Beam induced backgrounds at the CEPC Ref-TDR

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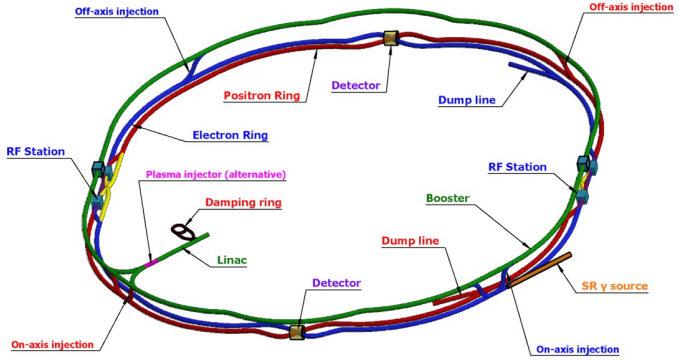
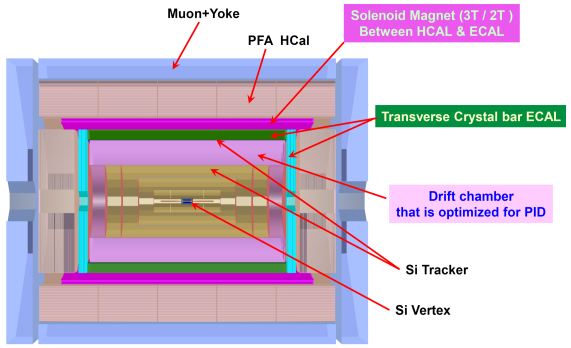
Introduction – CEPC MDI

- MDI stands for ”Machine Detector Interface”
  - Interaction Region and other components
  - 2 IPs
  - 33mrad Crossing angle
- Flexible optics design
  - Common Layout in IR for all energies – TDR 50MW
  - High Luminosity, low background impact, low error
  - Stable and easy to install, replace/repair

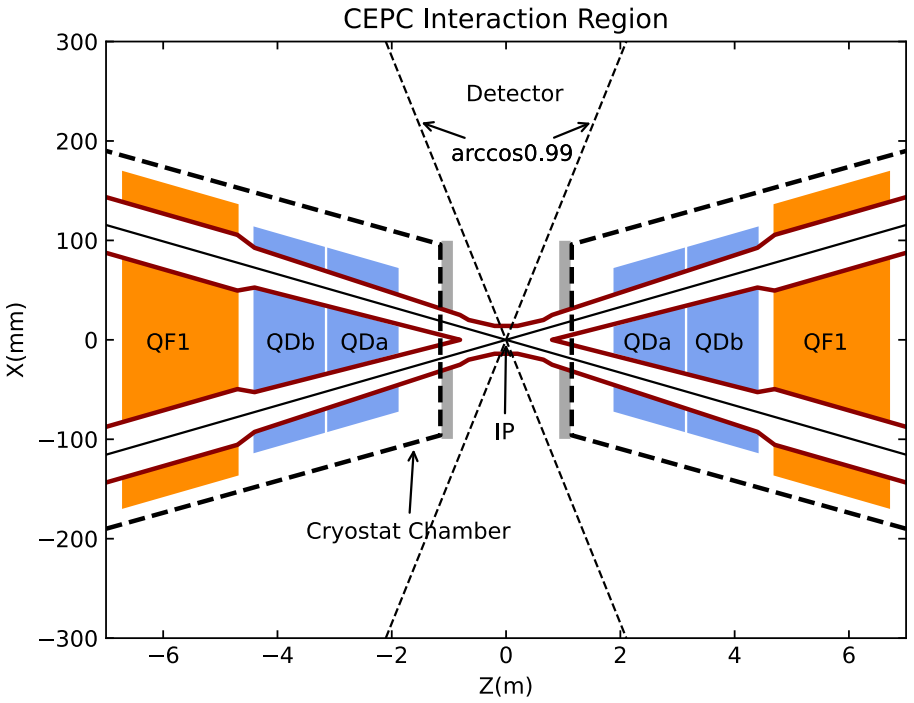


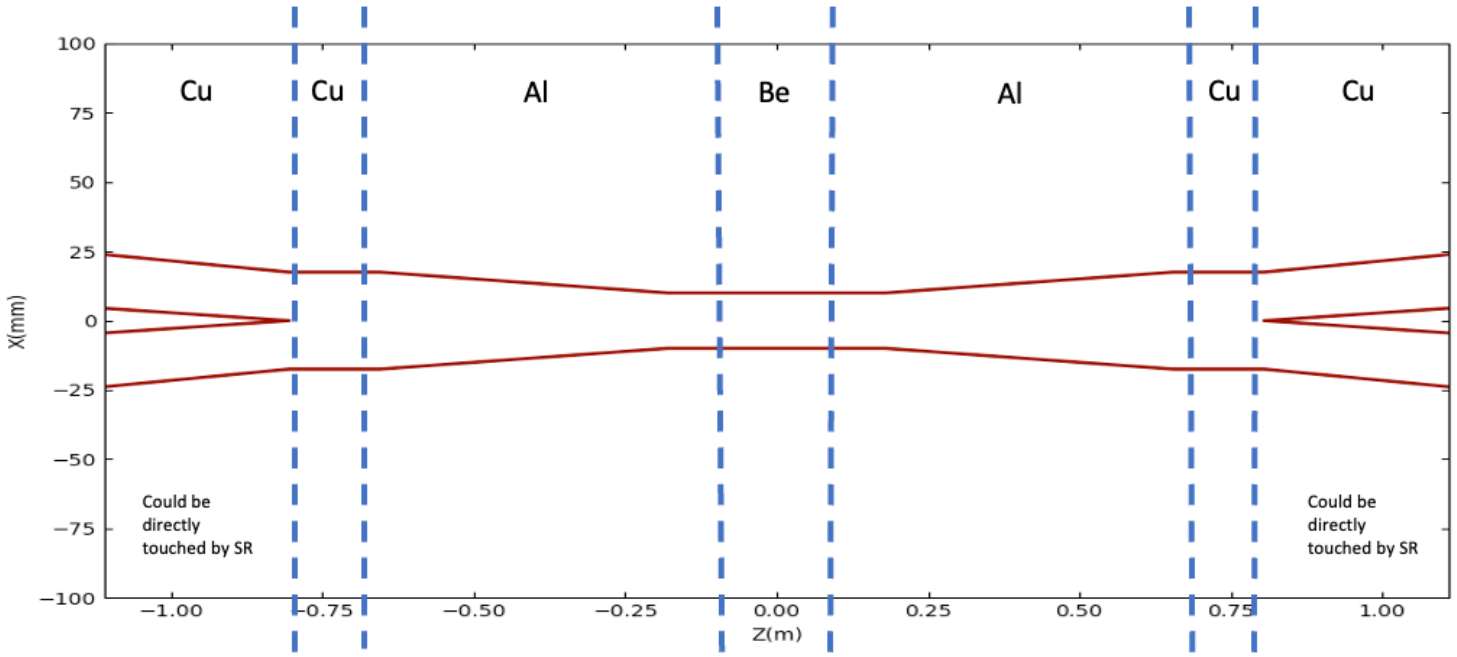


	Higgs	Z	W	$t\bar{t}$
Number of IPs	2			
Circumference (km)	100.0			
SR power per beam (MW)	50			
Half crossing angle at IP (mrad)	16.5			
Bending radius (km)	10.7			
Energy (GeV)	120	45.5	80	180
Energy loss per turn (GeV)	1.8	0.037	0.357	9.1
Damping time $\tau_x/\tau_y/\tau_z$ (ms)	44.6/44.6/22.3	816/816/408	150/150/75	13.2/13.2/6.6
Piwinski angle	4.88	29.52	5.98	1.23
Bunch number	446	13104	2162	58
Bunch spacing (ns)	355 (53% gap)	23 (10% gap)	154	2714 (53% gap)
Bunch population (10^{11})	1.3	2.14	1.35	2.0
Beam current (mA)	27.8	1340.9	140.2	5.5
Phase advance of arc FODO (°)	90	60	60	90
Momentum compaction (10^{-5})	0.71	1.43	1.43	0.71
Beta functions at IP β_x^*/β_y^* (m/mm)	0.3/1	0.13/0.9	0.21/1	1.04/2.7
Emittance $\varepsilon_x/\varepsilon_y$ (nm/pm)	0.64/1.3	0.27/1.4	0.87/1.7	1.4/4.7
Betatron tune ν_x/ν_y	445/445	317/317	317/317	445/445
Beam size at IP σ_x/σ_y (um/nm)	14/36	6/35	13/42	39/113
Bunch length (natural/total) (mm)	2.3/4.1	2.7/10.6	2.5/4.9	2.2/2.9
Energy spread (natural/total) (%)	0.10/0.17	0.04/0.15	0.07/0.14	0.15/0.20
Energy acceptance (DA/RF) (%)	1.6/2.2	1.0/1.5	1.05/2.5	2.0/2.6
Beam-beam parameters ξ_x/ξ_y	0.015/0.11	0.0045/0.13	0.012/0.113	0.071/0.1
RF voltage (GV)	2.2	0.1	0.7	10
RF frequency (MHz)	650			
Longitudinal tune ν_s	0.049	0.032	0.062	0.078
Beam lifetime (Bhabha/beamstrahlung) (min)	40/40	90/930	60/195	81/23
Beam lifetime requirement (min)	20	81	25	18
Hourglass Factor	0.9	0.97	0.9	0.89
Luminosity per IP (10^{34} cm^{-2} s^{-1})	8.3	192	26.7	0.8

Current Design of the IR

- Interaction Region Layout/Parameters
  - L* = 1.9m / Detector Acceptance = 0.99



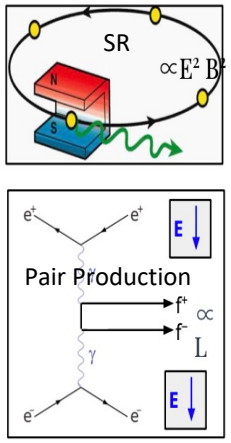


The length of Interaction Region is -7m~7m at TDR Phase

Background Estimation

- Single Beam
  - Touschek Scattering
  - Beam Gas Scattering(Elastic/inelastic)
  - Beam Thermal Photon Scattering
  - Synchrotron Radiation
- Luminosity Related
  - Beamstrahlung
  - Radiative Bhabha Scattering
- Injection

A. Natochii



Photon BG

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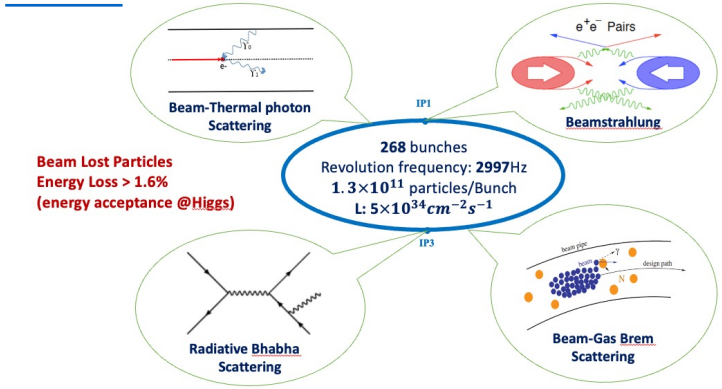
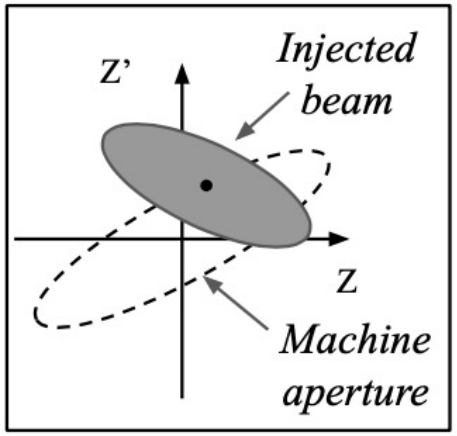


Beam Loss BG

A. Natochii



Injection BG

Background	Generation	Tracking	Detector Simu.
Synchrotron Radiation	BDSim	BDSim/Geant4	Mokka/CEPCSW/FLUKA
Beamstrahlung/Pair Production	Guinea-Pig++	SAD	
Beam-Thermal Photon	PyBTH[Ref]		
Beam-Gas Bremsstrahlung	PyBGB[Ref]		
Beam-Gas Coulomb	BGC in SAD		
Radiative Bhabha	BBBREM		
Touschek	TSC in SAD		

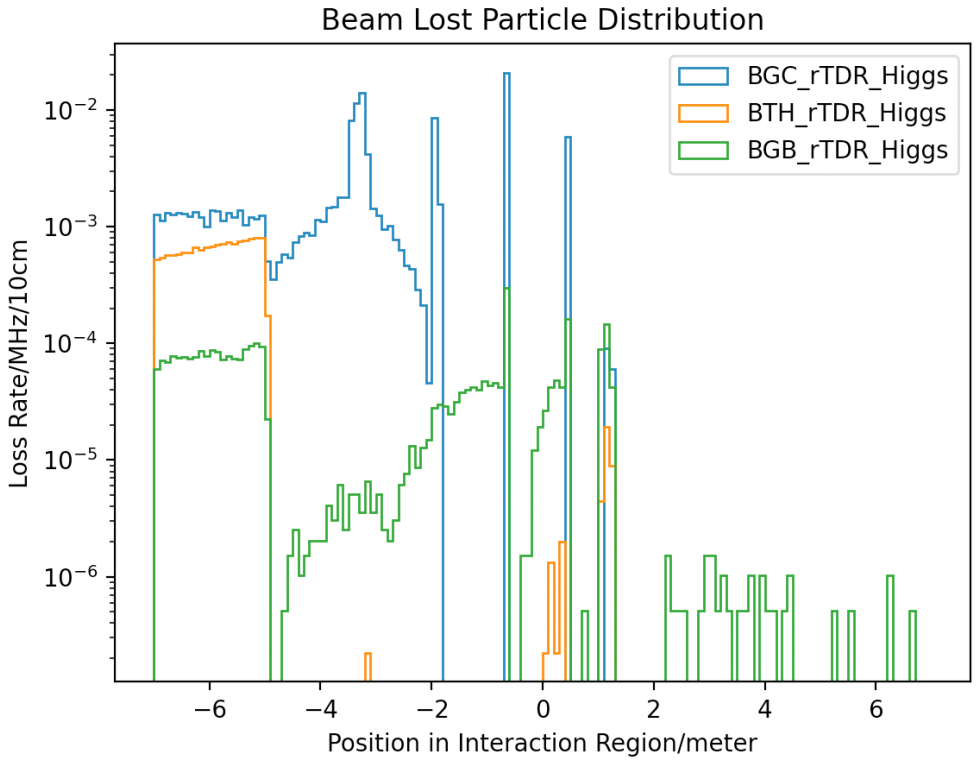
- One Beam Simulated
- Simulate each background separately
- Whole-Ring generation for single beam BGs
- Multi-turn tracking(50 turns)
  - Using built-in LOSSMAP
  - SR emitting/RF on
  - Radtaper on
  - No detector solenoid yet(Z updating)

Loss Distribution

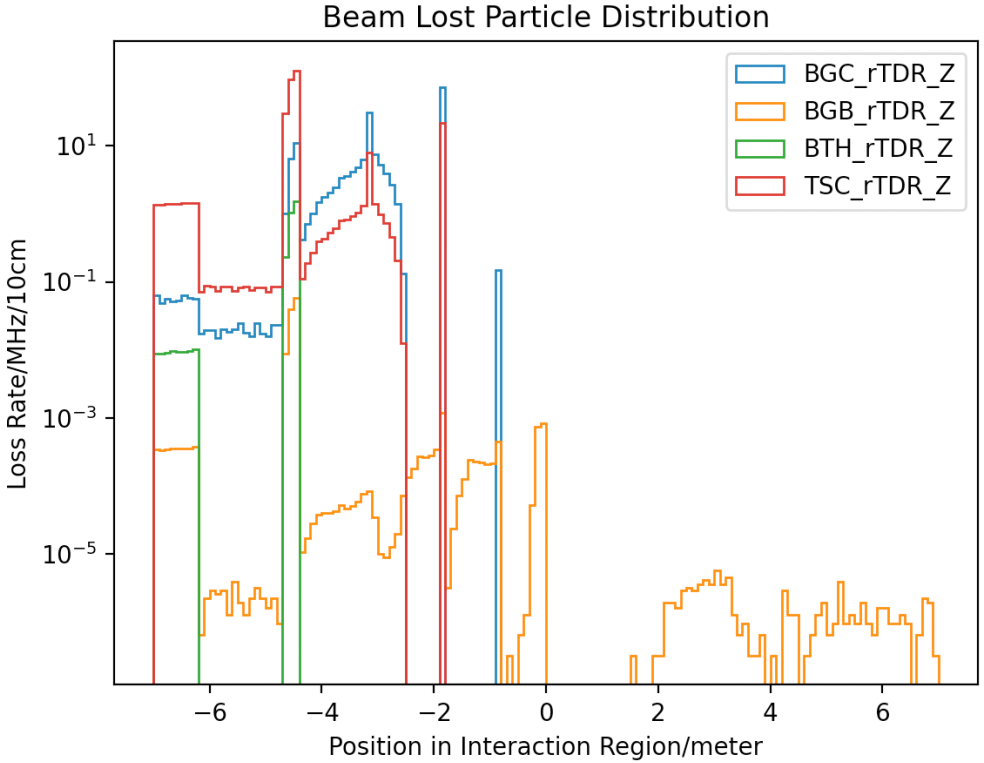
- Errors implemented
  - High order error for magnets
  - Beam-beam effect
- No Detector Solenoid in Tracking

$$Loss\ Rate = \frac{Loss\ Number}{Loss\ Time} = \frac{Bunch\ number * Particles\ per\ Bunch * (1 - e^{-1})}{Beam\ Lifetime}$$

@Higgs



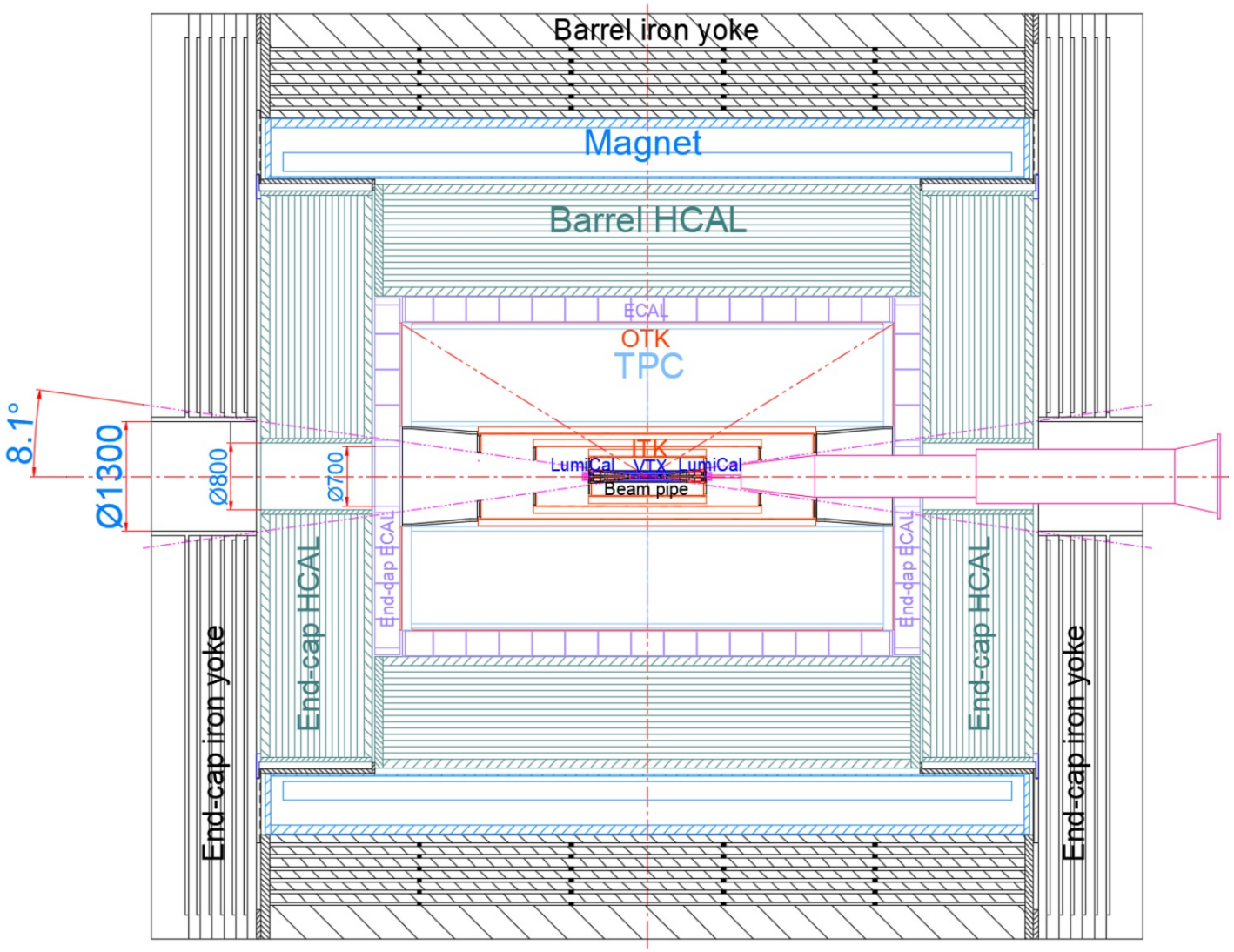
@Z-pole



Estimation of Impacts in the IR

- Noise on Detector(Backgrounds)
  - Occupancy
  - Estimate using the same tool with Physics simulation
- Radiation Environment(Backgrounds + Signal)
  - Radiation Damage of the Material(Detector, Accelerator, Electronics, etc…)
    - Estimate using the same tool with physics simulation including the dose calculation
    - Or FLUKA
  - Radiation Harm of the human beings and environment
    - Estimate using the same tool with physics simulation including the dose calculation
    - Or FLUKA

Current Status



Current Status II

Background	Mode	Generation	Tracking	Noise Estimation	Rad. Da. Esti.	Rad. Env. Esti.
Synchrotron Radiation	Higgs	Testing	To do	To do	To do	To do
	Z	To do	To do	To do	To do	To do
Beamstrahlung/Pair Production	Higgs	Done	-	Mass Pro. Done	Ready to Mass P	Ready to Mass P
	Z	Done	-	Ready to Mass P	Ready to Mass P	Ready to Mass P
Beam-Thermal Photon	Higgs	Done	Done w.o. Sol	Mass Pro. Done	Ready to Mass P	Ready to Mass P
	Z	Done	Done w.o. Sol	Ready to Mass P	Ready to Mass P	Ready to Mass P
Beam-Gas Bremsstrahlung	Higgs	Done	Done w.o. Sol	Mass Pro. Done	Ready to Mass P	Ready to Mass P
	Z	Done	Done w.o. Sol	Ready to Mass P	Ready to Mass P	Ready to Mass P
Beam-Gas Coulomb	Higgs	Done	Done w.o. Sol	Mass Pro. Done	Ready to Mass P	Ready to Mass P
	Z	Done	Done w.o. Sol	Ready to Mass P	Ready to Mass P	Ready to Mass P
Radiative Bhabha	Higgs	Done	Doing	Code Ready	Code Ready	Code Ready
	Z	Done	Doing	Code Ready	Code Ready	Code Ready
Touschek	Higgs	Done	Done w.o. Sol	Ready to Mass P	Ready to Mass P	Ready to Mass P
	Z	Done	Done w.o. Sol	Ready to Mass P	Ready to Mass P	Ready to Mass P