

Civil Engineering (CE) Studies for the 80km Tunnel Project

'Frontier Capabilities for Hadron Colliders 2013'
21 February 2013

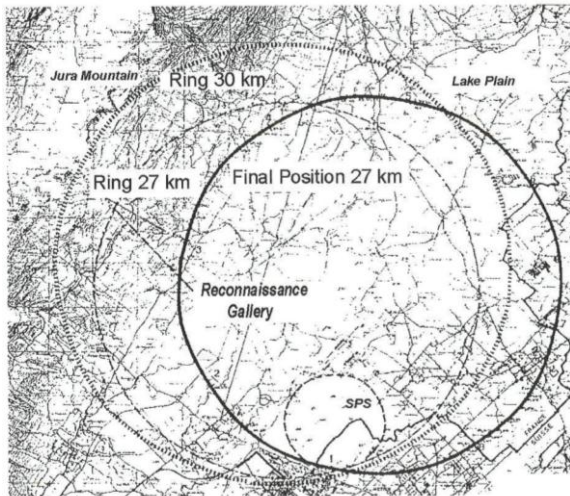
John Osborne and Caroline Waaijer
(CERN)

- Potential locations
- CE considerations
 - Geotechnical
 - Tunneling
 - Environmental
 - Optimization
- Cost estimate
- Feasibility / Risk issues
- Next steps

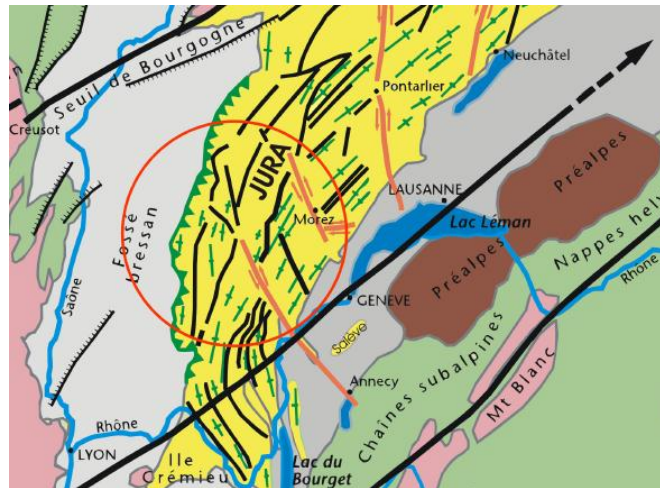
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Potential locations

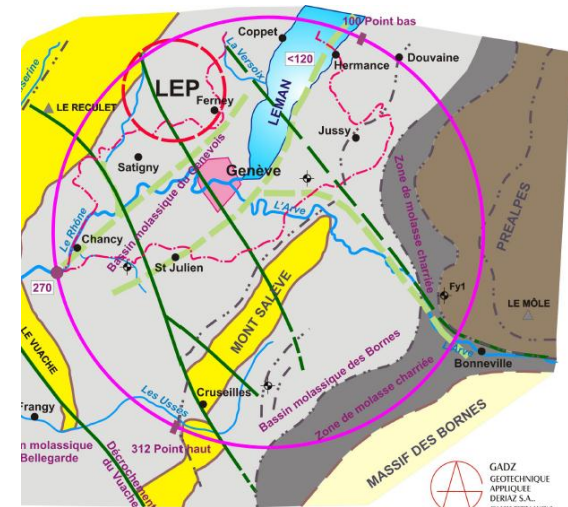
- Summer 2012 CERN GS-SE group were asked to study the pre-feasibility of an 80km ring tunnel in the CERN area.
- Options for a ring tunnel have been proposed in the past
 - LEP: 30km prior to 27km
 - VLHC: 240km & 113km



LEP 30km and 27km tunnel locations



VLHC 240km tunnel location

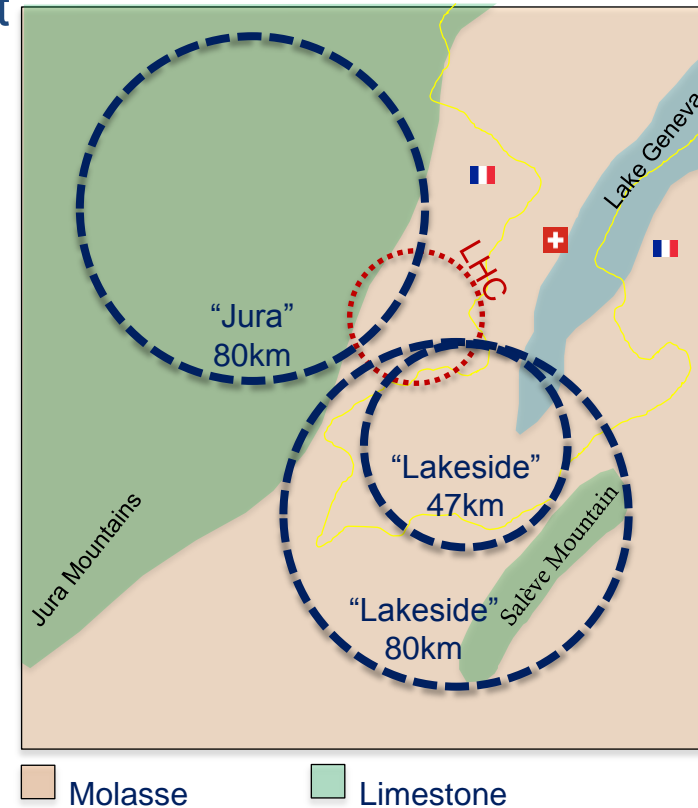


VLHC 113km tunnel location

Potential locations

- Several locations have been studied for the possibility to construct an 80km ring tunnel in the CERN area.
 - Location constraints
 - CERN area
 - Connected to LHC/SPS at one point
 - Depth (access shafts)

	Circumference	Average Depth	Max Depth below surface
LEP/LHC	27 km	100 m	170m
Jura	80 km	590 m	1270 m
Lakeside	80 km	280 m	690 m
Lakeside	47 km	220 m	320 m

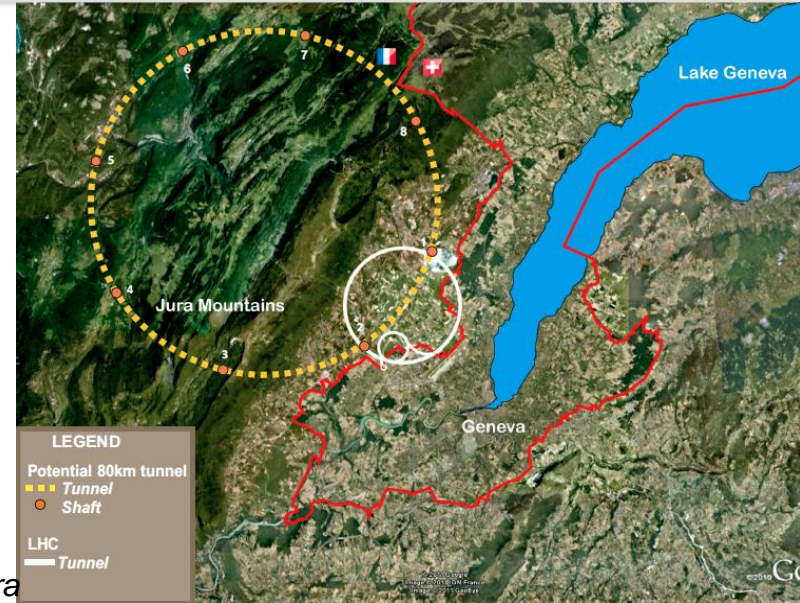


Potential locations

- Location 1:

80km Jura option

- Fully housed in France
- 90% in Jura Limestones
- 10% in Molasse
- Connected to LHC
- Shafts every 10km

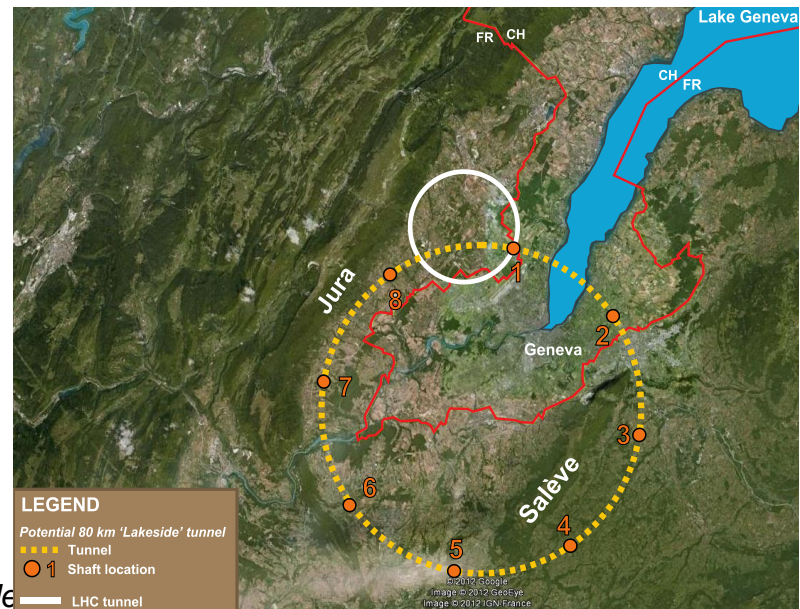


Option 1: 80km Jura

- Location 2:

80km Lakeside option

- Housed in France and Switzerland
- 10% in Limestones (Jura, Salève)
- 90% in Molasse
- Passes under Lake Geneva
- Around the back of the Salève
- Connected to LHC
- Shafts every 10km



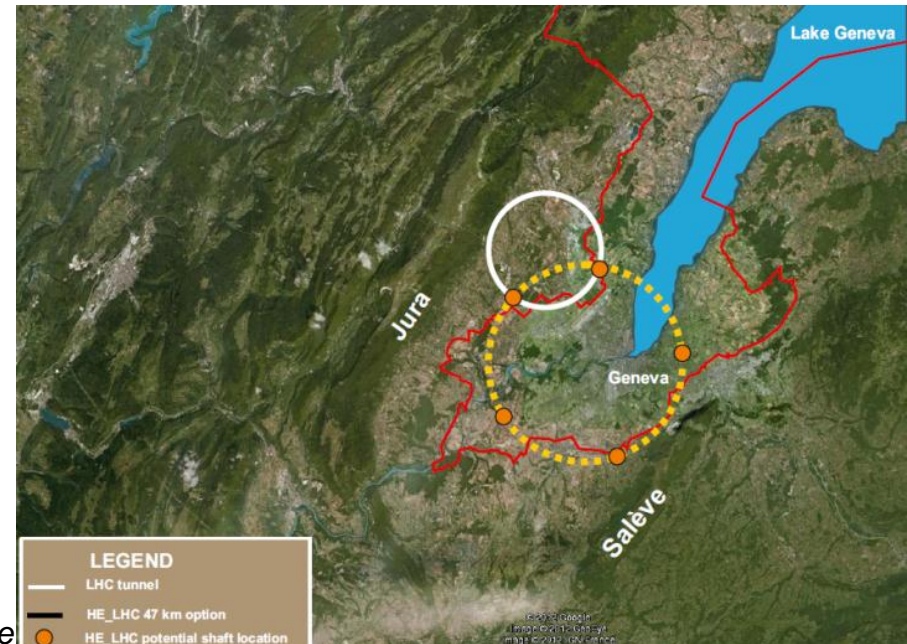
Option 2: 80km Lakeside

- Location 3:

- 47km Lakeside option**

- Studied from geotechnical viewpoint*

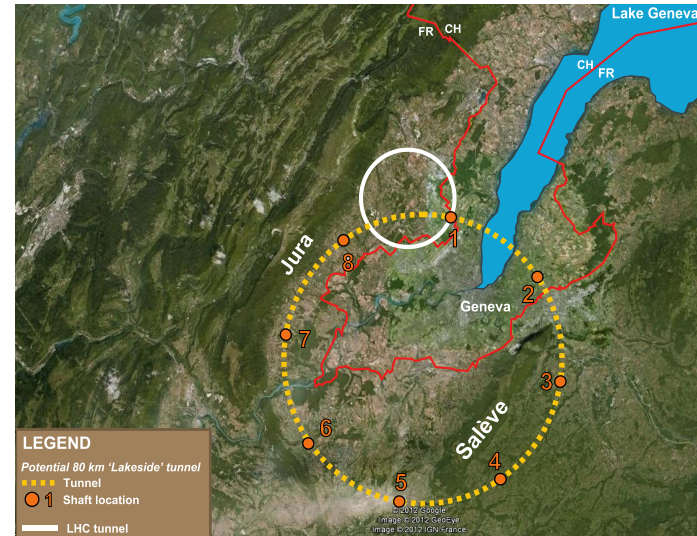
- Fully housed in the Molasse rock (preferred excavation rock in the Geneva area)
 - Under Lake Geneva
 - In front of Salève and Jura
 - Housed in France and Switzerland
 - Connected to LHC
 - Shafts every 10km
 - Too short for physics goal?



Option 3: 47km Lakeside

Potential locations

- Pre-feasibility study performed by CERN and the specialized firm ARUP.
 - Focused on
 - geology & hydrogeology,
 - tunneling & construction,
 - environmental impacts



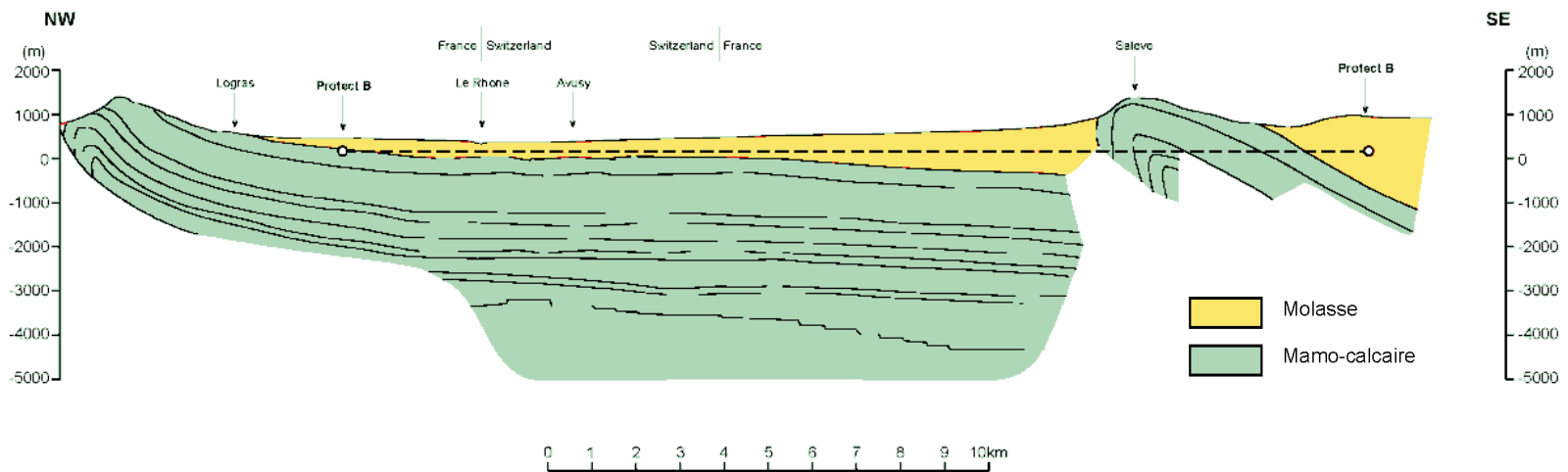
- Result: for the 80km long tunnel location 2 ‘**80km Lakeside**’ is most feasible.

	Risk										Total	Feasibility
	water ingress	heaving ground	weak marls	hydro carbons	support & lining	ground response & convergence	hydrostatic pressure & drainage	Pollution of aquifers	effect of shafts on nature	effects of shafts on urban areas		
Jura 80	5	3	0	0	5	4	5	5	4	2	33	
Lake 80	2	0	3	3	3	3	2	2	3	2	23	
Lake 47	1	0	2	2	2	2	1	1	2	5	18	

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Tunnel passes through

- Moraines
- Molasse
- Limestones



Simplified geological profile

Rock properties

- **Moraines**
 - Glacial deposits comprising gravel, sands silt and clay
 - Water bearing units

- **Molasse**
 - Mixture of marls, sandstones and formations of intermediate composition
 - Considered good excavation rock:
 - » Relatively dry and stable
 - » Relatively soft rock
 - However, some risk involved
 - » Weak marl horizons between stronger layers are zones of weakness
 - » Faulting and fissures due to the redistribution of ground stresses
 - » Structural instability

Compression strengths

Rock type	Average σ_c (Mpa)
Sandstone <i>weak</i>	10.6
<i>strong</i>	22.8
<i>Very strong</i>	48.4
Sandy marl	13.4
Marl	5.7

Rock properties

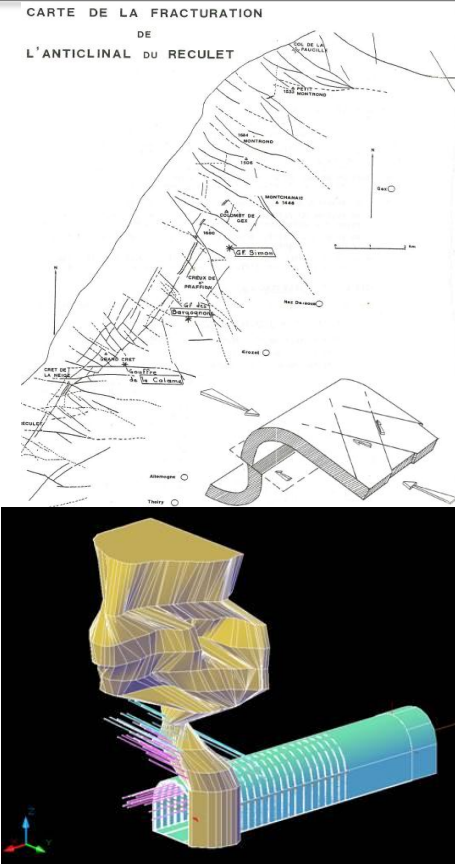
- Limestones

- Hard rock
- Normally considered as sound tunneling rock
- In this region fractures and karsts encountered
 - » Risk of tunnel collapse
 - » High inflow rates measured during LEP construction (600L/sec)
 - » Clay-silt sediments in water
 - » Rockmass instabilities

- Evaporates could be encountered

- Known to exist in the ‘deeper’ parts of the Jura mountain
- Unknown if these formations also exist at the foot of the Jura and Salève
- Contain the mineral anhydrite, which reacts to water and pressure changes -> bad rock for tunneling
 - » Major structural instabilities

Above: fractures in Jura
Below: model of tunnel collapse due to karst



Geneva plain
Underneath Lake Geneva
Through Jura and Salève Mountains

– 80km ring passes located :

- Geneva plain
- Underneath Lake Geneva
- Through Jura and Salève Mountains (~ 10%)

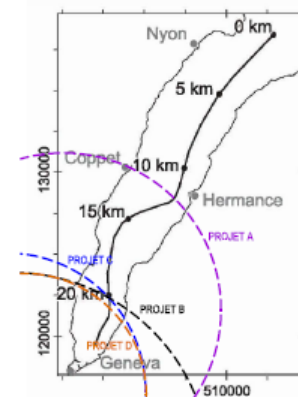
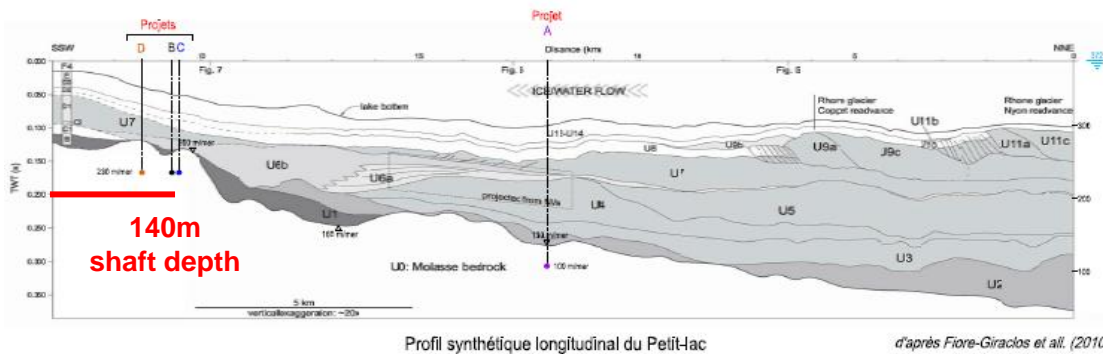
– Geneva plain area

- Consists of Moraines and Molasses
 - Tunnel, tunnel enlargements and caverns located in Molasse
 - Shafts located in Moraines and Molasse
- Near CERN the ground conditions are relatively well understood
- More information and studies needed for the south and east areas (below Rhone River and east of Geneva)
- During tunneling hydrocarbons could be encountered -> environmental issues and possible delays

Geneva plain
 Underneath Lake Geneva
 Through Jura and Salève Mountains

– Lake area consists of Moraines and Molasse

- Geology is not yet well understood
- Depth Moraine-Molasse interface needs to be determined
- Some seismic soundings performed for the possible construction of a road tunnel
 - Problems due to gas trapped in sediments -> more studies needed
- We know that the depth of the Molasse increases rapidly towards NE
- To ensure the positioning of the tunnel in the Molasse a minimal depth of ~ 140m is probably required



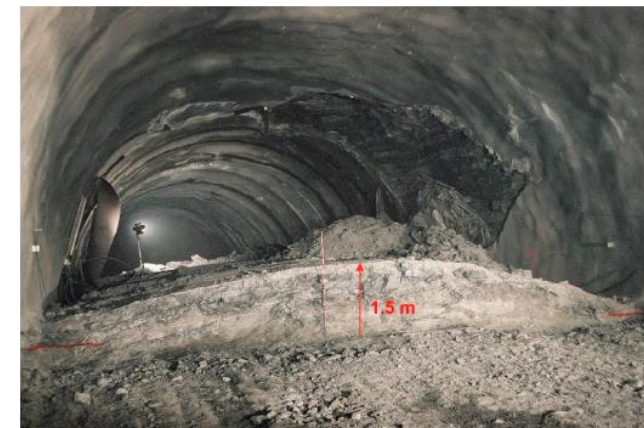
Geneva plain
Underneath Lake Geneva
Through Jura and Salève Mountains

– Mountain area consists of Limestones and evaporates

- For 10% of tunnel
- Difficult tunneling conditions
 - Local and unpredictable karst features
 - » Water conduits
 - » High flow rates (600L/sec)
 - Water transports silt-clay sediments
 - » Difficult to drawing off water through pressure relief holes
 - » Increase of water inflow over time
 - » Difficulties in removal of the water
 - » Risk of aquifer pollution & depletion
 - Anhydrites -> ‘badrock’ causes swelling
 - » Heaving of the tunnel invert
 - » Structural instabilities
 - » Probably low risk for 80km Lakeside option
but high risk for 80km Jura option



LEP tunnel collapse



Example of tunnel invert heave Chienberg tunnel, Switze

– Excavation methods

• Tunnel in Molasse

- TBM for main tunnel
 - » Tunnel advancement rate 150m/week
- Rockbreakers and roadheader for tunnel enlargements
 - » Tunnel advancement rate 30m/week



TBM

• Caverns in Molasse

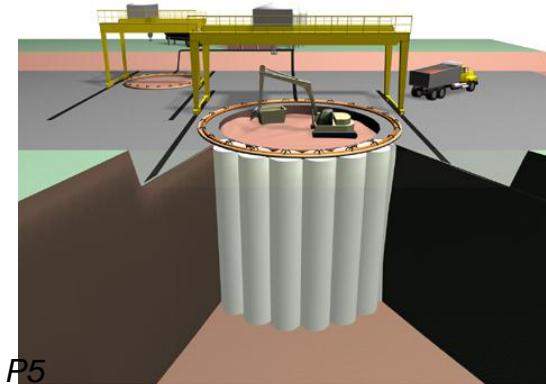
- Rockbreakers and roadheader



Roadheader

• Shafts in Moraines – Molasse

- Traditional excavation methods
- Rockbreakers and roadheader
- Special works faced with water bearing units
 - » Ground freezing
 - » Diaphragm walling
- Slipform technique for lining shaft



Ground freezing technique used at P5

– Excavation methods

- Tunnel in Limestone

- Choice between TBM and Drill & Blast (D&B)

- » Amount of tunneling through limestones is relatively short; D&B preferred
 - » In areas with karstic features D&B allows free access to the face for grouting/dewatering ahead of the face
 - » Tunnel advancement rate 20m/week



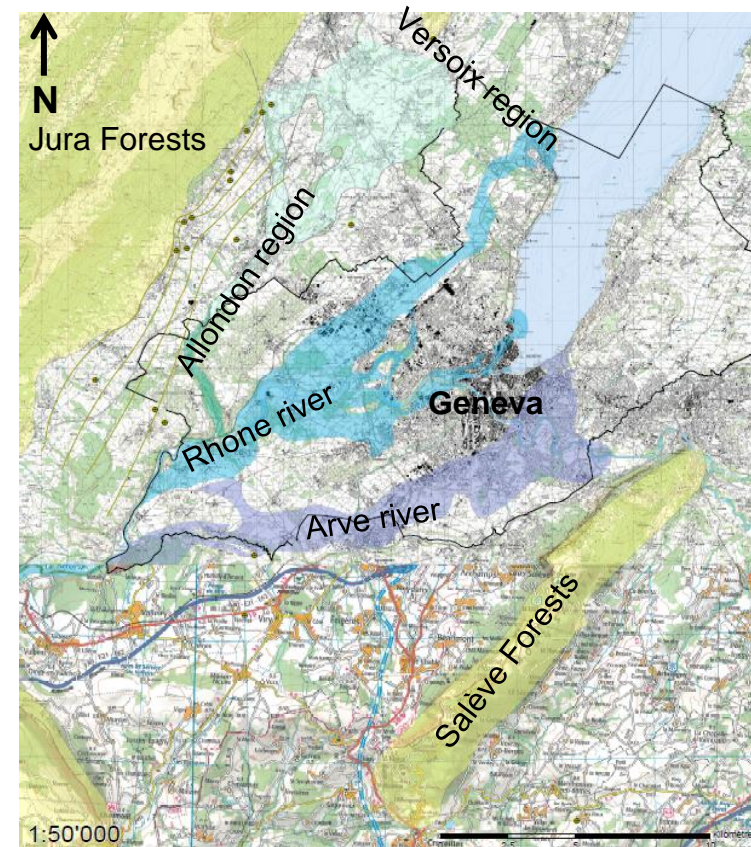
Drill & Blast

	TBM	Drill & Blast
Ground Type	Molasse	Jura Limestone
Water Pressures	up to 10bar	up to 30bar ?
Lining Options	<ul style="list-style-type: none"> • One pass undrained lining down to 100m • Two pass drained lining below 100m 	Two pass drained lining

CE considerations

Environmental

- For the 80km tunneling project, the environmental impacts should not be underestimated
 - project crosses many sensitive areas:
 - urban, agriculture, natural parks, protected groundwater areas etc.
 - Some main impacts issues to consider
 - Civil Engineering
 - Social acceptance
 - Landscape
 - Water protection
 - Natural areas
 - Radiation
 - Waste
 - Traffic



CE considerations

Environmental

- Some examples of issues to consider
 - Civil Engineering
 - Spoil deposit
 - Risk of encountering hydrocarbons in the Geneva plain
 - Risk of polluting aquifers due to Civil Engineering works
 - Risk of depleting aquifers due to pumping water related to water inflow in the tunnel (karst related)
 - Social acceptance & landscape
 - Location of shafts in urban and natural areas
 - Excavated spoil has to be deposited somewhere
 - Electricity cables, roads etc
 - Radiation effects

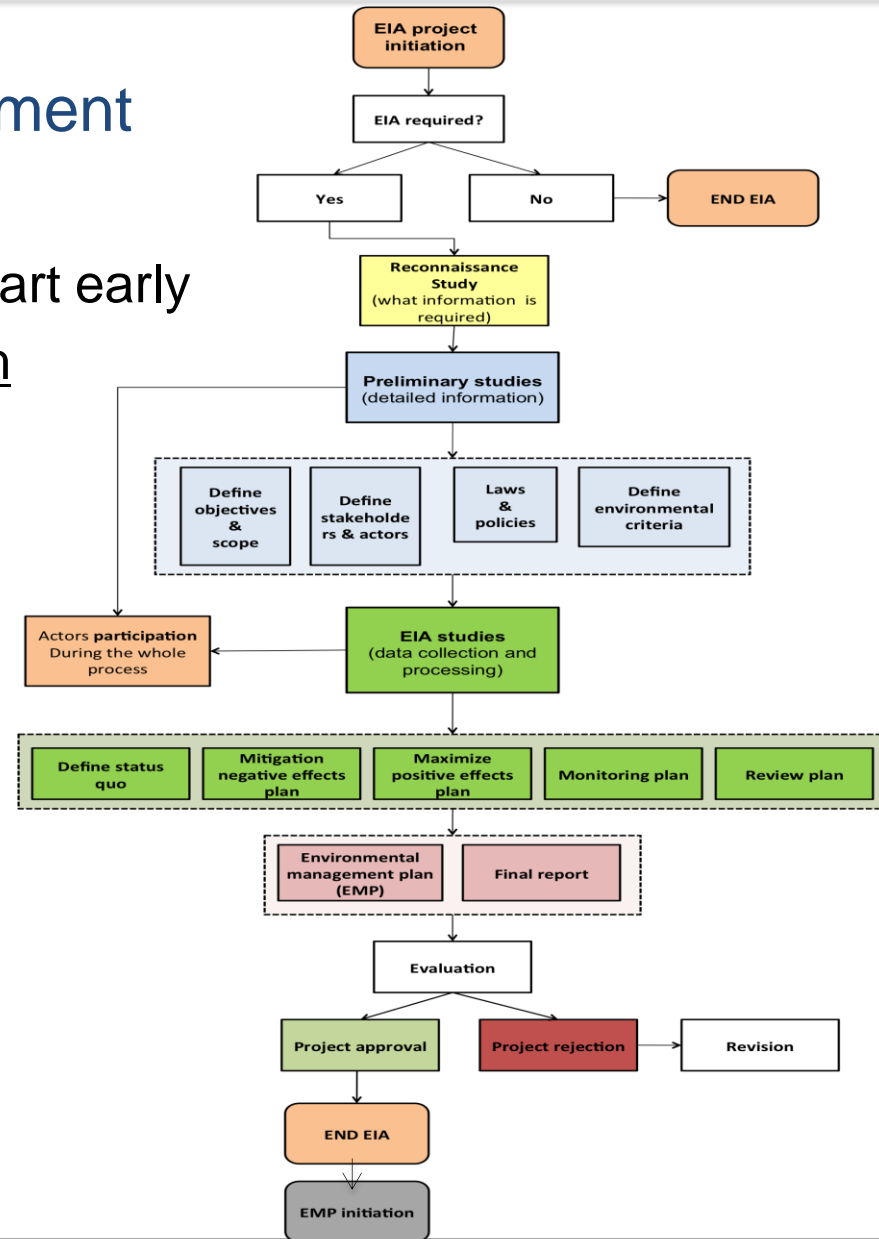
This is just the tip of the iceberg

CE considerations

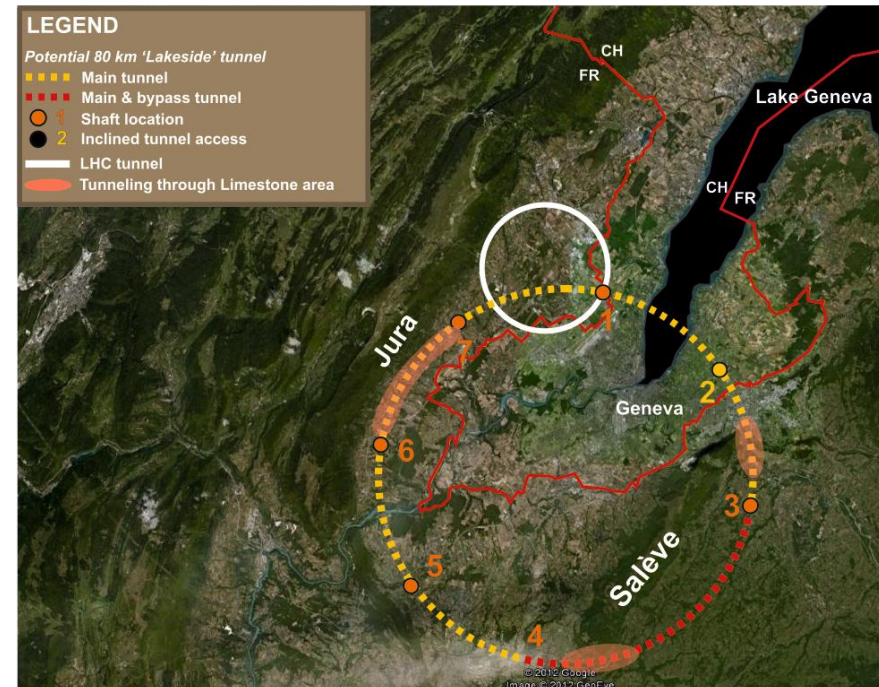
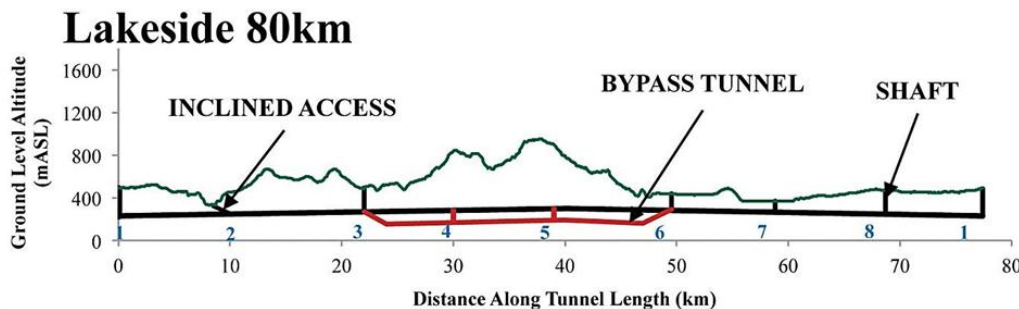
Environmental

- Environmental Impact Assessment (EIA)

- Long process, several stages, start early
- Will have to be approved by both FR and CH
 - Approval difficulties may be encountered as was recently the case for the CEVA railway expansion project



- Optimization studies for the project configuration have been started
 - Bypass tunnel in geological and environmental sensitive area
 - Inclined access tunnel in urban area
- More optimization studies needed
 - Incline tunnel?
 - More bypass tunnels?



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- Costing performed by the CERN GS-SE group
- Based on
 - Historical data (LEP, LHC, CLIC, ILC)
 - 2012 CHF unit costs from similar projects and contractors
 - Swiss standard catalogue used for cost breakdown structure
 - NO technical drawings available -> costing based on assumptions for project configuration
 - No optimization studies for the tunnel configuration have been performed yet.

- Assumptions
 - Tunnel
 - Internal diameter 5.6m
 - same as CLIC, standard size for European subway tunnels
 - 80km for machine tunnel
 - No tunnel enlargements
 - 33km for bypass tunnel and inclined access tunnel
 - Caverns
 - Two detector caverns
 - Six medium sized caverns at access points
 - Shafts
 - Two 18m internal diameter shafts connecting detector caverns with the surface
 - Five 9m internal diameter access shafts connecting the main tunnel with the surface

- Costs
 - Only the minimum civil requirements (tunnel, shafts and caverns) are included
 - 5.5% for external expert assistance (underground works only)
- Excluded from costing
 - Other services like cooling/ventilation/electricity etc
 - service caverns
 - beam dumps
 - radiological protection
 - Surface structures
 - Access roads
 - In-house engineering etc etc
- Cost uncertainty = 50%
- Next stage should include costing based on technical drawings

CE works	Costs [kCHF]
Underground	
Main tunnel (5.6m)	
Bypass tunnel & inclined tunnel access	
Dewatering tunnel	
Small caverns	
Detector caverns	
Shafts (9m)	
Shafts (18m)	
Consultancy (5.5%)	
TOTAL	

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Some examples of issues (that need further studies)

- **Geotechnical**
 - Unknown geology in lake area
 - Local ground stresses unknown
 - Risk of water ingress in limestone areas & moraines
- **Tunneling**
 - Risks related to karstic features and weak zones (faulting) in Jura
 - Degree of tunneling support
 - Heave of tunnel invert

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Feasibility /Risk Issues

Some examples of issues (needs to be studied in more detail)

- Environment
 - Risk of environmental impacts such as civil engineering, social acceptance, pollution of aquifers etc
 - Risk of encountering hydrocarbons
 - Risk of EIA rejection
- Costs
 - Risk of cost increase due to all issues mentioned

	Risk												
	water ingress	heaving ground	weak marls	hydro carbons	support & lining	ground response & convergence	hydrostatic pressure & drainage	Pollution of aquifers	effect of shafts on nature	effects of shafts on urban areas	Total		
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Lake 47	1	0	2	2	2	2	1	1	2	5	18		High

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- Project only in its very initial stage

- To continue further the following steps are required
 - Define project requirements
 - Detector cavern requirements, dump caverns, shielding requirements, other services defined, etc.etc.
 - Perform siting studies
 - Optimization studies for the tunnel configuration
 - E.g. tunnel inclination, shaft locations, increase tunnel circumference etc.
 - Create preliminary technical Civil Engineering designs
 - Continue feasibility studies
 - Continue environmental impact studies

THANK YOU FOR YOUR ATTENTION