# Positron Source Overview and Layout for BAW-2

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# THE PROPOSAL

- **A relocation of the positron source systems from the nominal 150 GeV point of the electron Main Linac to the exit of the electron Main Linac (≤250 GeV depending on physics scenario), and integrated into the beginning of the Beam Delivery System.**

- **The new baseline proposal includes a description of a possible low energy operating scheme. The scheme (10 Hz running, alternate pulse) is consistent with the RDR.**

**"Physics runs are possible for energies above √s = 200 GeV."**

- **The positron yield is ≥ 1.5 over this energy range and enables operation with the RDR parameters or the 'Reduced Beam Parameter Set.'**

# OUTLINE of this OVERVIEW

- SOURCE REQUIREMENTS
- BASIC RDR DESIGN & PERFORMANCE
- OMD OPTIONS
- HISTORICAL DEVELOPMENT
- LOW ENERGY RUNNING and 10Hz OPERATION
- KEEP ALIVE OR AUXILIARY SOURCES
- 3D LAYOUT OF E+ SOURCE IN CENTRAL REGION
- SOME CONCLUSIONS

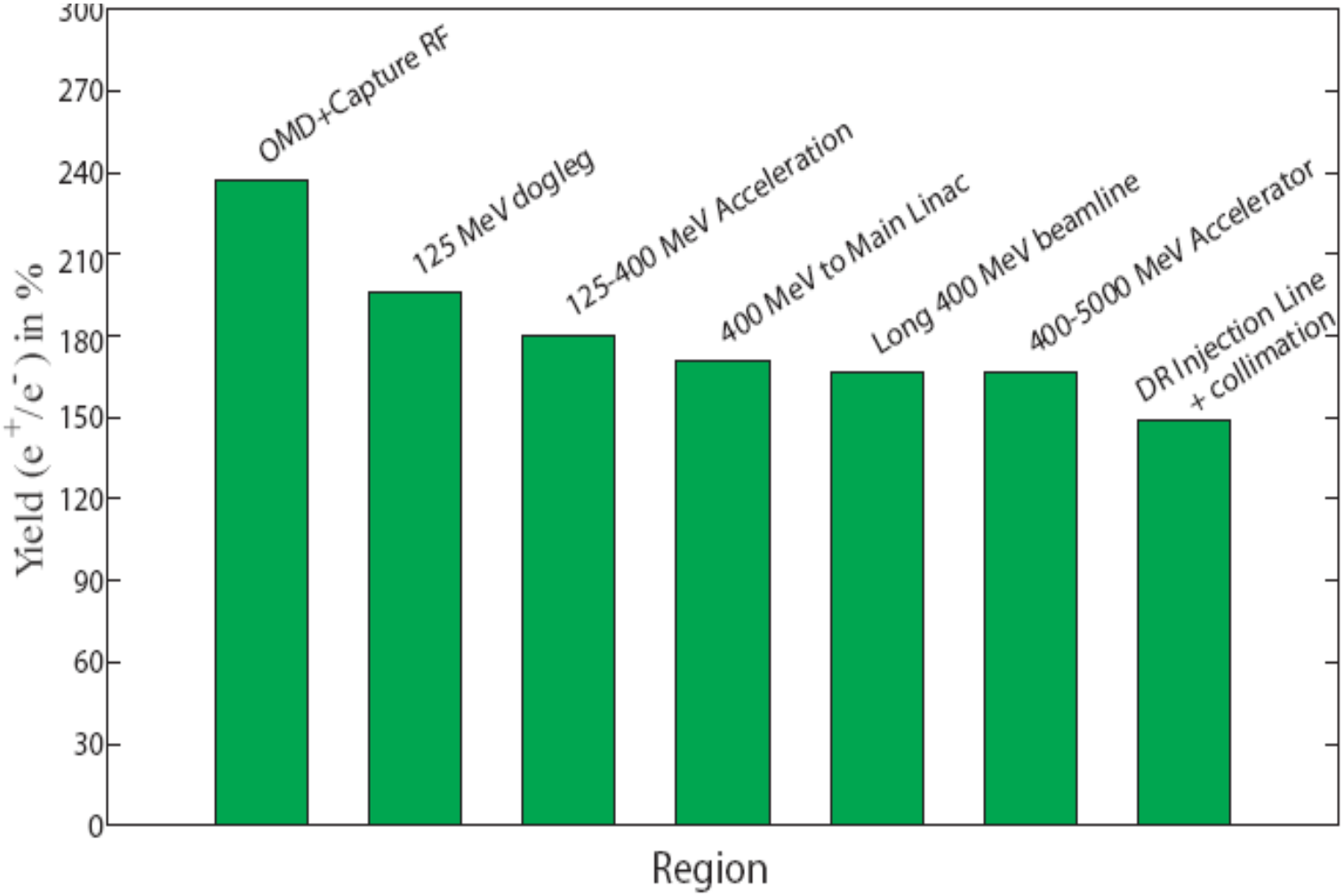
# SOURCE PARAMETERS from RDR

TABLE 2.3-1
Nominal Positron Source parameters († upgrade values).

Equal to electrons per bunch at the IP. Overall yield of one

| Beam Parameters | Symbol | Value | Units |
|---|---|---|---|
| Positrons per bunch at IP | $n_b$ | $2\times10^{10}$ | number |
| Bunches per pulse | $N_b$ | 2625 | number |
| Pulse repetition rate | $f_{rep}$ | 5 | Hz |
| Positron energy (DR injection) | $E_0$ | 5 | GeV |
| DR transverse acceptance | $\gamma(A_x+A_y)$ | 0.09 | m-rad |
| DR energy acceptance | $\delta$ | $\pm$ 0.5 | % |
| DR longitudinal acceptance | $A_l$ | $\pm3.4\times\pm25$ | cm-MeV |
| Electron drive beam energy | $E_e$ | 150 | GeV |
| Electron beam energy loss in undulator | $\Delta E_e$ | 3.01 | GeV |
| Positron polarization † | $P$ | ~60 | % |

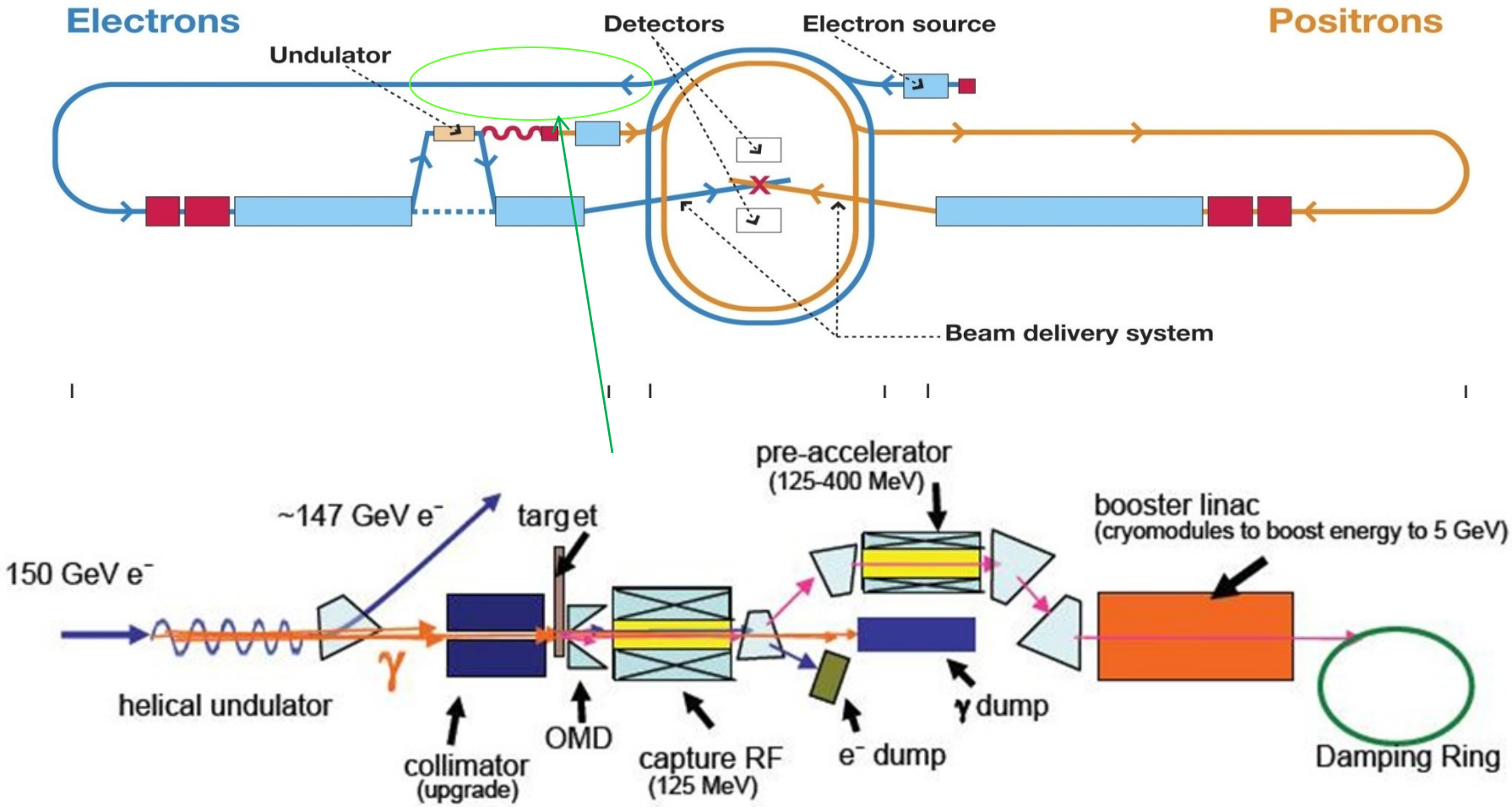
# YIELD AT VARIOUS POINTS THROUGH E+ SYSTEM LEADING TO VALUE OF 1.5 AT ENTRANCE TO DAMPING RING




2.3-5. Positron yield in various parts of the Positron Source.

# ILC RDR baseline "Schematic" of Major Subsystems

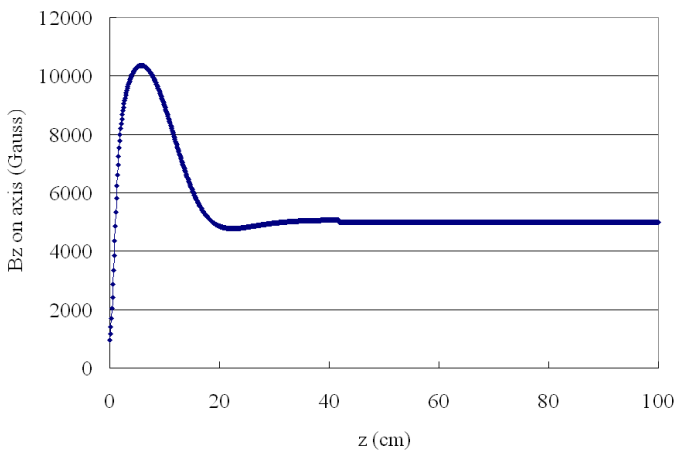
## Not to any scale



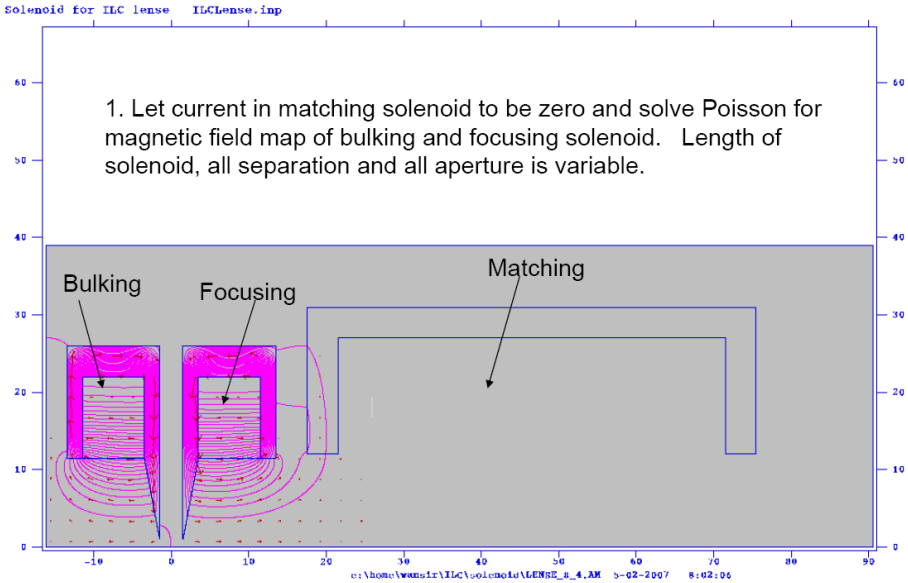
# Quarter wave solenoid

## Used in present design calculations

- Low field, 1 Tesla on axis, tapers down to 1/2 T.
- Capture efficiency is only 25% less than flux concentrator
- Low field at the target reduces eddy currents
- This is probably easier to engineer than flux concentrator
- SC, NC or pulsed NC?



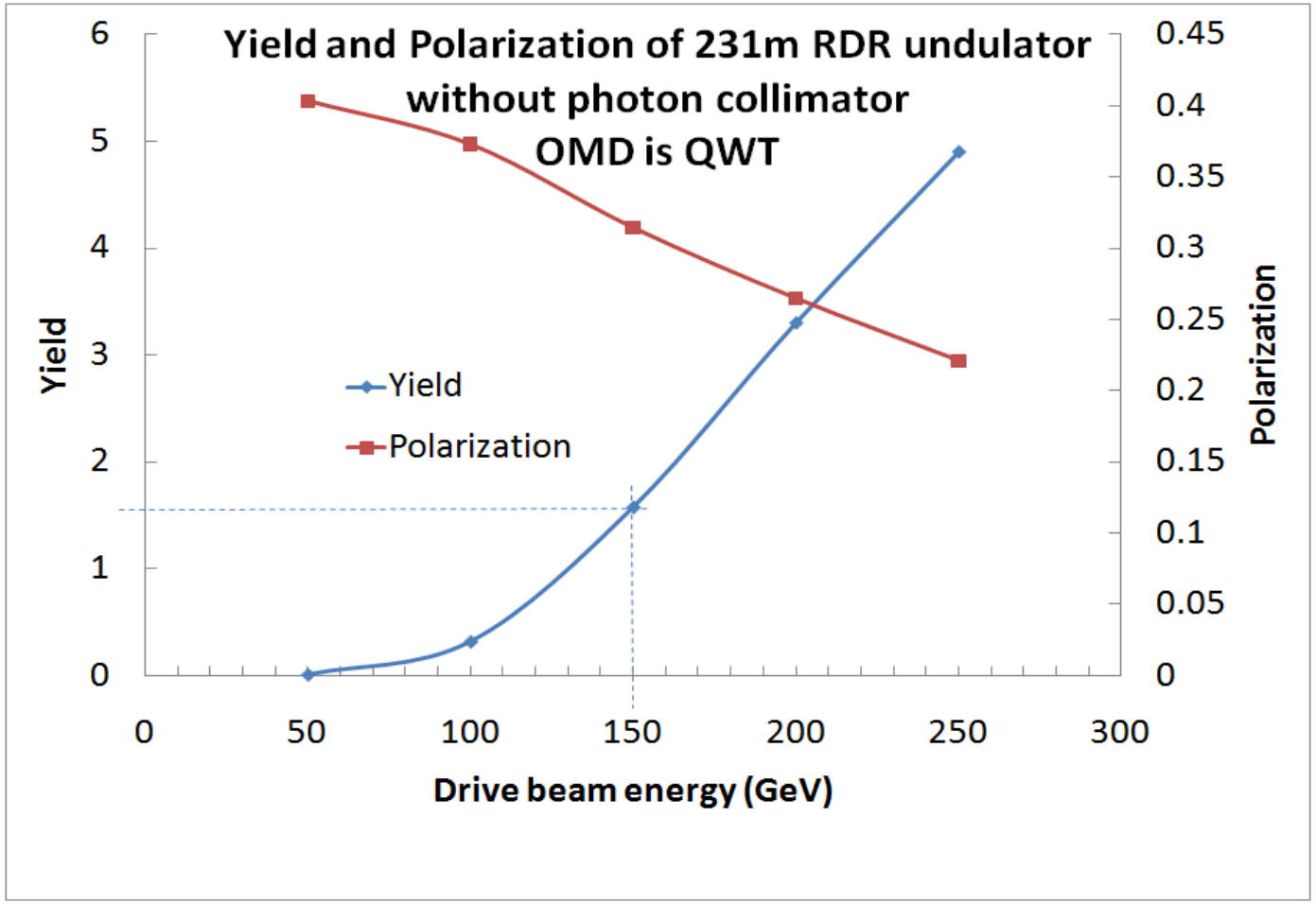

ANL ¼ wave solenoid simulations




The target will be rotating in a B field of about 0.2T

W. Liu

# An Example of yield and polarization with different drive beam energies.



# Alternative OMD's Optical Matching Devices

- Same target
- Beam and accelerator phase optimized for each OMD
- OMD compared:
  - AMD
  - Flux concentrator
  - ¼ wave transformer
  - Lithium lens

| OMD | Capture efficiency |
|---|---|
| Immersed target, AMD<br>(6T-0.5T in 20 cm) | ~30% |
| Non-immersed target, flux concentrator<br>(0-3.5T in 2cm, 3.5T-0.5T 14cm) FUTURE? | ~26% |
| 1/4 wave transformer<br>(1T, 2cm) TODAY | ~15% |
| 0.5T Back ground solenoid only | ~10% |
| Lithium lens | ~29% |

# What is a FLUX CONCENTRATOR

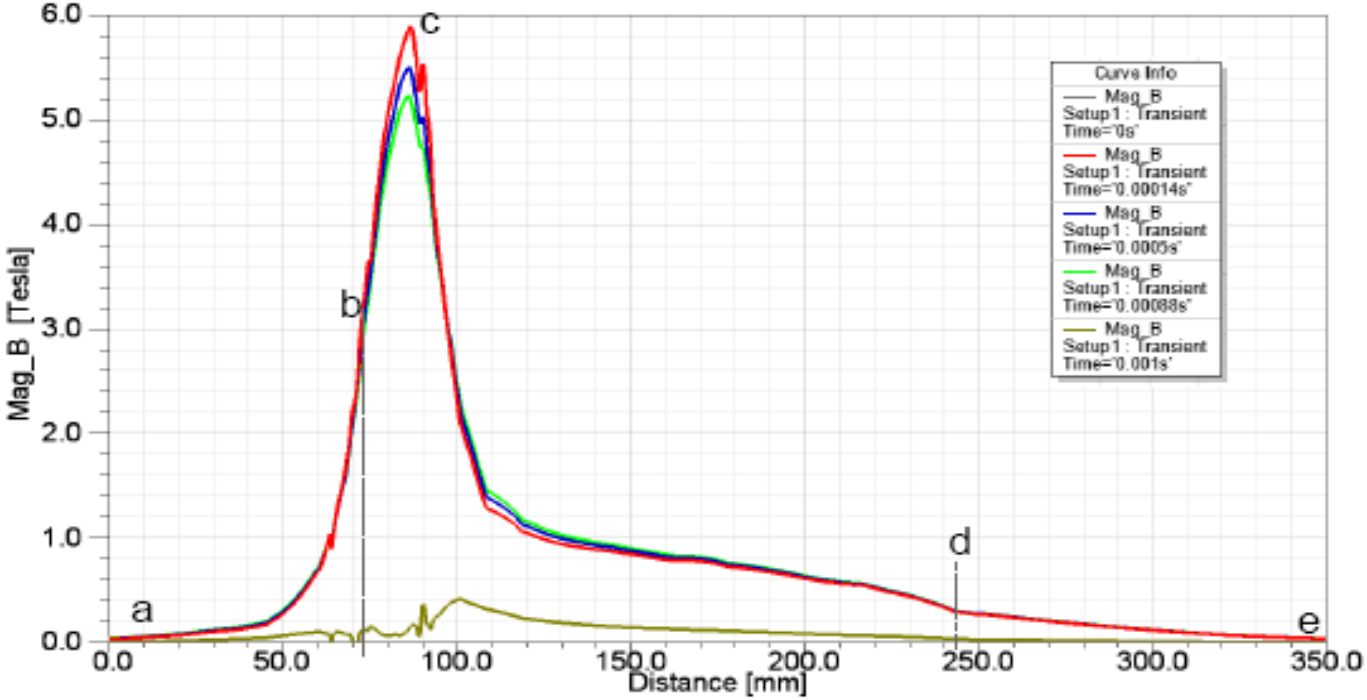
## Cryogenic Pulsed Flux Concentrator

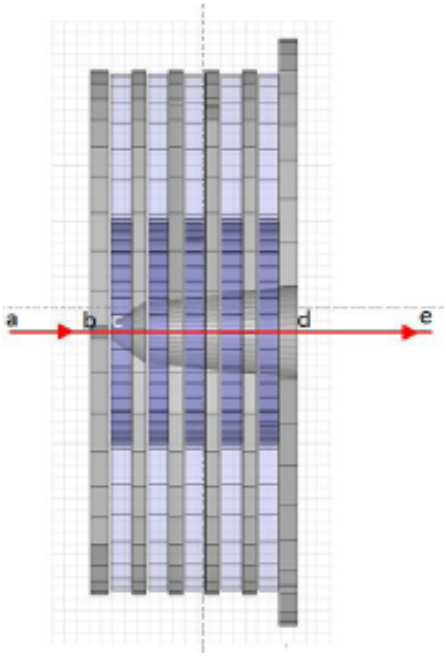
- Flux Concentrator is the RDR baseline
  - **The more conservative QWT was used for recent studies**
- 1 millisecond pulsed flux concentrator is desired to increase capture efficiency
  - **Reduced number of undulators**
  - **Lower photon beam power on target**
    - Reduced stress and power on target
    - Reduced radiation load on target
    - Reduced radiation load in the accelerating sections
- Previous liquid nitrogen cooled, 40ms pulsed flux concentrator built and operated by Brechna at SLAC
  - **We have started from that design**

**From J .Gronberg 11/11/2010**

27/09/2006 **Global Design Effort** 14

# Flux Concentrator Field



# Prototyping plan

**As of Nov 2010**

- Finalizing design choices:
  - **Electric insulation material for radiation resistance**
  - **Energizing coil configuration with impedance matched to pulse forming network to create 1 ms flat top**
- Prototyping stage 1:
  - **Build prototype and pulse at room temperature with low duty cycle**
- Prototyping stage 2:
  - **Cool with liquid nitrogen, run with low duty cycle, minimal refrigeration plant**
  - **Verify pulse length and flat top**
- **Reach this stage by late 2012**
- Prototyping stage 3:
  - **Full refrigeration plant**
  - **Operate at full duty cycle**

# Brief History of Designs and Layouts From RDR on.

- Insert at Mid Linac → Complicates any design changes (gradient or energy upgrade) and operation of the linac.
- Conceptual to Detail design → Has revealed more complexity and longer insert than RDR
- Complex underground layouts → Impact on site and layout. High radiation vaults and shafts. Many different subsystems need RF or Pulsed power. Unsuitable for single tunnel designs Need two tunnel design in mid linac!
- Add machine protection system for undulator → longer insert
- Some concerns about operation that requires front half of linac to run at high gradient all the time then accelerate or decelerate in second half.
- Linac insert becoming less and less attractive !

# Brief History of Designs and Layouts Leading up to SB2009

- End of Linac sharing with BDS → Revisit pro's and cons
- Reduces number of components or systems →Cost savings
- Reduced underground volume for all central region but maintain support tunnel shared with BDS → Cost savings
- Remote radioactive handling in central region only → Site simplification and cost savings.
- Variable drive beam energy and vary undulator length→ Conservative above 300 GeV but fails performance goals at 250 and below.
- Start re-considering options!
- With modifications to DR etc, evaluate 5+5 or 10 Hz operation with good yield at all energies. → Cost increase

# 10 Hz System Operation

- E- Source, DR's and e-Linac operate at 10 Hz
- E- Linac energy alternates between 100 to 125 GeV (for collisions)and ≥ 150 GeV (for E+ production with yield ≥ 1.5) but uses the whole linac length at low gradient.
- DR's Damping time reduced to ½ of RDR value
- E+ DR operates with 50% duty cycle
- Need some additional transport lines to dump the electron beam used for e+ production. Several options need study.

All are technically feasible but (RED) indicates increased cost.

- Many related talks today by Gai, Fukuda, Adolphsen, Kuchler, Guiducci, Brachmann, Kubo, and by Garbincius and Clarke tomorrow morning.

# Alternatives to 10 Hz Solution but still Helical Undulator Based

Continue to optimize undulator, target, OMD etc for better yield at low energies, for example

- Use TGT with Flux Concentrator instead of QWT (as assumed in RDR) Ongoing R&D at LBNL
- Use higher field and shorter period undulators, see later talks by Wei Gai and Jim Clarke
- Use Liquid Metal TGT's (e.g. Li Lens)
- Low Charge Parameters see Jie Gao talk

Can or could be (should be, given adequate resources) considered as future options but they are not yet ready to be the basis for the much needed

***BASELINE for TDR 2012***

design and TLCC at this point in time.

# Concept of "Auxiliary" or "Keep Alive Source " without the E- Linac and Undulator

- During commissioning or during startup after maintenance periods it would be desirable to provide an alternative source of positrons (or E-) to the Damping Ring. The RDR design had a "Keep alive source" at the end of the linac, which could produce a low intensity 'diagnostic' beam.
- This consisted of a 500 MeV e- injector linac and a duplicate target, OMD, capture accelerator in the central region. In SB2009 there is an equivalent to the KAS which shares the same target, OMD, accelerators to 400MeV, --- an auxiliary (AUX) source.
- In the studies of the Central Region layouts with the E+ source overlapping with the BDS, a conceptual AUX Source electron linac (L-Band, S-Band or X-Band ?) has been incorporated.

# EXAMPLE LAYOUT OF THE CENTRAL REGION & E+ SOURCE

## A Walkthrough with JMP

## Credits to

Jim Clarke (*STFC* Daresbury *Lab*) ,
Norbert Collomb (*STFC*)

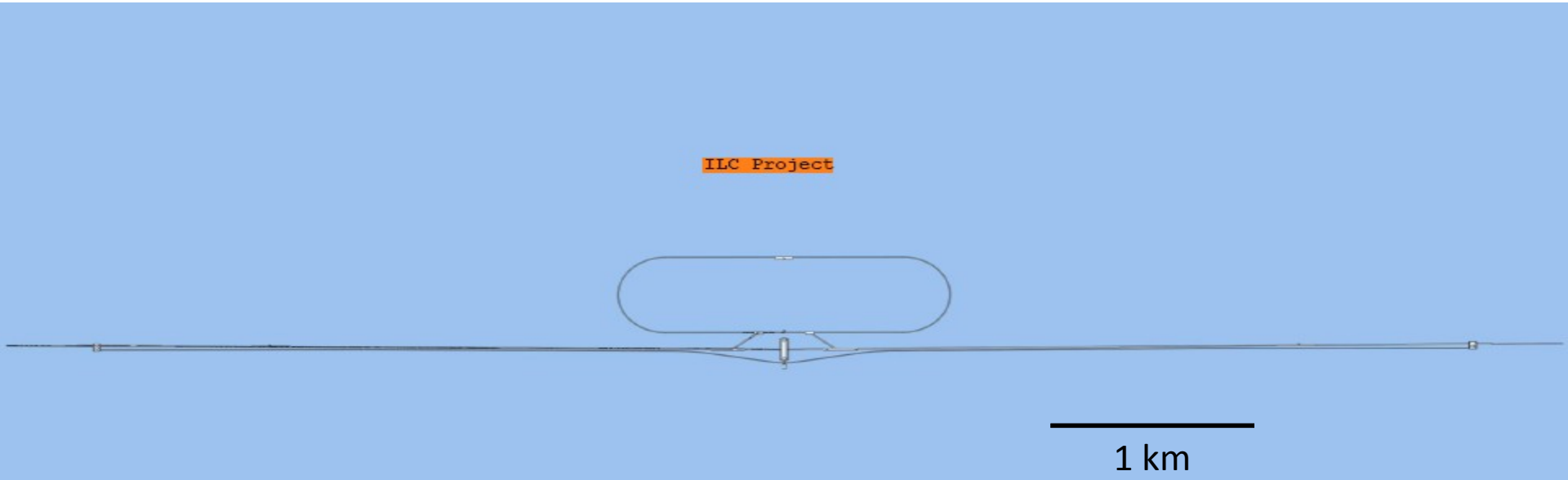
plus all the

CFS and Technical Systems Teams

**Slides 20 through 26 would be applicable today for an E+ source insert in the mid-point of the linac**

# Central Region +/- 3 km

**Sources, Damping Rings ,Beam Delivery Systems and IR Hall drawn to approximate scale**



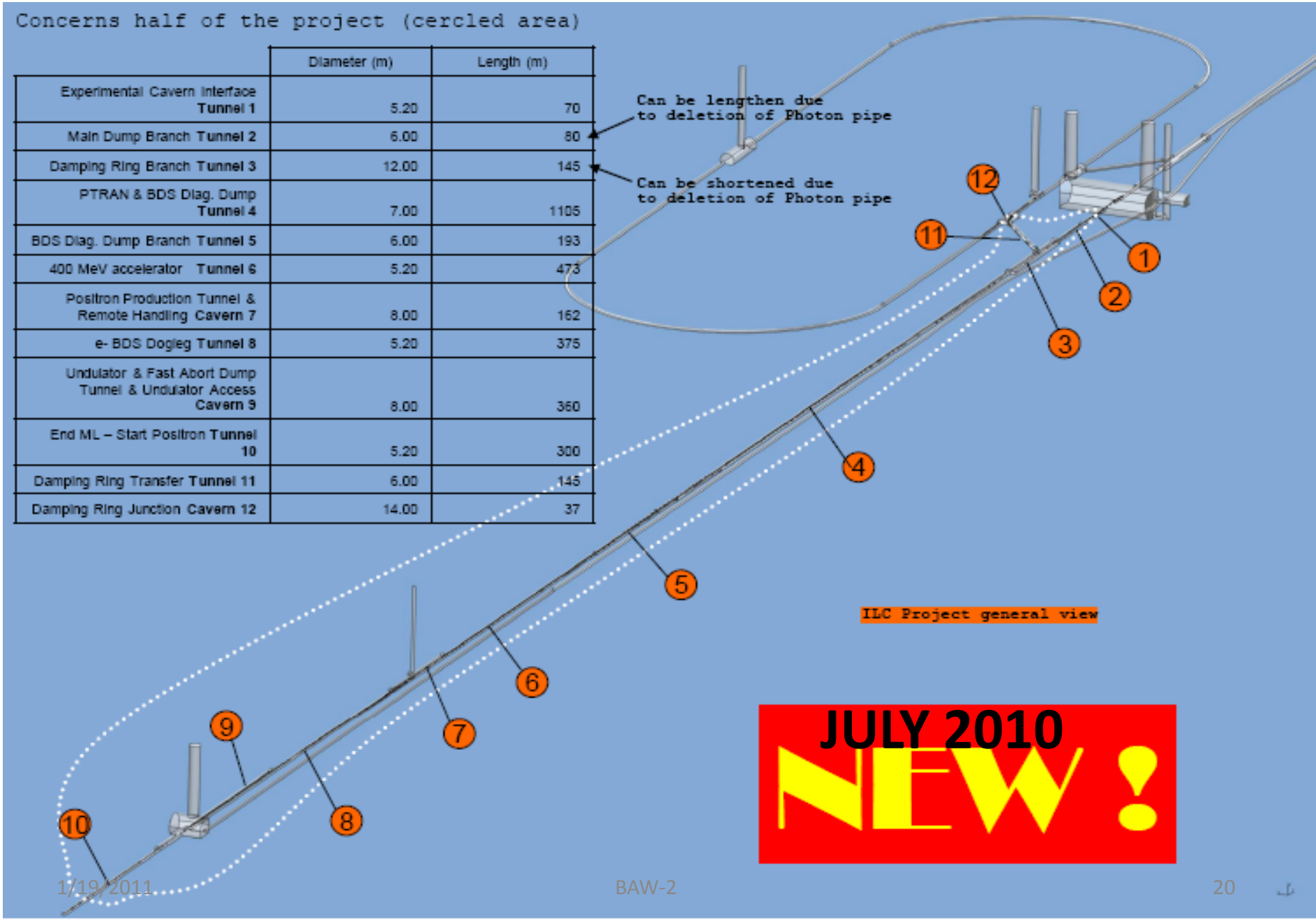

NEW !

**Means new as of JULY 2010**

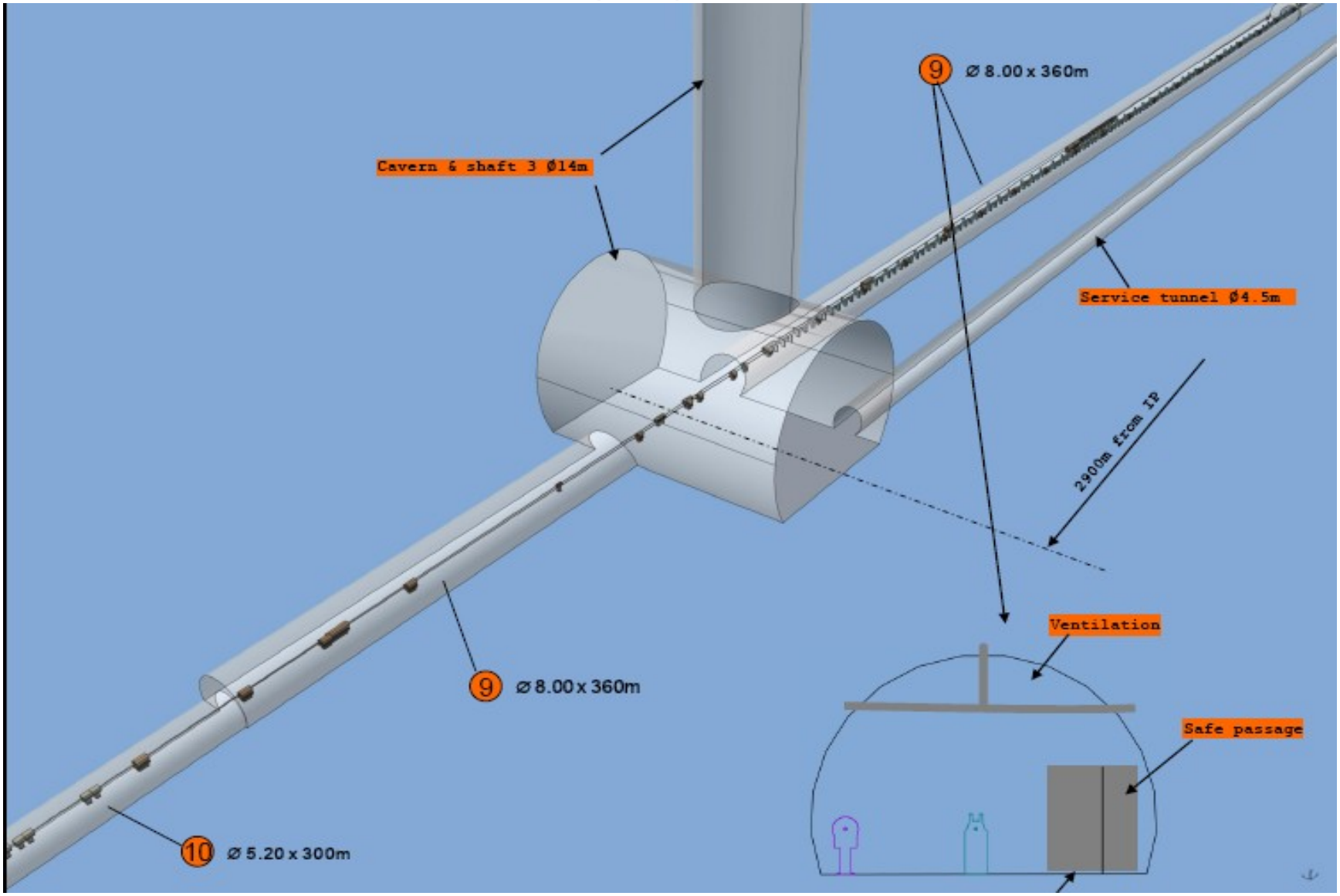
# End of Linac to IR Hall

Concerns half of the project (cercled area)

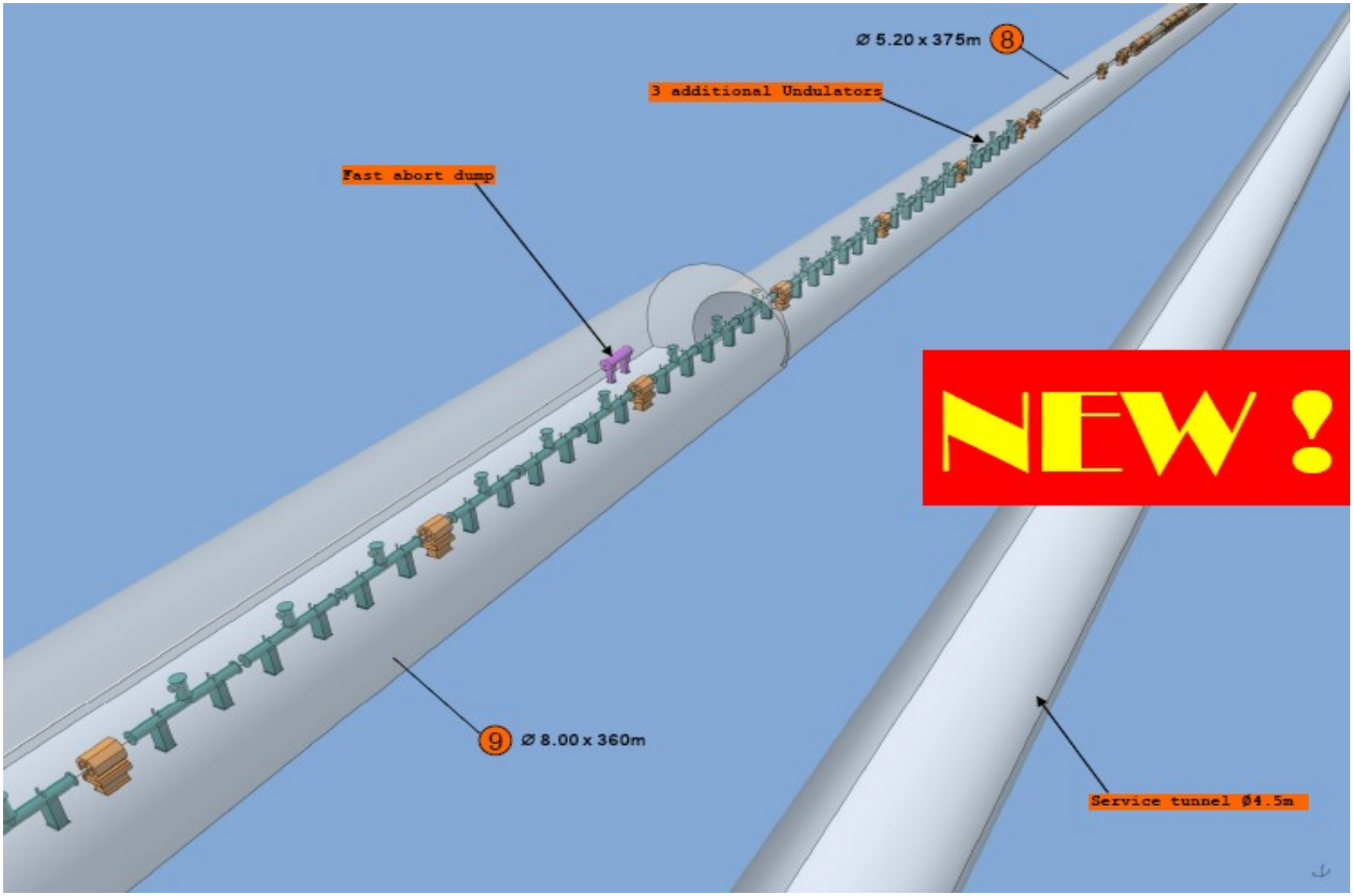
| | Diameter (m) | Length (m) |
|---|---|---|
| Experimental Cavern Interface Tunnel 1 | 5.20 | 70 |
| Main Dump Branch Tunnel 2 | 6.00 | 80 |
| Damping Ring Branch Tunnel 3 | 12.00 | 145 |
| PTRAN & BDS Diag. Dump Tunnel 4 | 7.00 | 1105 |
| BDS Diag. Dump Branch Tunnel 5 | 6.00 | 193 |
| 400 MeV accelerator Tunnel 6 | 5.20 | 473 |
| Positron Production Tunnel & Remote Handling Cavern 7 | 8.00 | 162 |
| e- BDS Dogleg Tunnel 8 | 5.20 | 375 |
| Undulator & Fast Abort Dump Tunnel & Undulator Access Cavern 9 | 8.00 | 360 |
| End ML – Start Positron Tunnel 10 | 5.20 | 300 |
| Damping Ring Transfer Tunnel 11 | 6.00 | 145 |
| Damping Ring Junction Cavern 12 | 14.00 | 37 |



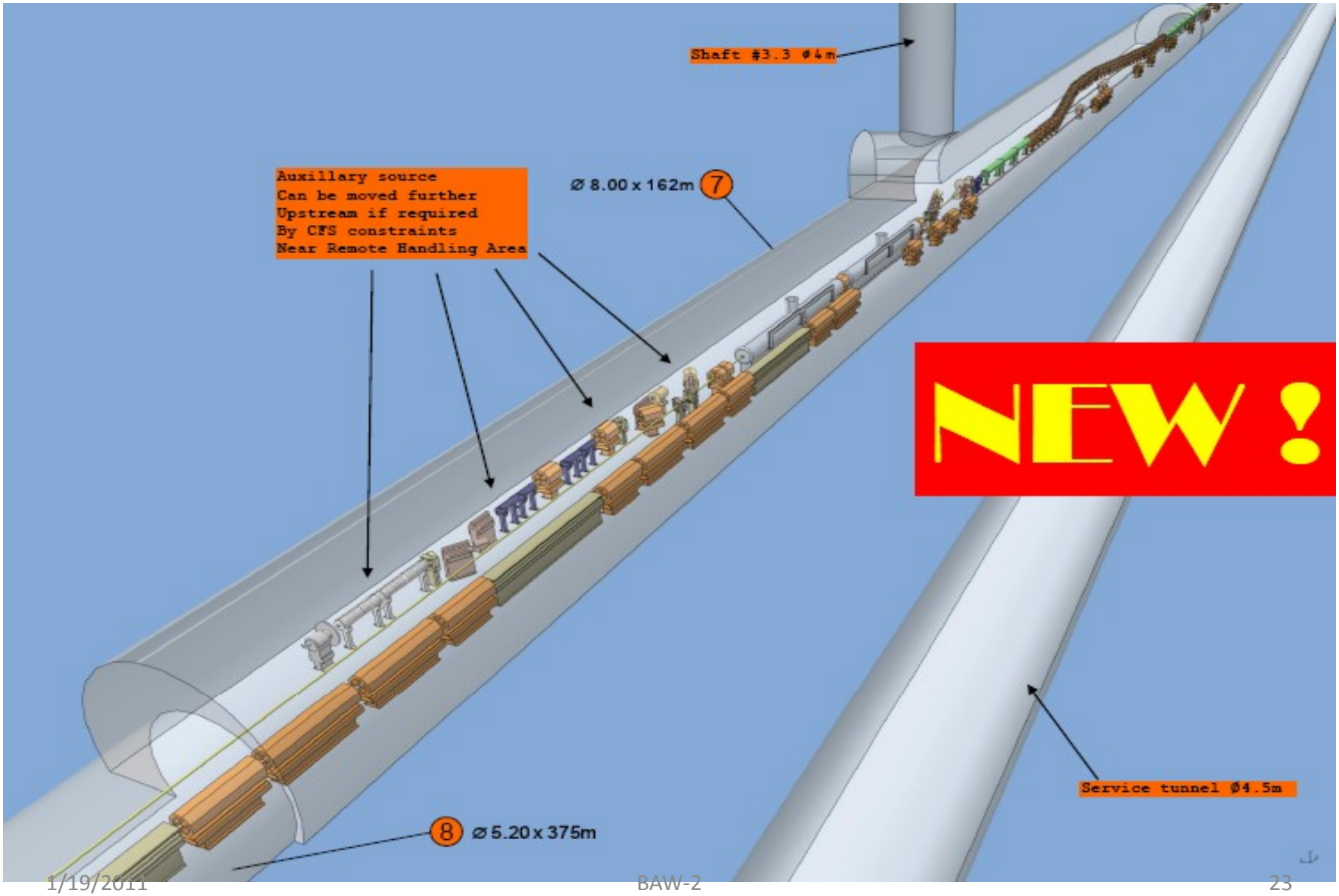
# END OF LINAC Showing installation shaft



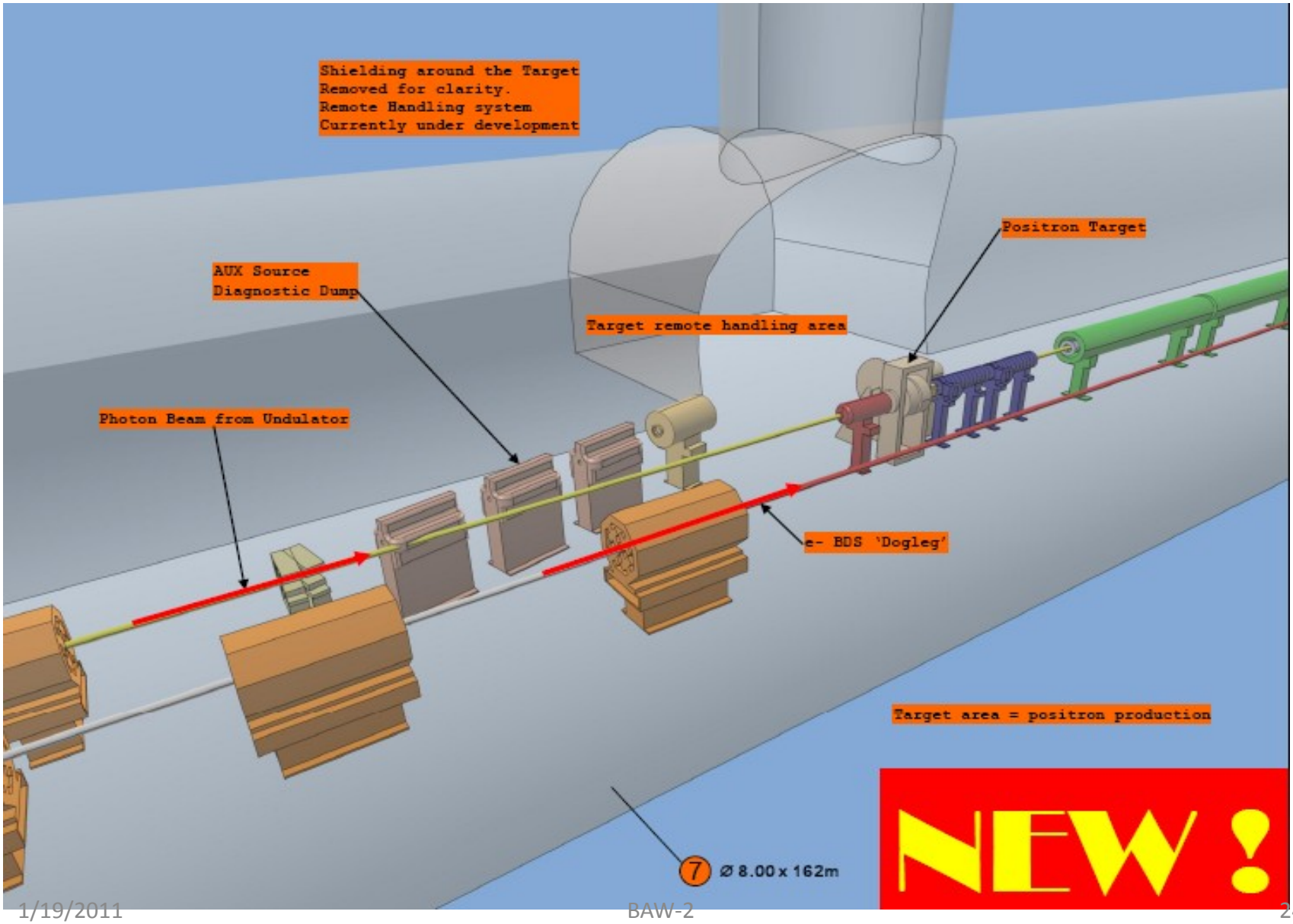
# UNDULATOR and DRIFT



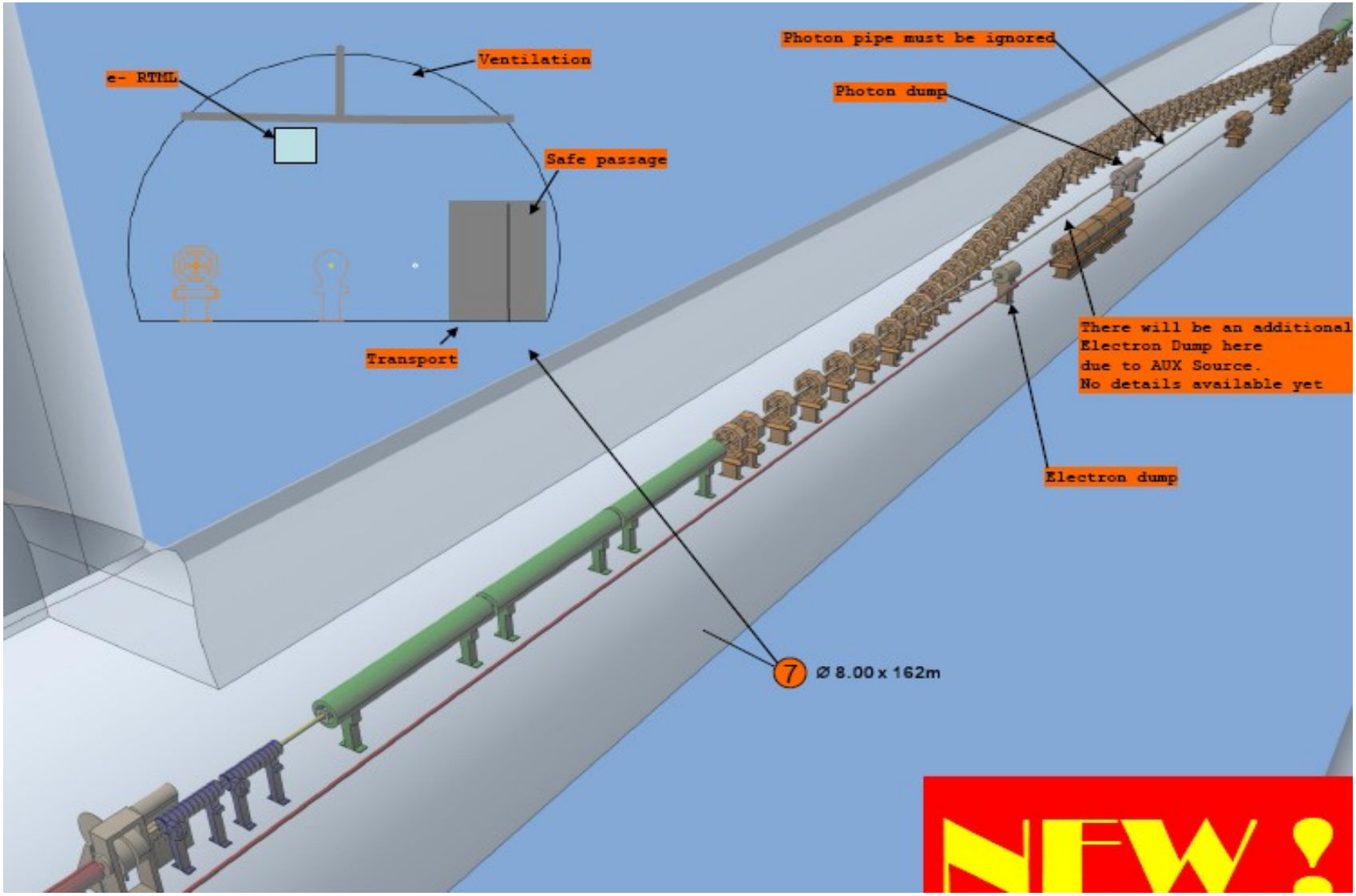
# BDS DOGLEG and AUX SOURCE



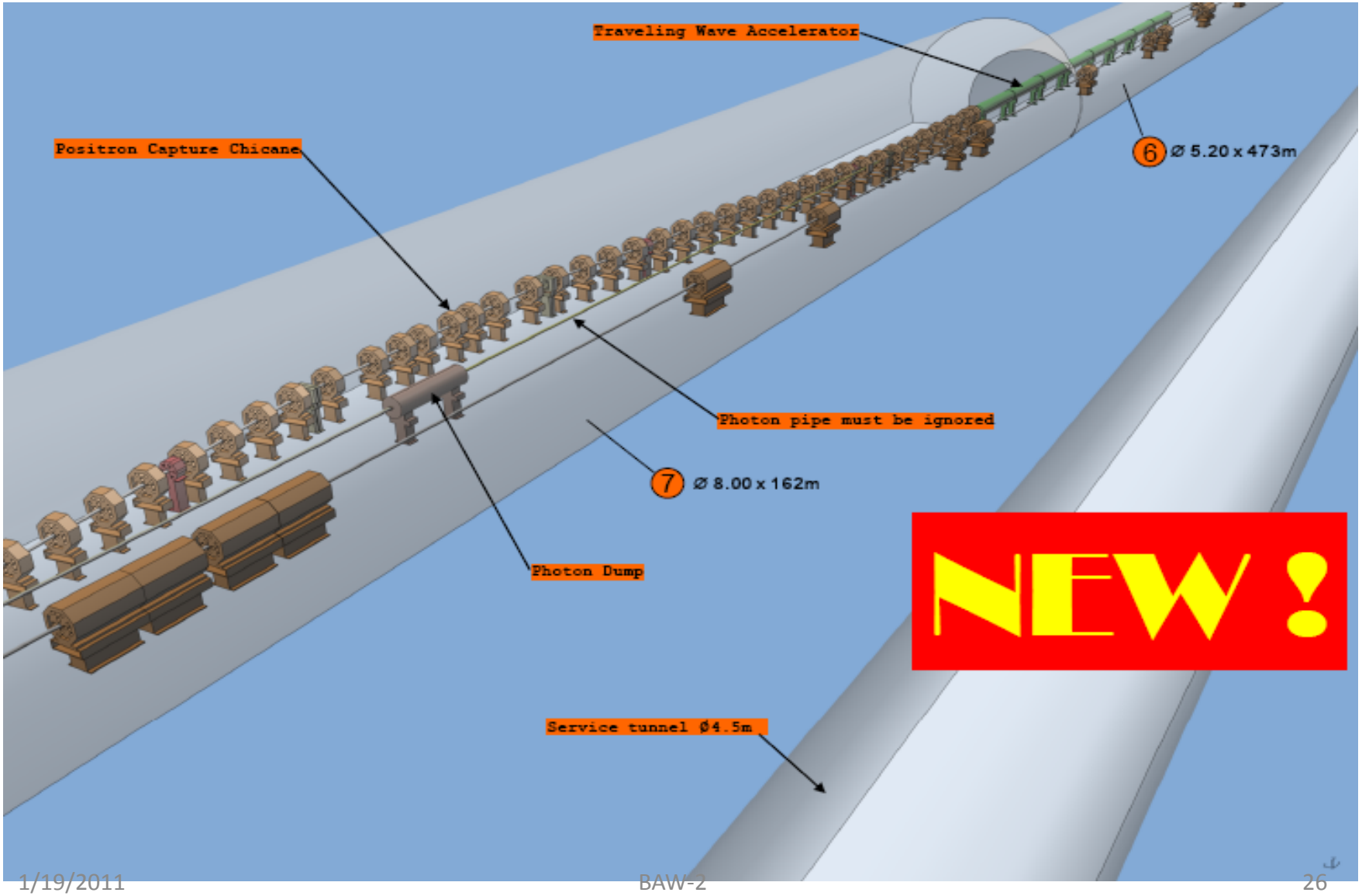
# TGT, OMD, etc and Vault



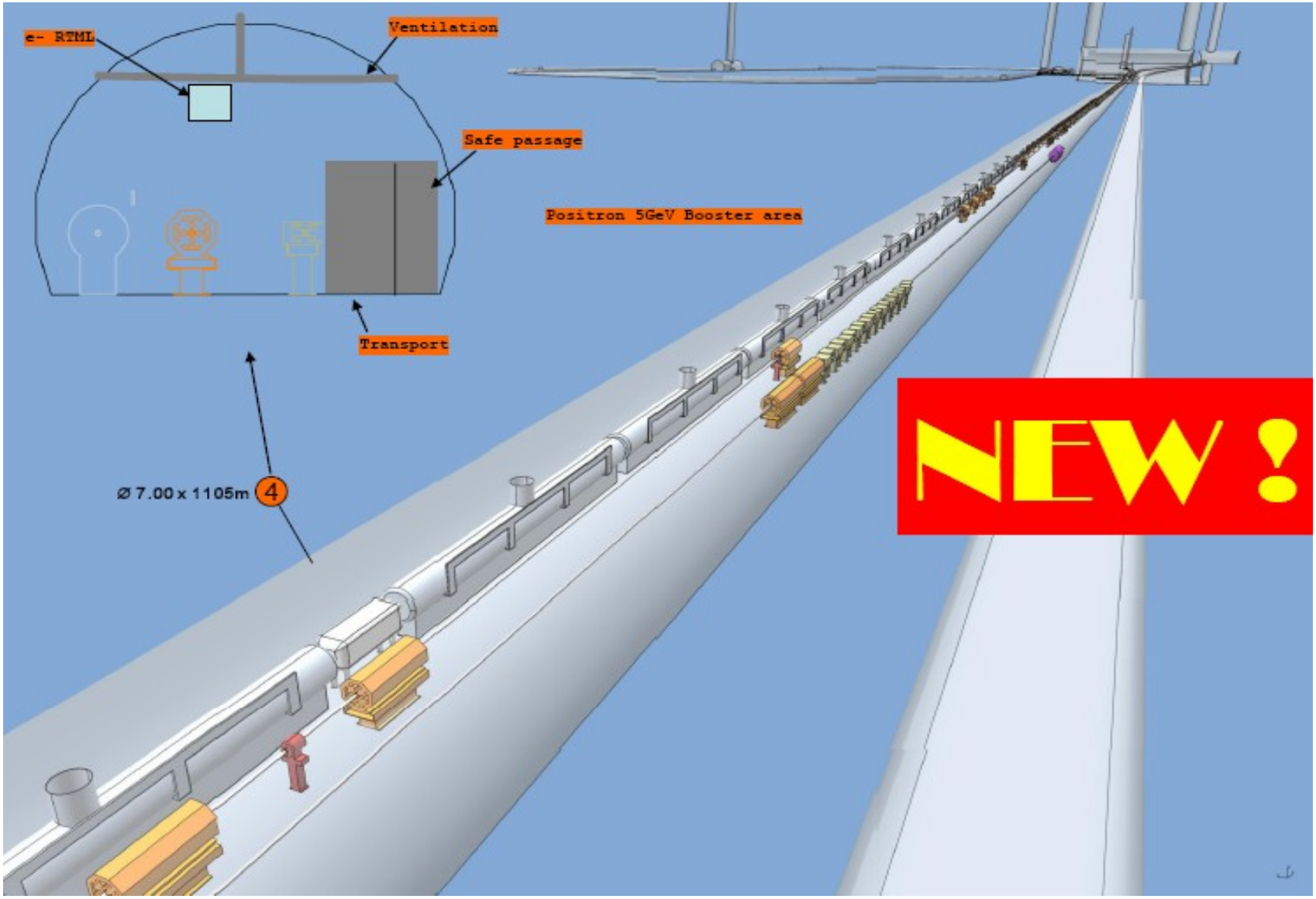
# 125 MeV Capture Accelerator, Beam separation and Dumps



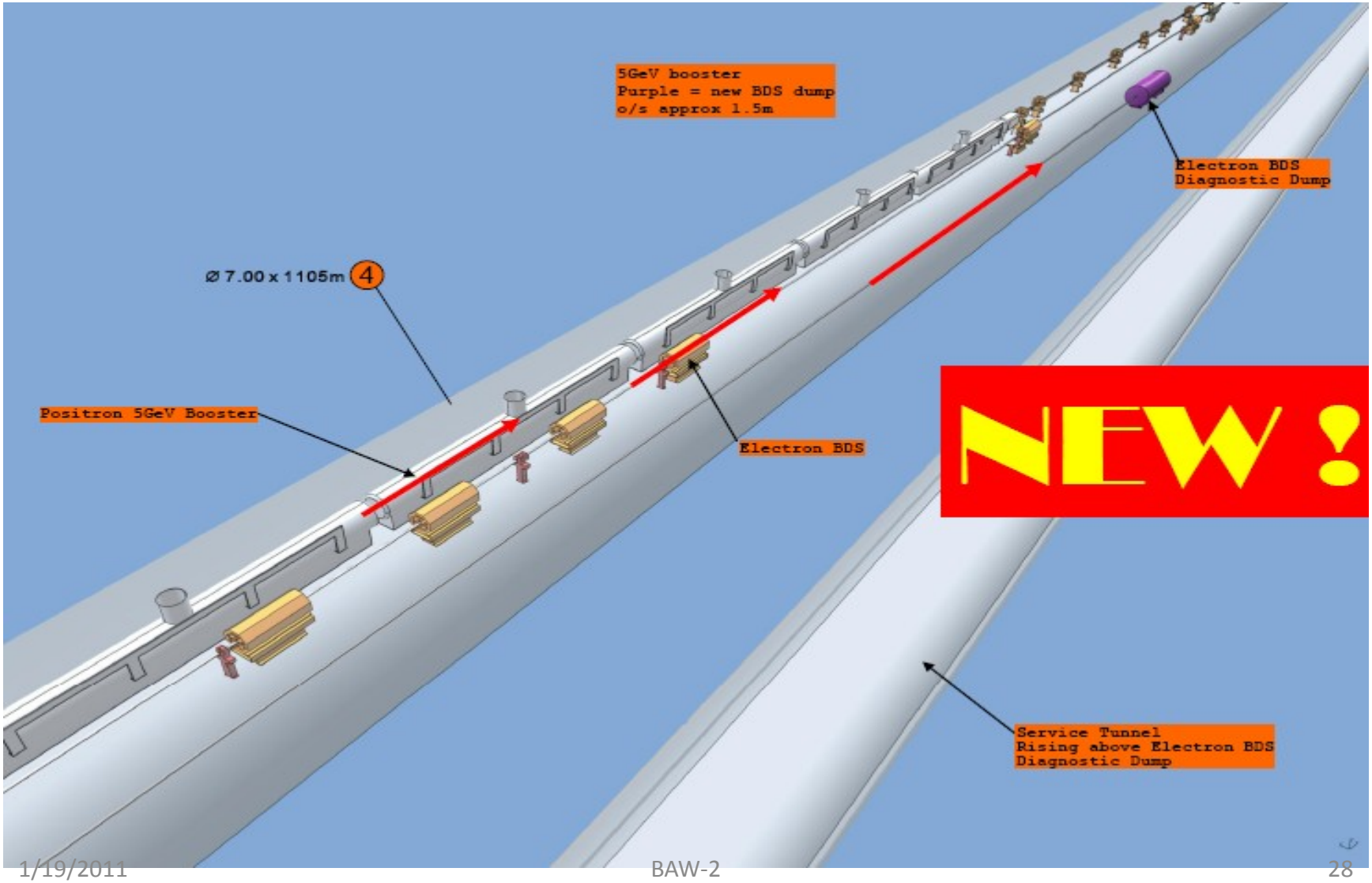
# Capture Chicane to TW Accelerator



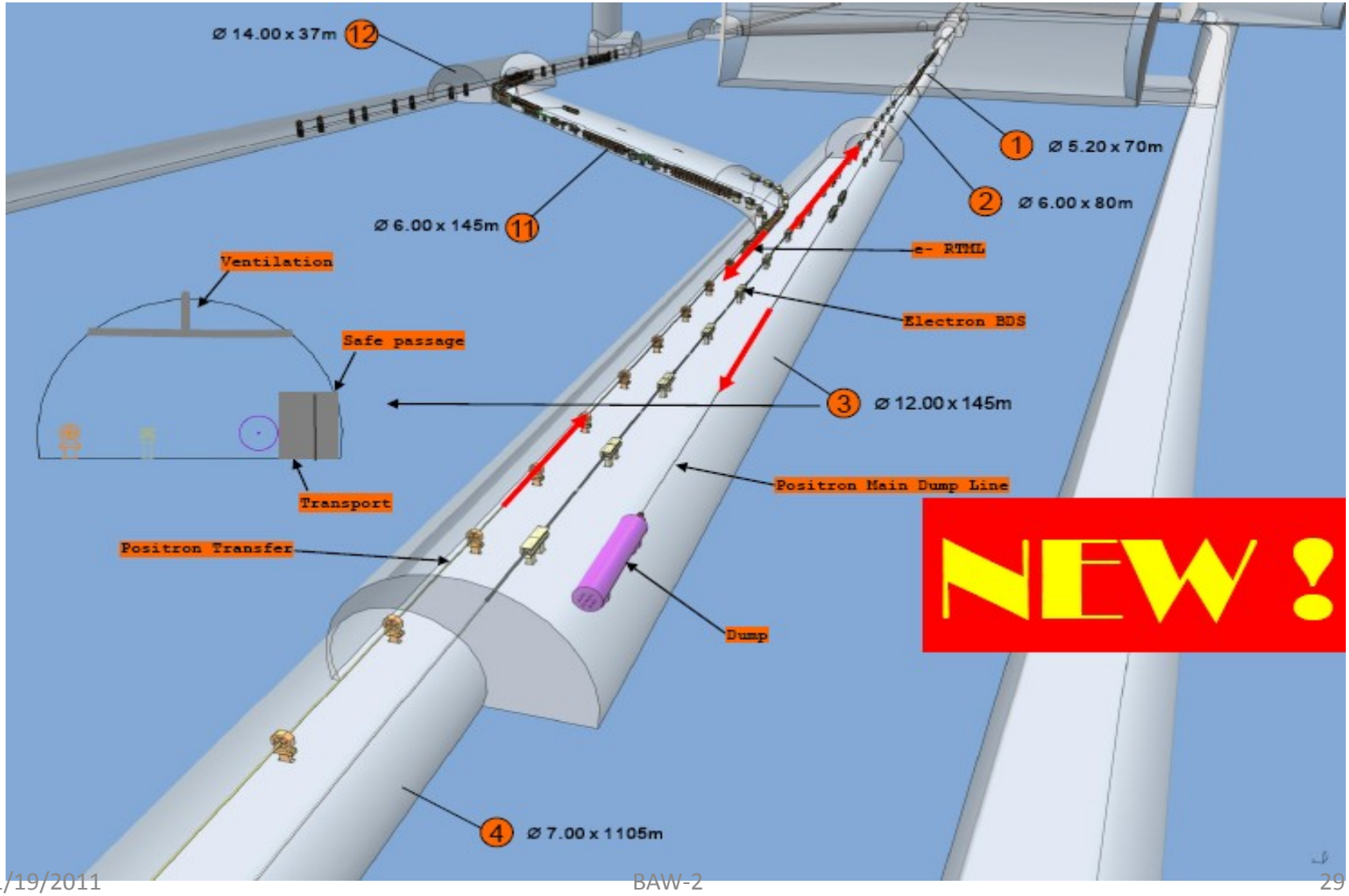
# 5 GeV Booster and BDS Optics



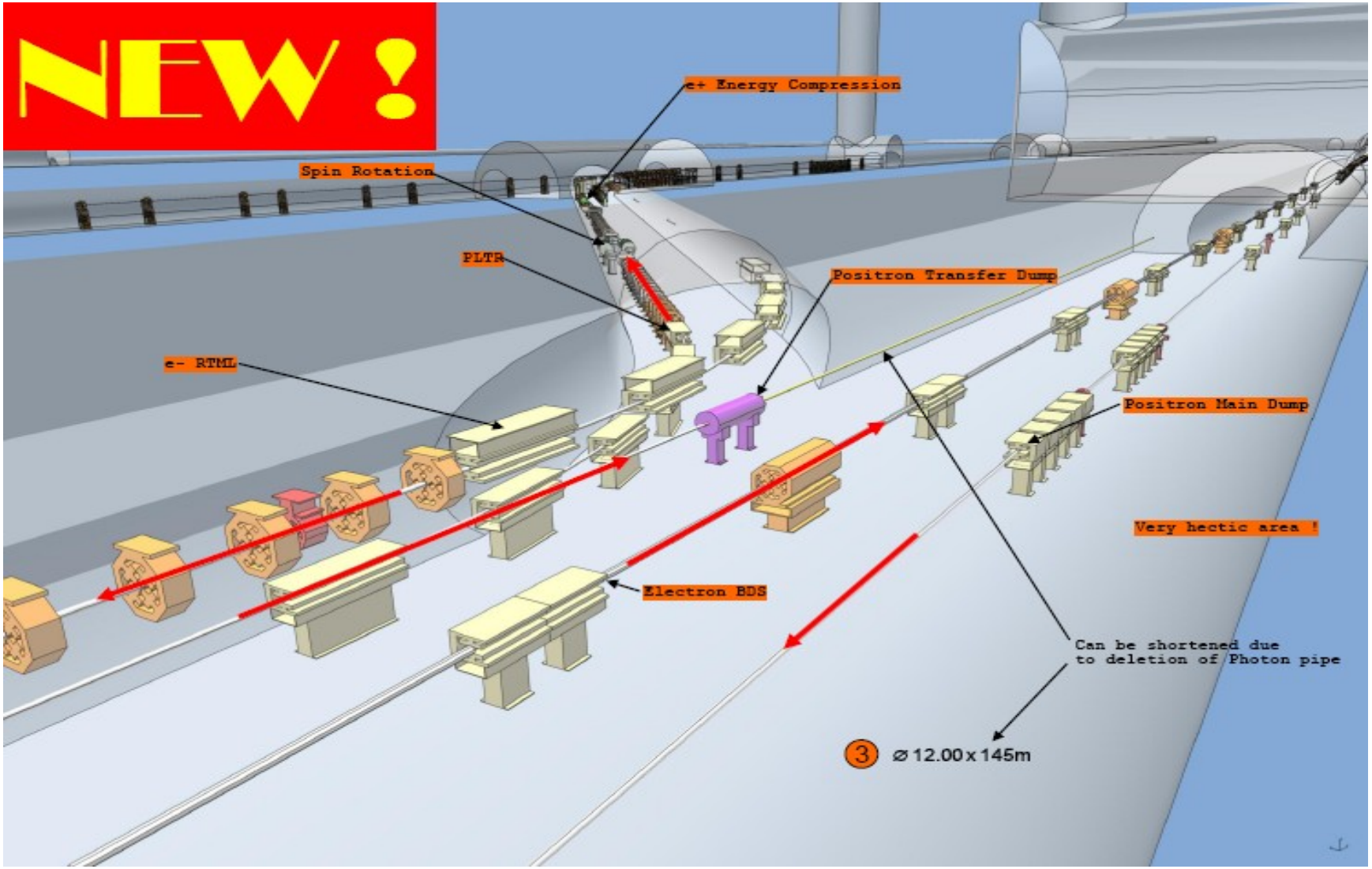
# More of 5 GeV Booster and BDS Diagnostic or Tune-up Dump



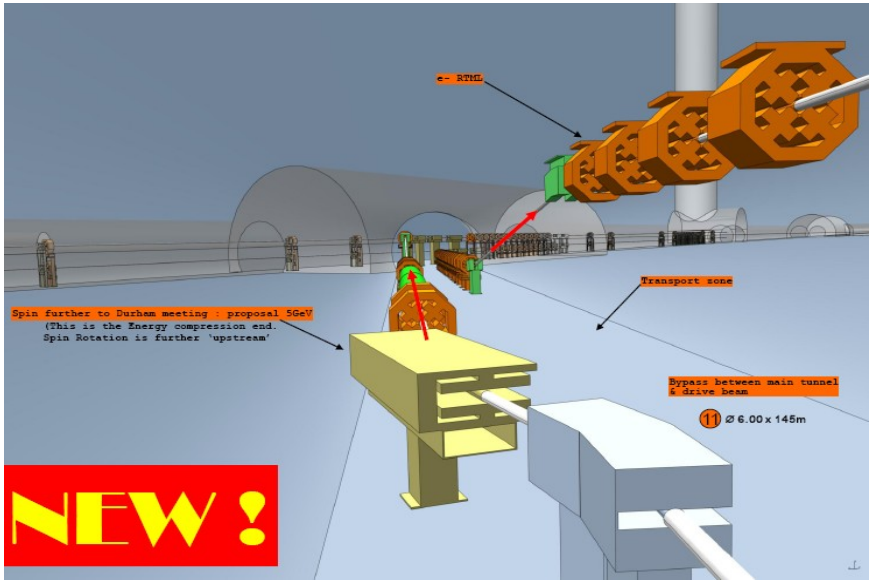
# Continued BDS and E+ transport past the MAIN 20 MW E+ DUMP

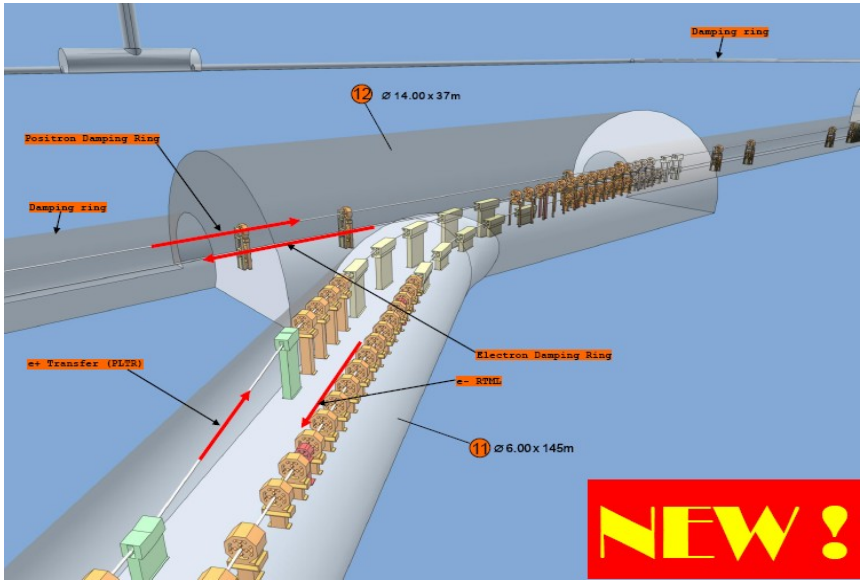


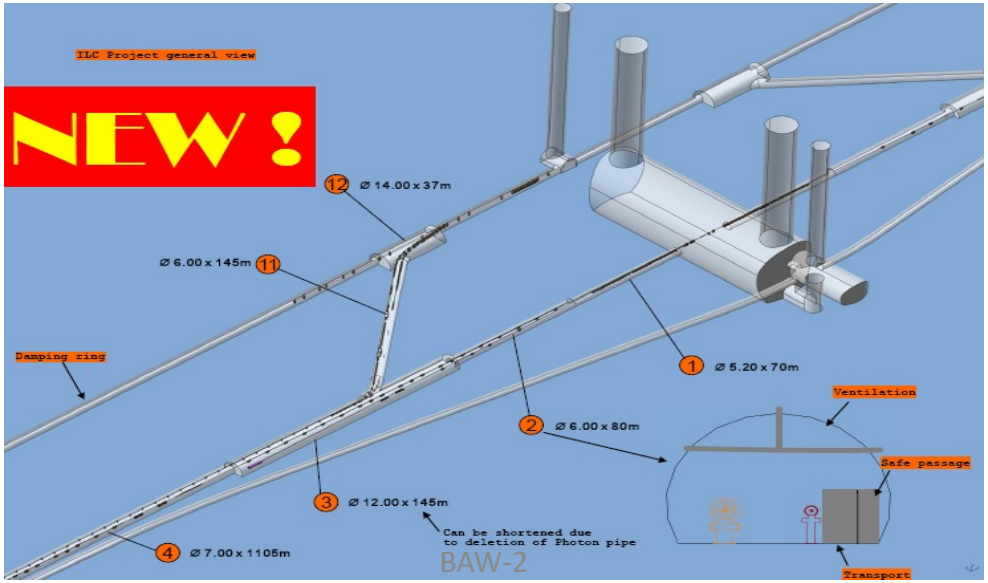
# Separation of E+ Beam to DR and E- BDS to IR + E- RTML



# Beams to and from the DR and IR



# Some conclusions

A final evaluation of having the e+ source systems at the end of the electron linac and 10Hz operation at low energies, should wait until after the upcoming presentations of impacts on CF&S, Technical Systems and Cost.

**HOWEVER**

It looks very attractive as the new Baseline for the continuing engineering studies aimed at the Technical Design and cost, and for studies of site specific designs including optimization of tunnel cross sections, alcoves and vaults.