# Tracing Substance Translocation and Accumulation in Plants using Radioisotopes

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# TUNL-Phytotron Collaboration

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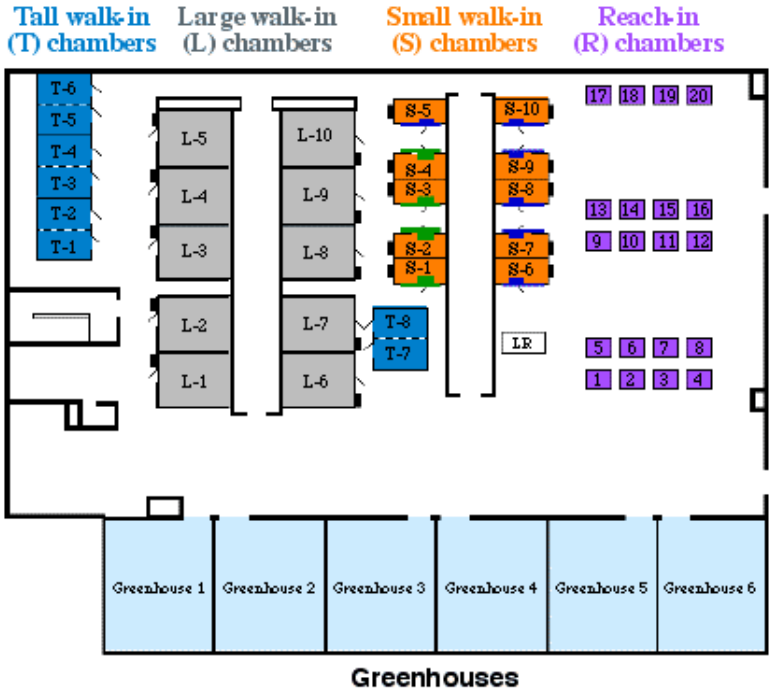
# Radioisotope Production at TUNL

| | |
|---|---|
| 1. $^{11}CO_2$ (half life = 20 min.)<br>$^{14}N + p \rightarrow {}^{11}C + \alpha$<br>Target: gas | 3. $^{18}F^-$ (half life = 109 min.)<br>$^{18}O + p \rightarrow {}^{18}F + n$<br>Target: $^{18}O$ enriched water |
| 2. $^{13}NO_3^-$ (half live = 10 min.)<br>$^{16}O + p \rightarrow {}^{13}N + \alpha$<br>Target: $^{18}O$ depleted water | 4. $H_2{}^{18}O$ (half life = 2 min.)<br>$^{16}O + p \rightarrow {}^{15}O + d$<br>Target: water |

# The Phytotron Facility

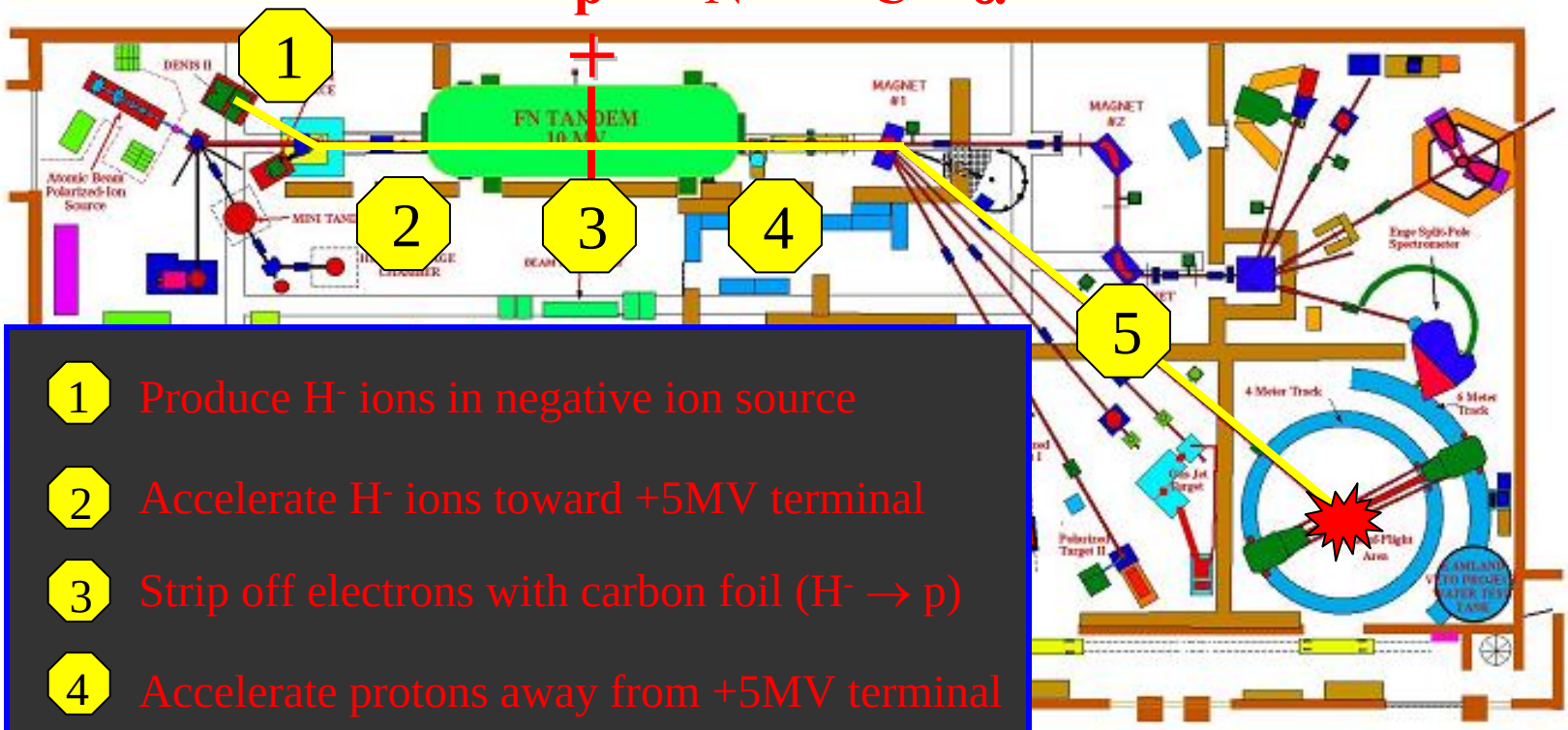
- Controlled Environment Facility
- Growth chambers can control many factors:
  - Soil type
  - Air Temperature
  - Light levels (total & UV)
  - Carbon dioxide concentration
  - Relative humidity
  - Nutrients
  - Air pollutants



# Carbon-11 Production

## Triangle Universities Nuclear Laboratory

$$p + {}^{14}N \rightarrow {}^{11}C + \alpha$$

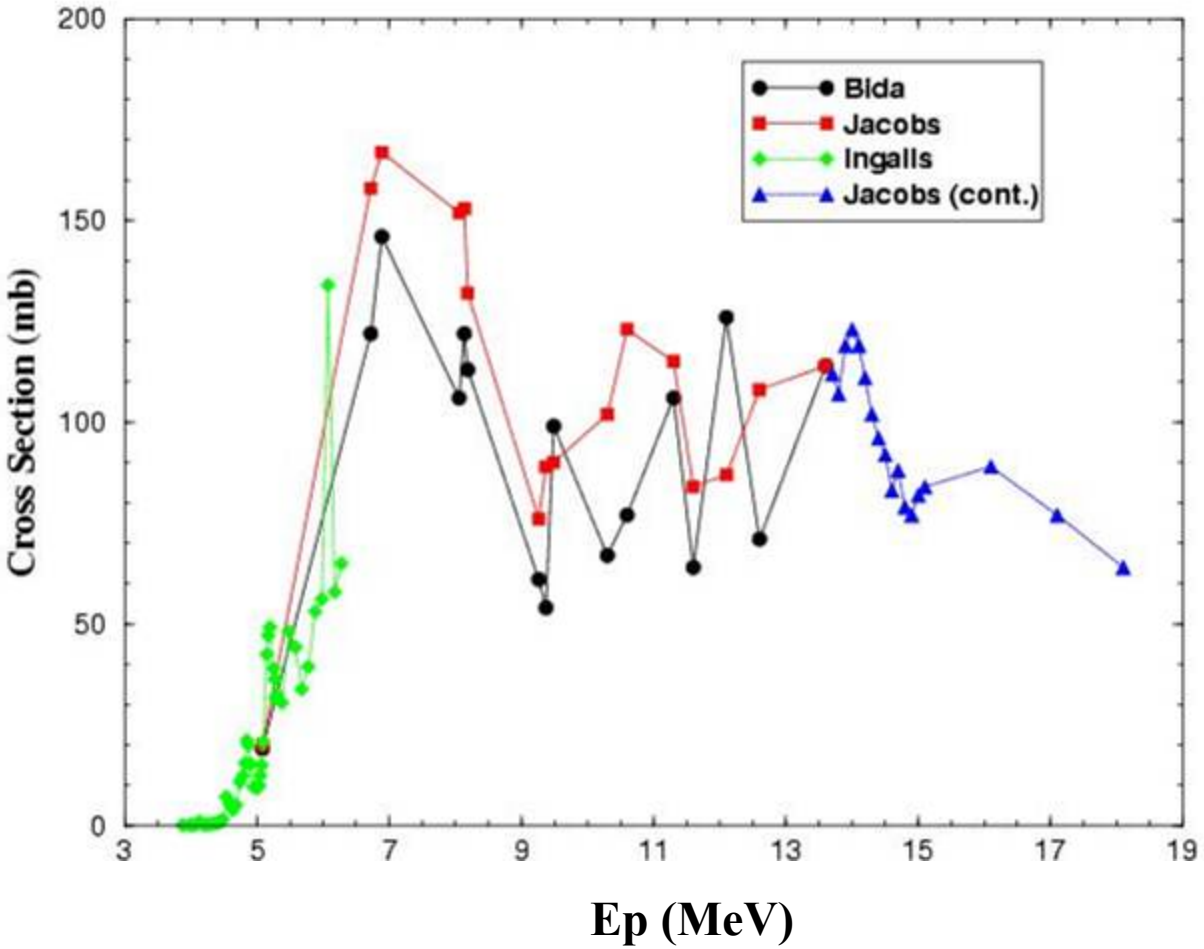



1. Produce $H^-$ ions in negative ion source
2. Accelerate $H^-$ ions toward +5MV terminal
3. Strip off electrons with carbon foil ($H^- \rightarrow p$)
4. Accelerate protons away from +5MV terminal
5. Bend p in magnet and collide on $^{14}N$ target

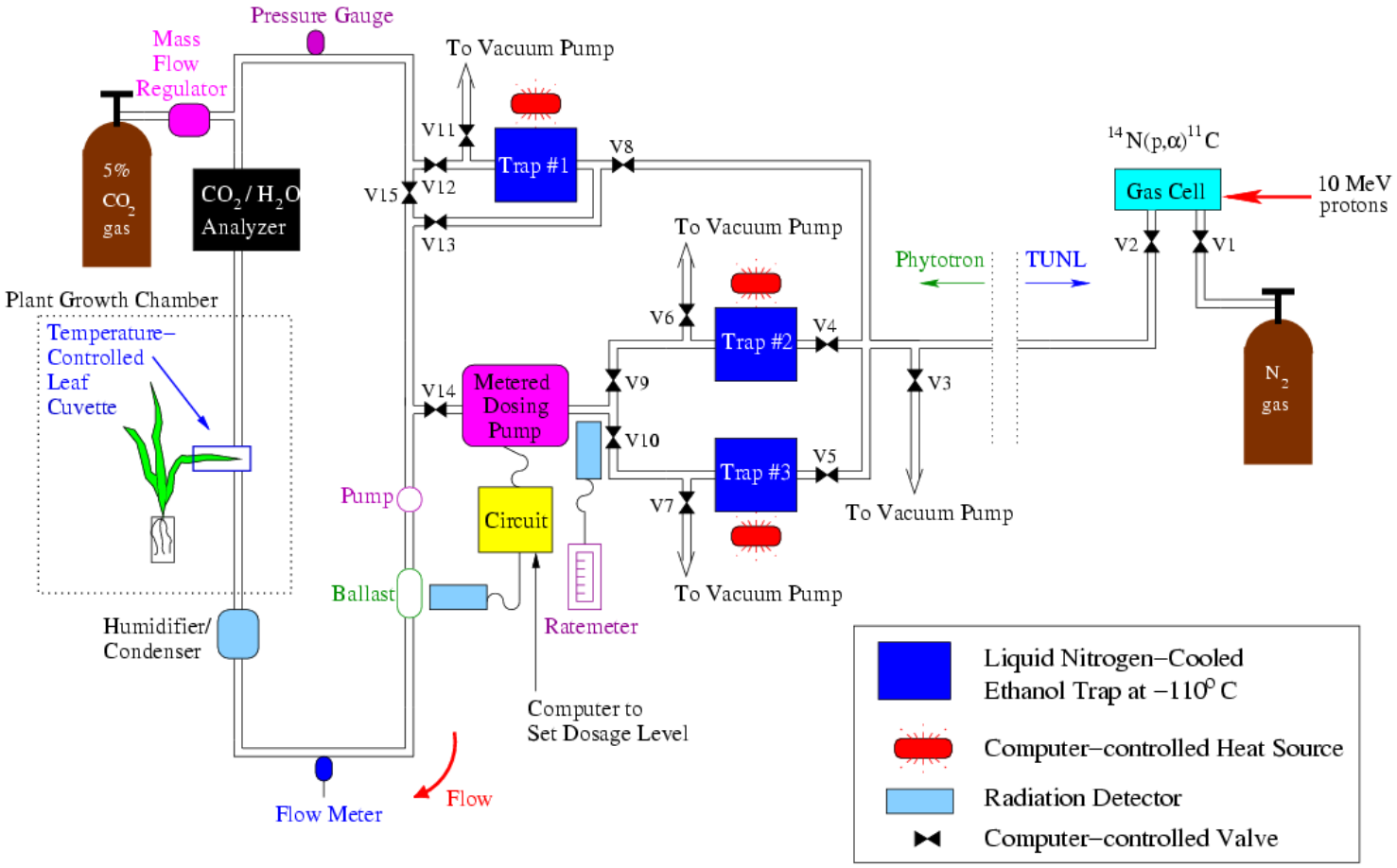
# $^{11}CO_2$ Production

$^{14}N$ (gas target) + p (beam) → $^{11}C$ + α

$^{14}N(p,\alpha)^{11}C$ Cross Section

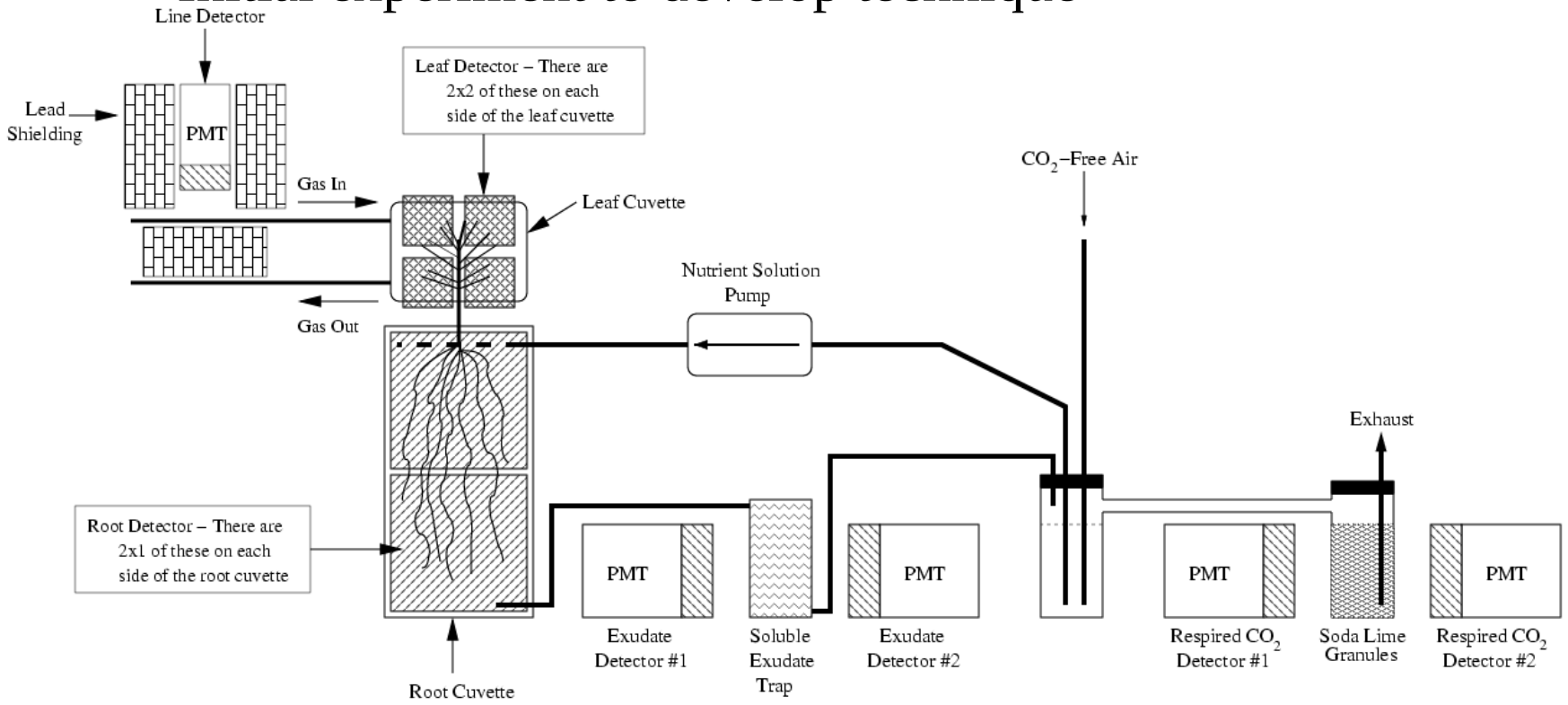


# Radioactive Materials Handling System

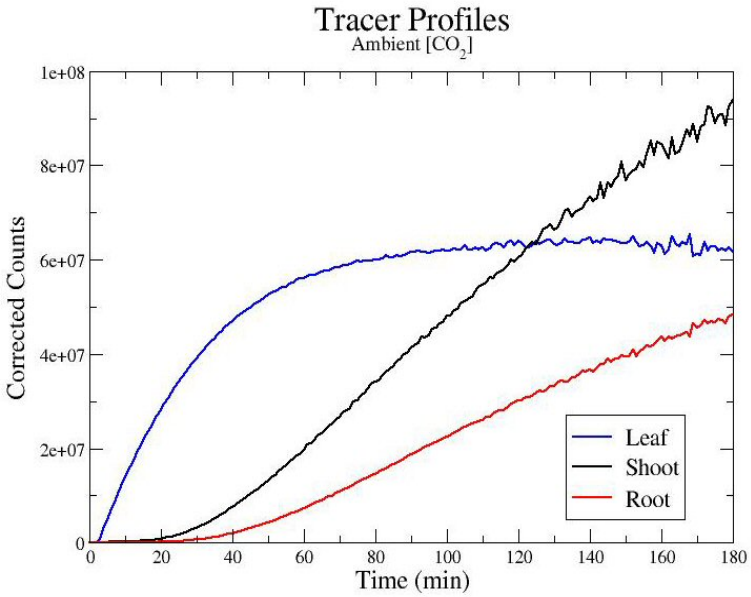


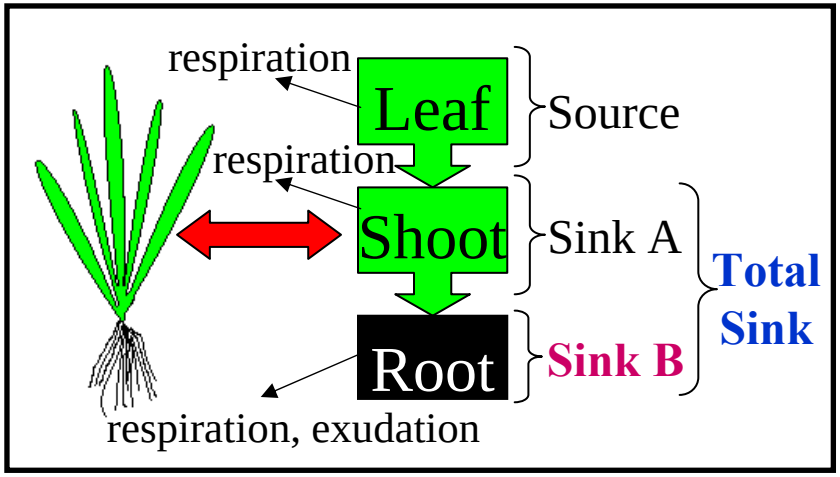
# Root Exudation Experiment

- Carbon compounds released from roots as soluble exudates
- $CO_2$ gas respired from roots
- Quantify as fraction of carbon transported to roots
- Initial experiment to develop technique



# Statistical Model




Discrete observation times: $t_k$ where k = 0, 1, 2, …

$\mathbf{Y_k}$ = counts in **Sink B** at time $t_k$ (output)

$\mathbf{U_k}$ = counts in **Total Sink** at time $t_k$ (input)

$$Y_k = - a_1 Y_{k-1} - a_2 Y_{k-2} - \ldots - a_n Y_{k-n} + b_0 U_k + b_1 U_{k-1} + \ldots + b_m U_{k-m}$$

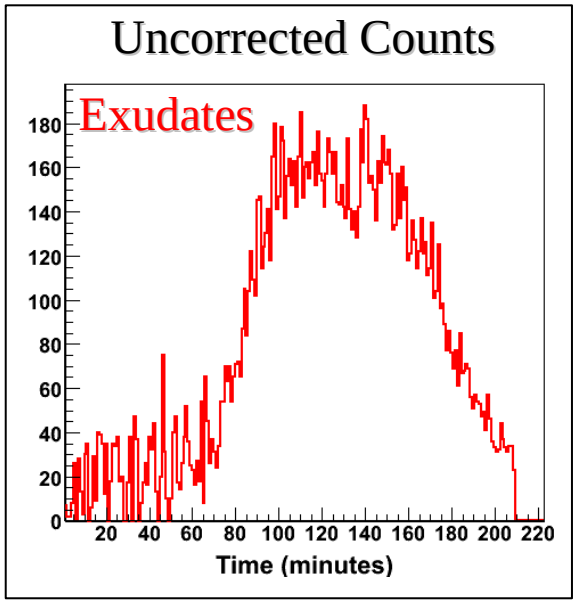
**Extract Physically Significant Quantities:**

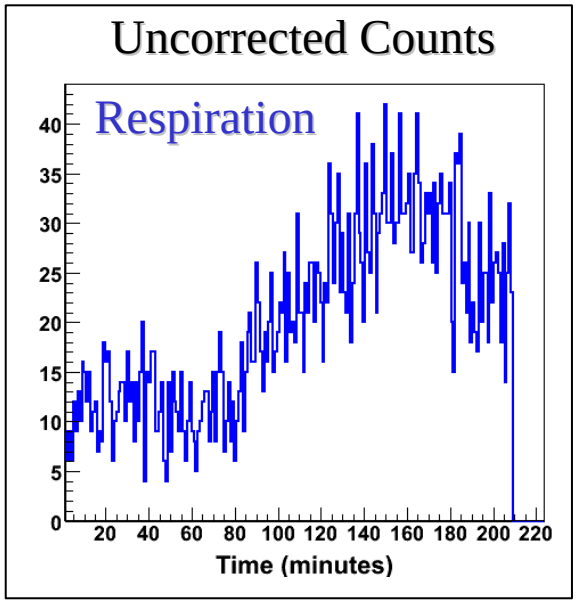
(1) Gain – fraction of input that shows up at the output

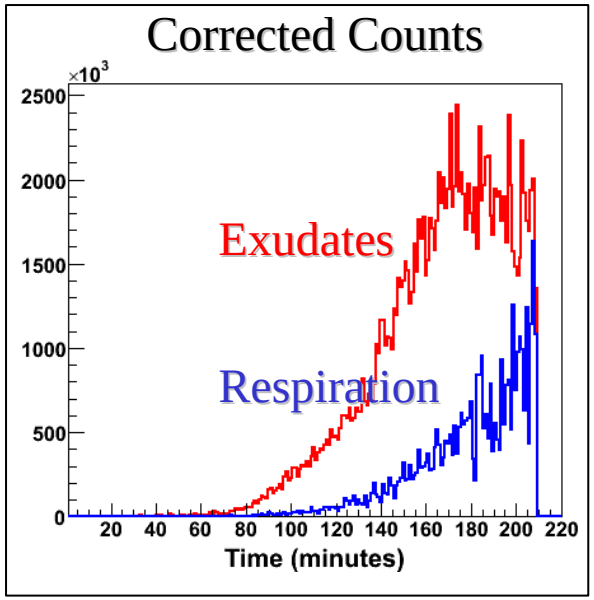
(2) Average transit time

# Development Measurements

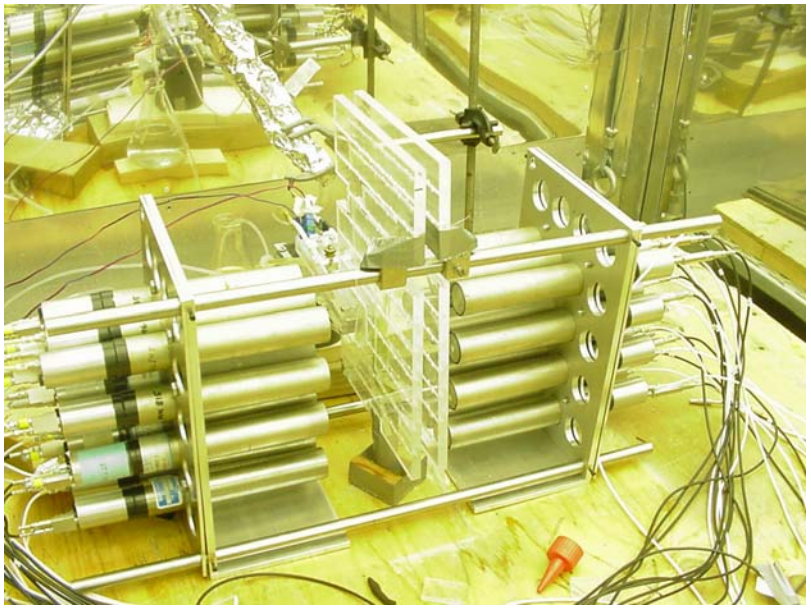
| Plant Type | Root Fraction | Root Exudate Fraction | Root Respiration Fraction |
|---|---|---|---|
| Barley | 0.15 ± 0.05 | 0.05 ± 0.01 | 0.017 ± 0.004 |
| Bean | 0.078 ± 0.005 | 0.04 ± 0.01 | 0.0044 ± 0.0002 |
| Pine | 0.0024 ± 0.0001 | N/A | N/A |



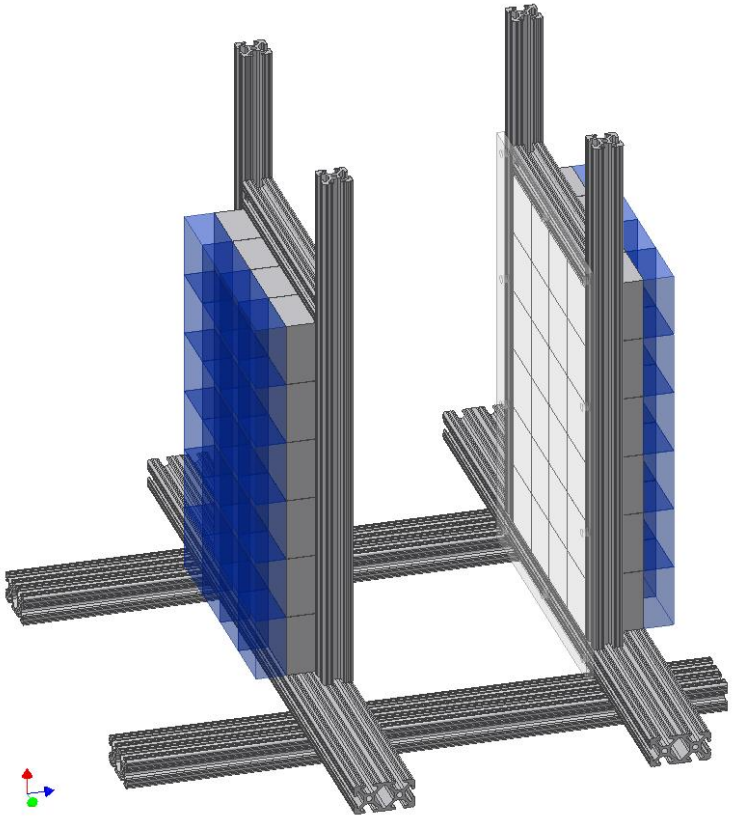



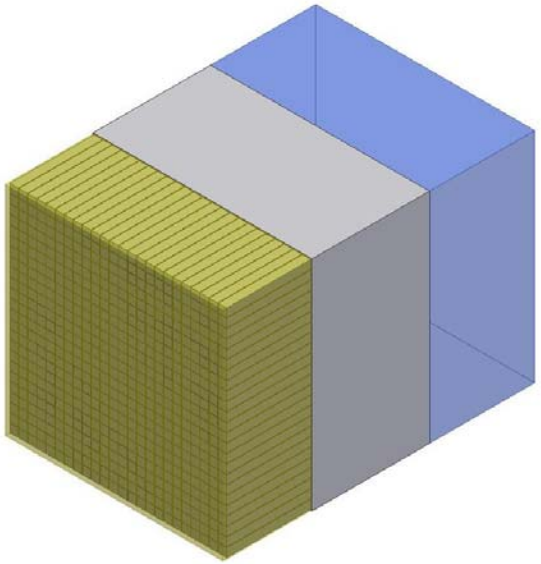
# 2D Imaging



# High resolution 2D imagers



20 cm x 30 cm field of view



5 cm x 5 cm x 1.5 cm
2mm x 2mm pixels (0.1 mm gap)