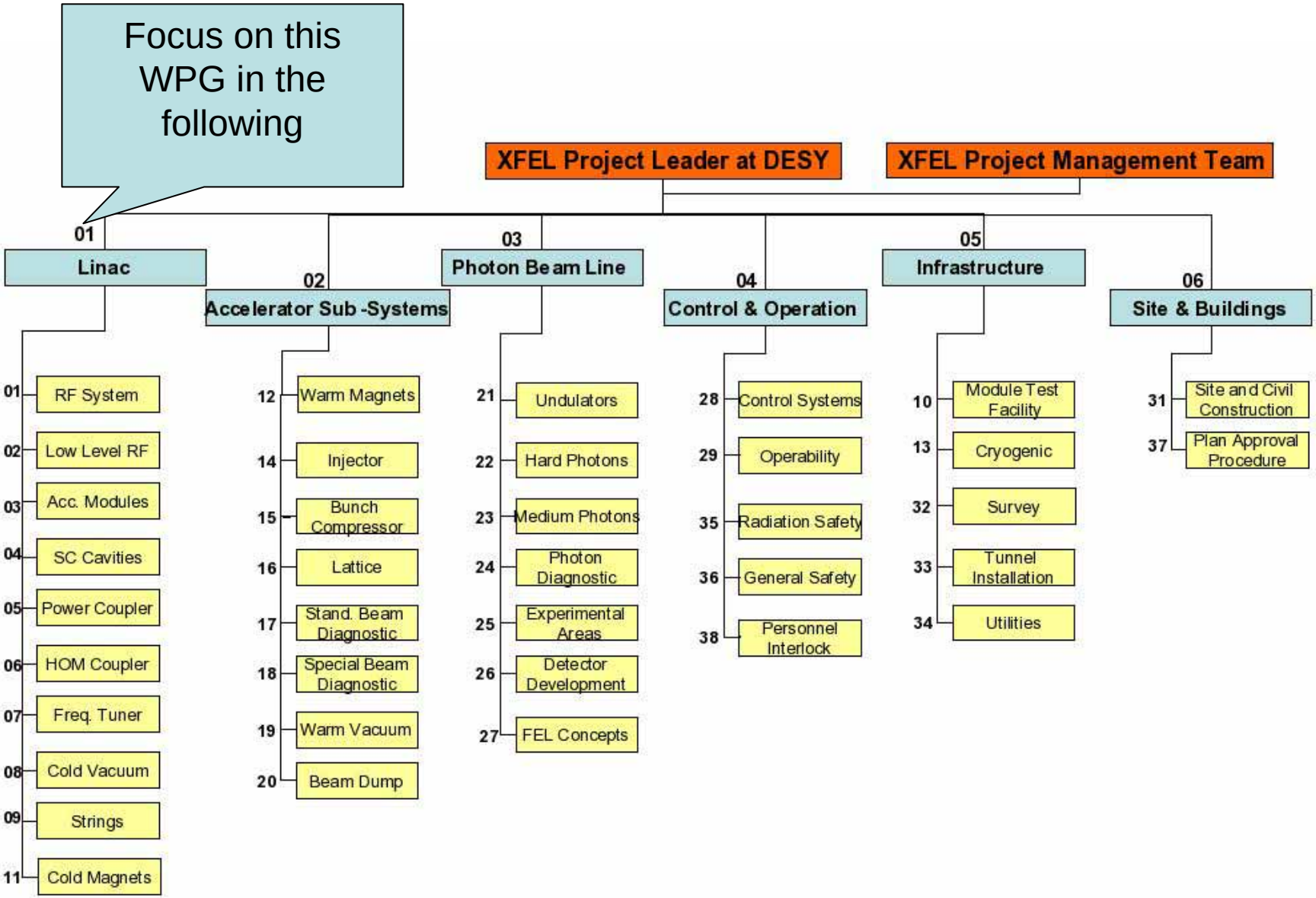


- Assumes final project approval & funding at European level in ~mid 2006
- Site approval (“PFV”) and preparations for placing orders for civil construction before official project start

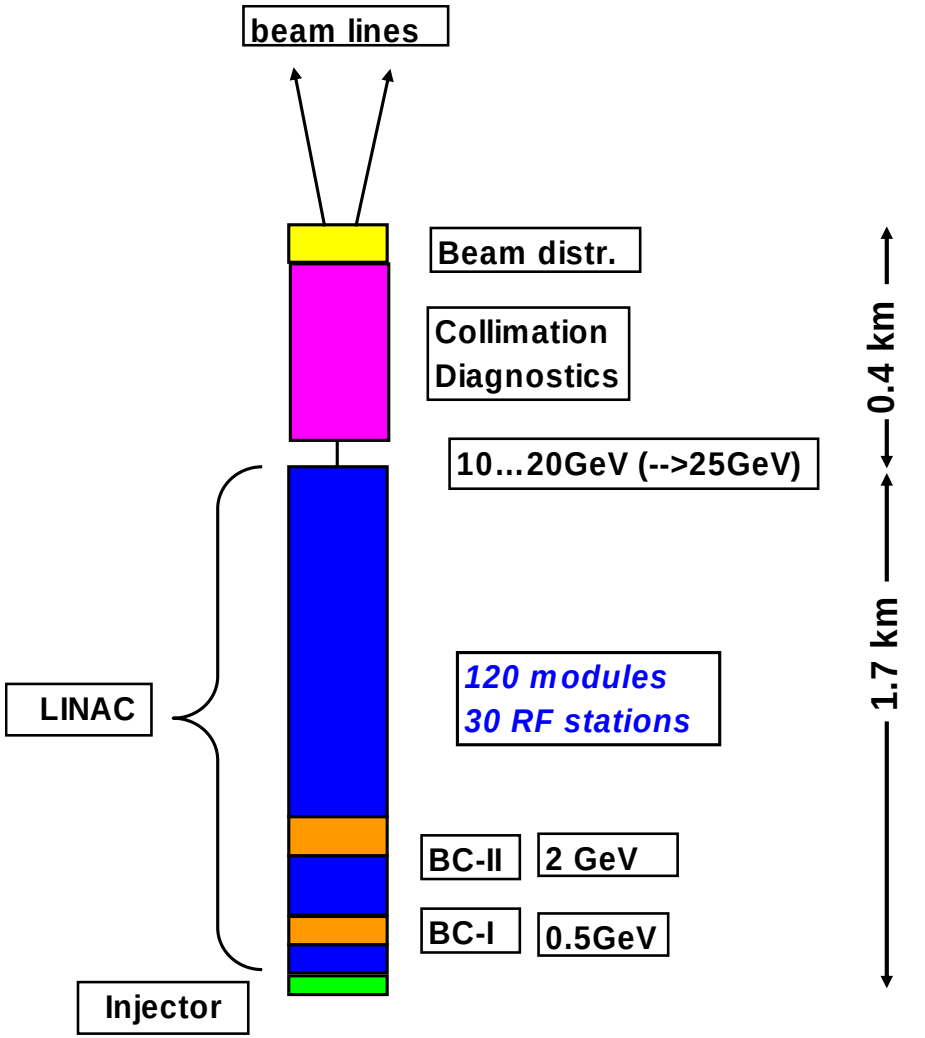
Estimated total project cost 793M€, year 2005 basis, not including project preparation and escalation over construction period



The way the cost distribution is presented here reflects the present work package structure of the XFEL project group


Focus on this WPG in the following
XFEL Project Leader at DESY
XFEL Project Management Team
01
Linac
02
Accelerator Sub -Systems
03
Photon Beam Line
04
Control & Operation
05
Infrastructure
06
Site & Buildings
01 RF System
02 Low Level RF
03 Acc. Modules
04 SC Cavities
05 Power Coupler
06 HOM Coupler
07 Freq. Tuner
08 Cold Vacuum
09 Strings
11 Cold Magnets
12 Warm Magnets
14 Injector
15 Bunch Compressor
16 Lattice
17 Stand. Beam Diagnostic
18 Special Beam Diagnostic
19 Warm Vacuum
20 Beam Dump
21 Undulators
22 Hard Photons
23 Medium Photons
24 Photon Diagnostic
25 Experimental Areas
26 Detector Development
27 FEL Concepts
28 Control Systems
29 Operability
35 Radiation Safety
36 General Safety
38 Personnel Interlock
10 Module Test Facility
13 Cryogenic
32 Survey
33 Tunnel Installation
34 Utilities
31 Site and Civil Construction
37 Plan Approval Procedure

Accelerator schematic layout



Main linac	
Beam energy	20 GeV
acc gradient	22.9 MV/m
Bunch spacing	200 ns
beam current	5 mA
power→beam p. klystron	3.8 MW
incl. 10% + 15% overhead	4.8 MW
matched Q_{ext}	$4.6 \cdot 10^6$
RF pulse	1.37 ms
Beam pulse	0.65 ms
# bunches p. pulse	3250
Rep. rate	10 Hz
Av. Beam power	650 kW

Input for cost estimate

- TDR2001: industrial studies for production of ~20,000 cavities, treatment, and assembly of modules
- Oct 2002: update of studies for smaller # of components
- Application of scaling rules (cost/component vs. # components) for single components (e.g. tuners, RF couplers)
- Overall consistency check: cost per module factor ~1.7 higher for XFEL linac than for TESLA linac
- In contrast to TDR2001, no large reduction factor assumed for RF system components (e.g. need ~40 instead of ~600 klystrons – manufacturer wouldn't set up new large-scale production facility)
- Counter check with present prices and experience from other projects where possible (TTF, HERA)

Method for personnel cost estimate

- For each work package, the amount of required laboratory personnel for the construction phase was estimated (FTEs)
- A matrix map was created between the DESY M-division technical groups and the work packages (how much of the work per WP would be done by which M-group)
- From the known salary structure in each M-group thus the salary structure for the WPs was derived (this procedure was simplified by defining small number of salary classes, in the final representation just two: “scientific” and “technical”)
- Different costs per FTE in the different WPs are the result – on average (all WPs) this figure is 77k€/FTE (2005) including overhead

Approach to cost uncertainty/risk analysis

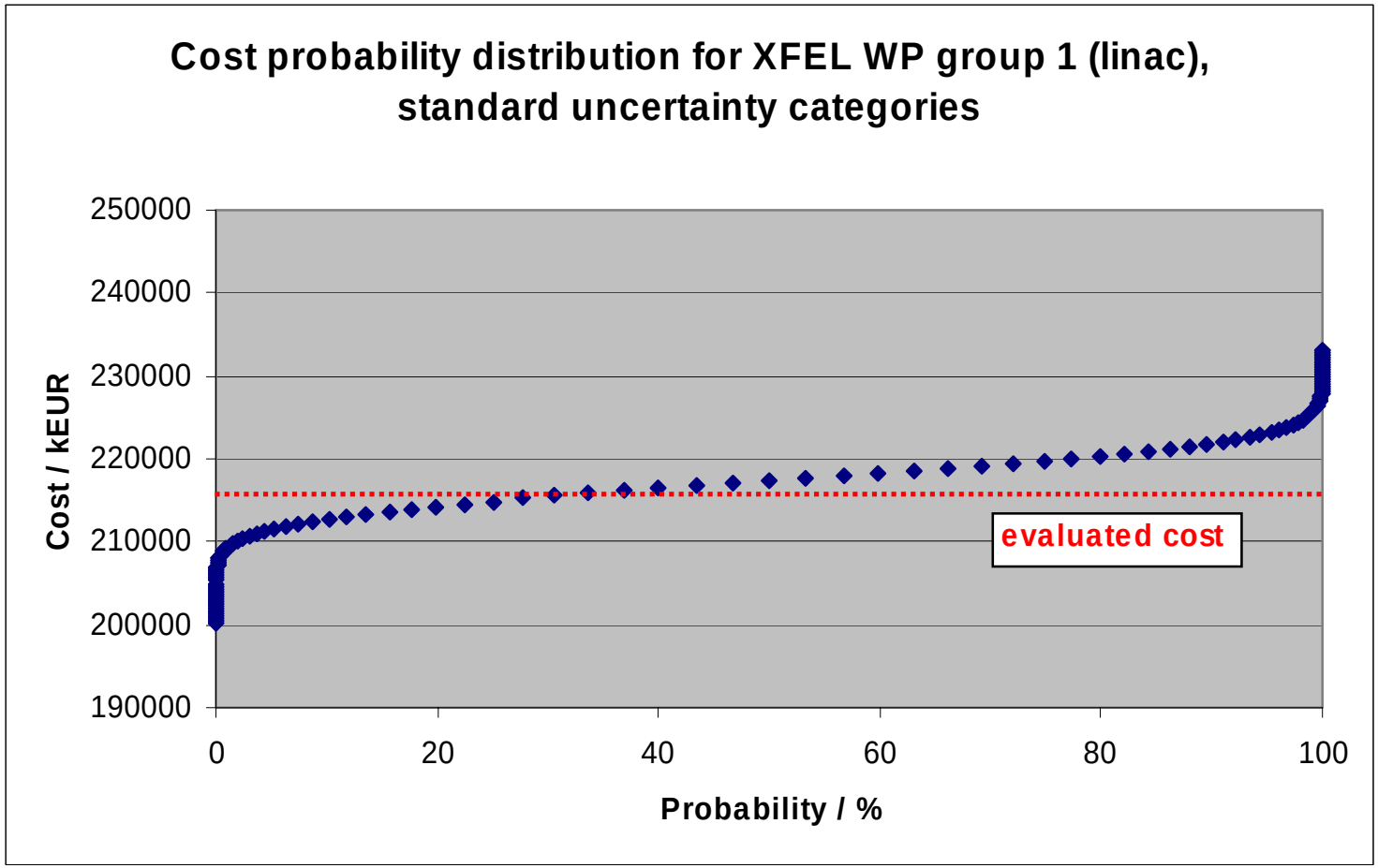
- Detailed analysis for the entire project is in progress; methodology is described here for the largest (~27% of total cost) XFEL Work Package group (WPG01, linac)
- Statistical analysis of cost probability distribution using a set of uncertainty categories for the cost items in the WPs (named “standard” categories in the following)
- Determination of maximum risk with “conservative” (or rather: pessimistic) uncertainty assumptions:
  - **Present prices for components/sub-systems (low number, partially prototypes!) have been collected where available**
  - **Upper limit for cost risk defined by assuming that only half of the cost reduction from present price to price used for the XFEL cost evaluation can be achieved**

Standard cost uncertainty categories

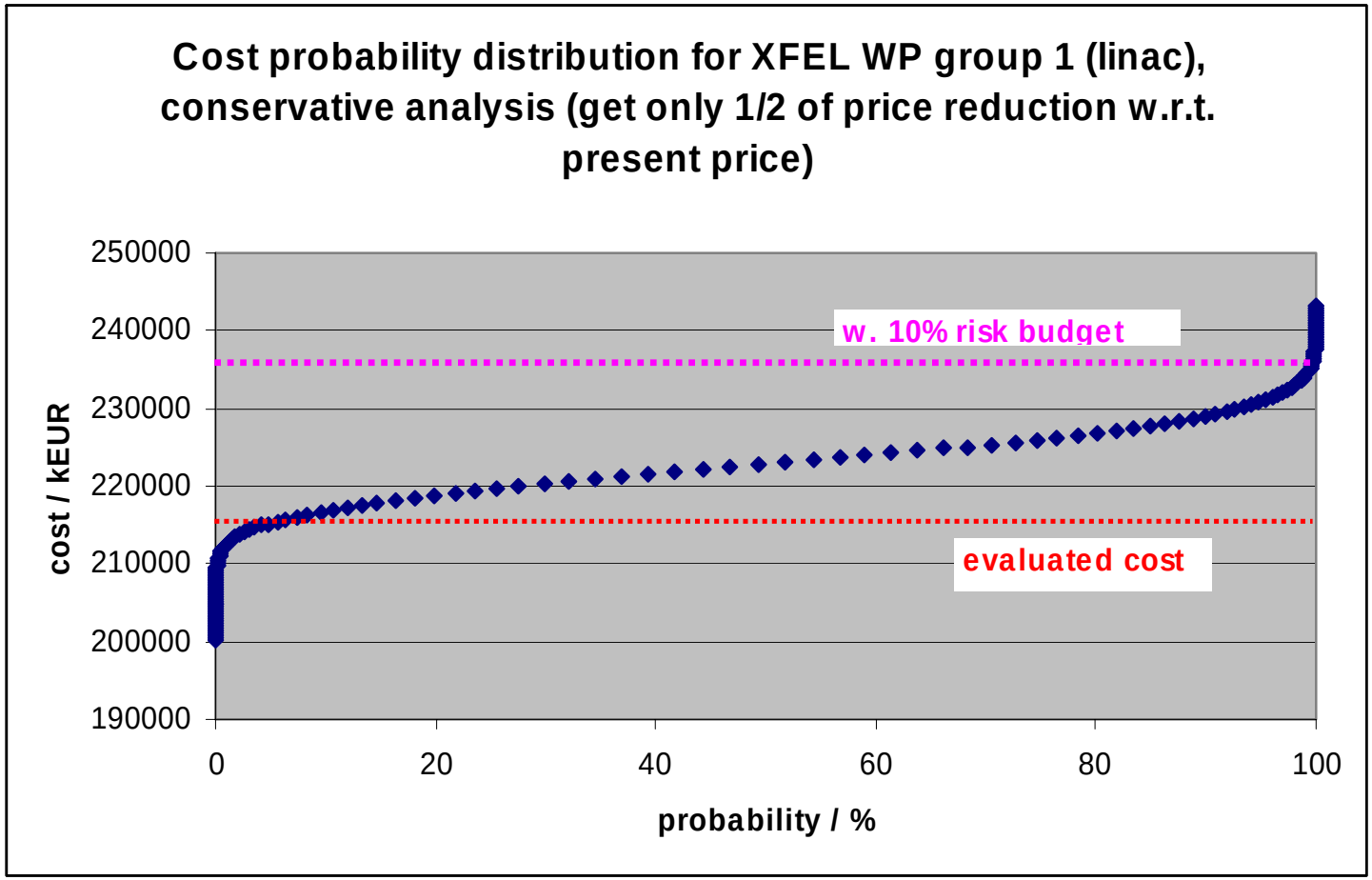
Category	definition	lower/upper range
C1	good experience and present price for this component/sub-system are available, no cost scaling for large quantities has been applied	-10% / +10%
C2	experience and present price for similar components/sub-systems are available, no or only minor scaling to large quantities has been applied	-20% / +20%
C3	present price is available, significant (>25%) cost scaling to large quantities has been applied	-10% / +20%
C4	present price is available, price from industrial study is used which results in significant (>25%) cost reduction for production of large quantities	-10% / +20%
C5	present price not available, price from industrial study is used	-10% / +20%
C6	Required technology pushes state-of-the art, significant R&D still required	-10% / +50%
P1	personnel requirements well known due to present experience or with similar systems in previous large scale projects	-10% / +10%
P2	personnel requirements less certain or relatively large fraction of R&D included in this WP	-20% / +20%

Furthermore, raw material cost uncertainties (volatility of metal and currency markets) have been added where appropriate (e.g. Niobium sheets & parts)

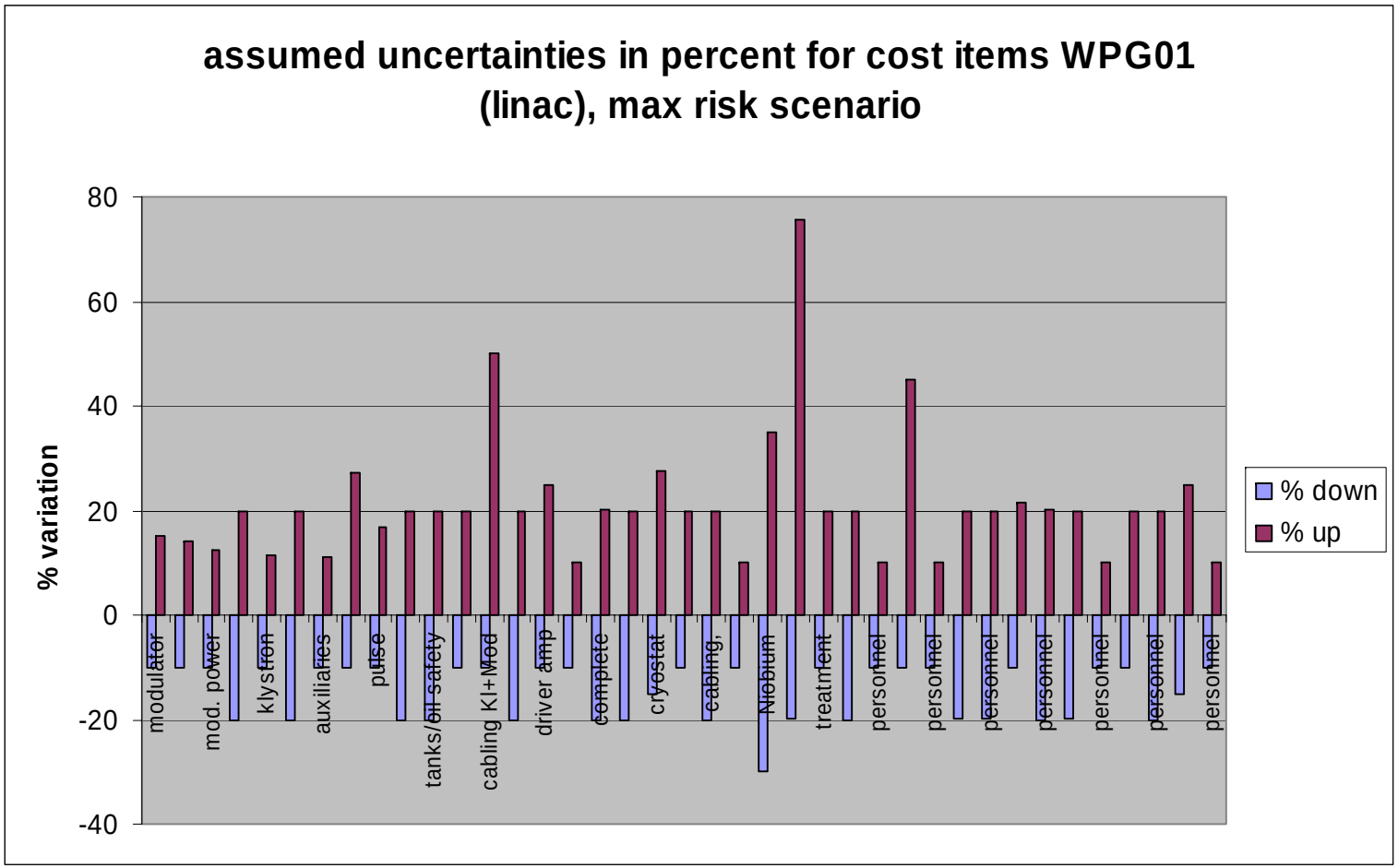
Result of analysis with standard categories



Result of maximum risk analysis



Max risk analysis cont'd



Risk of delays due to problems at manufacturers (or participating institutes)

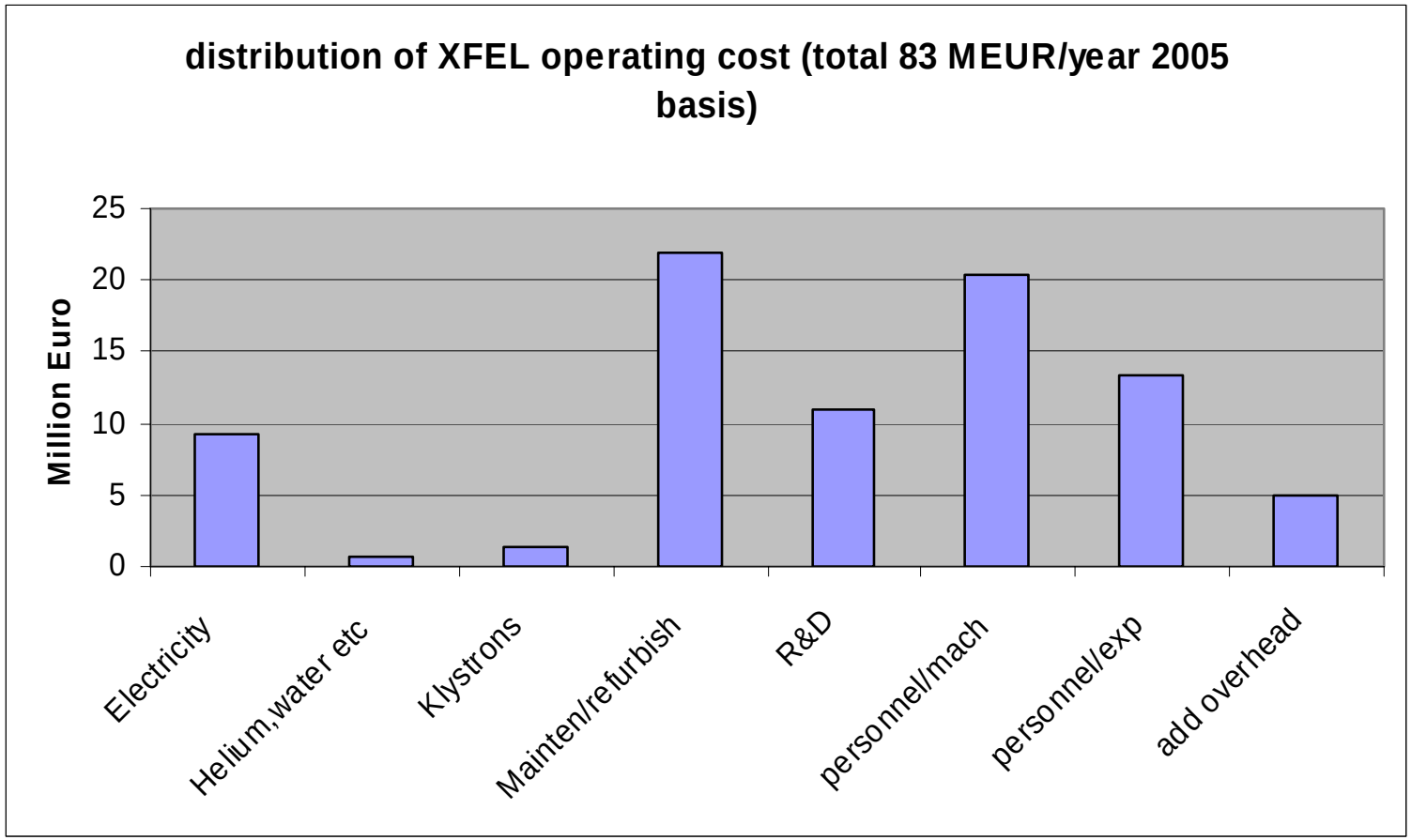
- E.g. over-commitment (or as extreme case, bankruptcy) at manufacturer can cause delay of project construction
- Delay can to some extend be minimized by re-scheduling installation, testing or technical commissioning
- The resulting cost risk is determined by multiplying the delay with the personnel cost per unit time
- Resulting cost risk for a delay of 6 months is approximately **2% (~15M€)** of the total project cost

Conclusions regarding risk analysis

- Methodology will be applied to all Work Package groups – overall picture not expected to drastically change
- Adjust the estimated cost by ~+1…2% to match the probability distribution at 50% (instead of ~35%)
- Risk budget of about 10% of total project cost appears reasonable

- This analysis of uncertainties does not include cost modifications due to changes in the detailed design of the facility or additional R&D items identified by STI – final cost update will be prepared as part of the TDR

Operation cost



Operation cost cont'd

- Estimated personnel is 265 FTEs for accelerator & infrastructure, 166 FTEs for photon beam lines & exp. area (salary classes derived similarly as for construction phase)
- Electricity cost assumes 14MW/5,500h + 3.4MW/full year at 8c/kWh
- Maintenance/repair, refurbishment and R&D are assumed with ~2% of initial investment each
- Additional overhead introduced to cover expenses for user service, guest scientists, student programme, etc.